



**544
New
Items**

2024 Full-Line Product Catalog



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corecutterusa.com



Our customers always come first, for without them, we wouldn't be here.

Core Cutter, LLC is a family owned and operated high performance carbide cutting tool manufacturer located in Farmingdale, Maine. We manufacture a variety of standard, modified and custom-made solid carbide tooling with fast turnaround from print to ship. We are honored to have the opportunity to present you with the fundamentals of our company.

Our Promise

We are committed to outstanding customer service and superior product quality. We promise to continually meet or exceed your expectations in all aspects of the cutting tool industry.

Our Team

The Core Cutter Family consists of exceptionally skilled engineers, machine operators, quality inspectors, technical support and customer service professionals. We are dedicated to providing you with 100% customer satisfaction from start to finish.

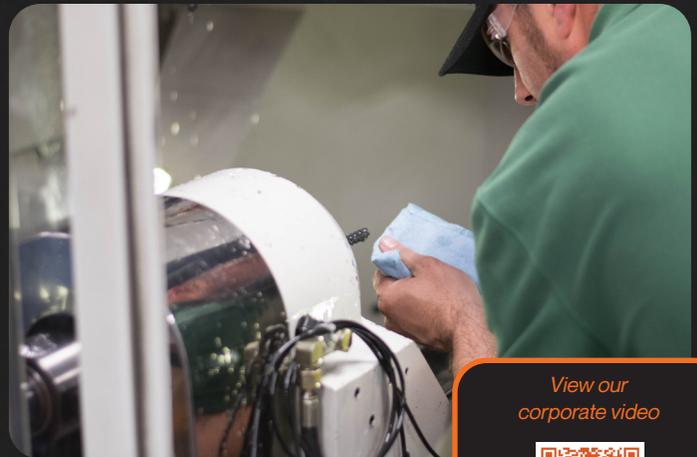
Our Focus

In order to continually meet our customers' needs, we remain focused on continual improvement in all aspects of carbide tool manufacturing. We are fueled by a passion for innovation, motivating us to design better tools, better processes and creative solutions to our customers' machining needs.

We look forward to being of service to you and your team.



James R. Graham, President/Owner



*View our
corporate video*



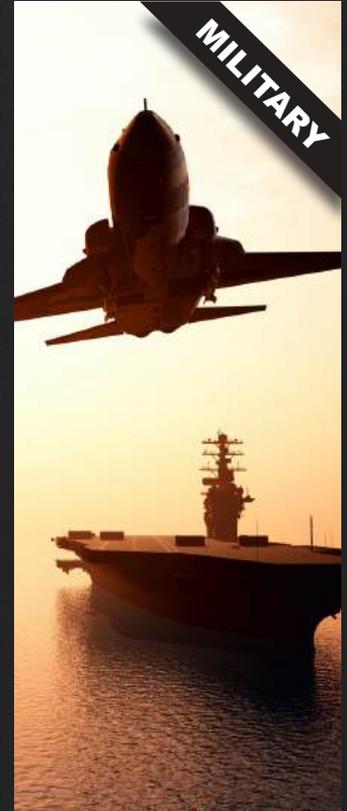
Core Cutter LLC
120 Technology Dr.
Gardiner, ME 04345

THE MARKETS WE SERVE

Market diversity helps us maintain a strong competitive advantage.

Our objective is to become the cutting tool provider of choice and most trusted by our customers. We gained our initial experience in the highly competitive and demanding aerospace sector, an environment that will challenge, refine, and solidify your manufacturing procedures and products.

All of the market categories indicated have a strong presence among our current clients, who are very satisfied with our dependability, technical assistance, and exceptional customer service. We have the capability, willingness, and proficiency to act as a reliable provider of cutting tools in whatever market area you are currently involved in or want to enter.



ENERGY



MEDICAL



ENGINES



GENERAL MACHINING



ARMAMENT

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N P M K S H

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FERROUS TOOLING (& Titanium)

P M K S H

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N P M K S H

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OUR TOOL COATINGS

Our standard tool coatings are detailed below, others upon request.

**Previously Named,
LATUMA*



A-Max		A-Max is an AlTiN-based coating with a dark gray appearance. It can withstand wet and/or dry machining operations, greater speed & feed rates, and a higher aluminum content that allows superior oxidation resistance and hot hardness.		Materials Steel Hardened Steel Stainless Steel Cast Iron Super-Alloys Titanium
Tool Series Impacted		VST4, VST4-RN, VST4-CB, FEM5		
Coloration	Hardness (GPa)	Coefficient of Friction	Max. Service Temp (C°)	
Dark Grey	38-32	0.6	1,000	

C-Max

Application of C-Max at high temperatures to ferrous, titanium, and toughened materials results in maximum adhesion, an incredible smooth finish, and optimal edge strength while preserving the tool's high heat shock stability and wear resistance.



C-Max		Application of C-Max at high temperatures to ferrous, titanium, and toughened materials results in maximum adhesion, an incredible smooth finish, and optimal edge strength while preserving the tool's high heat shock stability and wear resistance.		Materials Steel (>45HRC) Stainless Steel Cast Iron Super-Alloys Titanium
Tool Series Impacted		VMF, VMF-CB		
Coloration	Hardness (GPa)	Coefficient of Friction	Max. Service Temp (C°)	
Light Grey	41-35	0.6	1,100	

**Previously Named,
HardCarbon*



D-Max		This is our non-ferrous metal machining coating; it is thin, smooth, and has a high hardness level, which makes it perfect for machining aluminum alloys and other non-ferrous metals like copper, silver, or gold, GFRP, and CFRP.		Materials Aluminum Copper Brass CRFP Poly GFRP
Tool Series Impacted		AL2, AL2-RN, AL3, AL3-RN, AL3-CB		
Coloration	Hardness (GPa)	Coefficient of Friction	Max. Service Temp (C°)	
Rainbow	50-60	0.1-0.2	500	

**Previously Named,
Alcrona Pro*



P-Max		Our versatile coating choice, P-MAX, offers remarkable wear resistance, thermal shock stability, and hot hardness. It can withstand wet or dry applications, as well as higher cutting rates and feeds. Its improved layer structure permits a wide range of applications.		Materials Carbon Steel Alloy Steel Stainless Steel Cast Iron Super-Alloys Titanium
Tool Series Impacted		QTR3, QTR3-RN, VST5, VST5-RN, VST5-CB, CMS, CMH		
Coloration	Hardness (GPa)	Coefficient of Friction	Max. Service Temp (C°)	
Bright Grey	39-33	0.6	1,100	

New

T-Max

Unique in that it maintains a very smooth surface and guarantees process stability, our newest coating has a composition based on TiAlN/TiSiN and has a very high thermal stability. It is designed to provide maximum wear resistance during machining of stainless steel, HRSA's, titanium, and hardened steels.



T-Max		Unique in that it maintains a very smooth surface and guarantees process stability, our newest coating has a composition based on TiAlN/TiSiN and has a very high thermal stability. It is designed to provide maximum wear resistance during machining of stainless steel, HRSA's, titanium, and hardened steels.		Materials High Alloyed Steel Stainless Steel Super-Alloys Titanium
Tool Series Impacted		VST6, VST6-RN, VST6-CB, VXR4 & VXR5		
Coloration	Hardness (GPa)	Coefficient of Friction	Max. Service Temp (C°)	
Red-Gold	41-43	0.4	1,100	

* Please note that while the names of the tool coatings have changed, the coatings themselves have not. Furthermore, we have added a brand-new coating called T-Max to our lineup of products.

CUSTOM MADE TOOLING

If you need custom tooling made for a specific application, we can help!

Providing the right solution, not just a tool, is what we do well. Our cutting tool engineers are experienced with building some of the most complex special tool configurations in the industry. You can be sure that we will encompass all our resources with any custom-built tooling solutions your application demands.

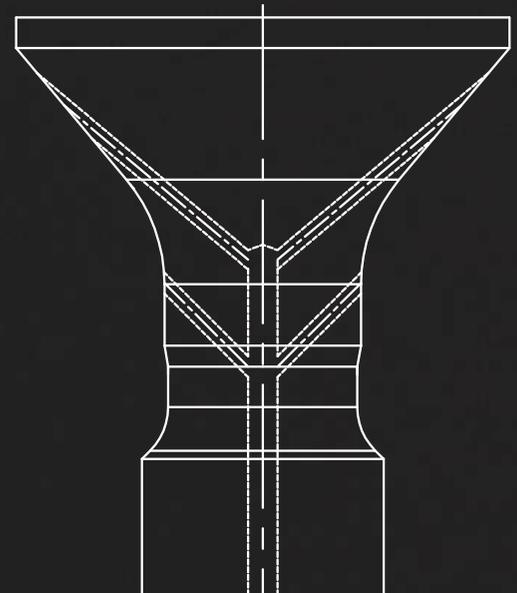
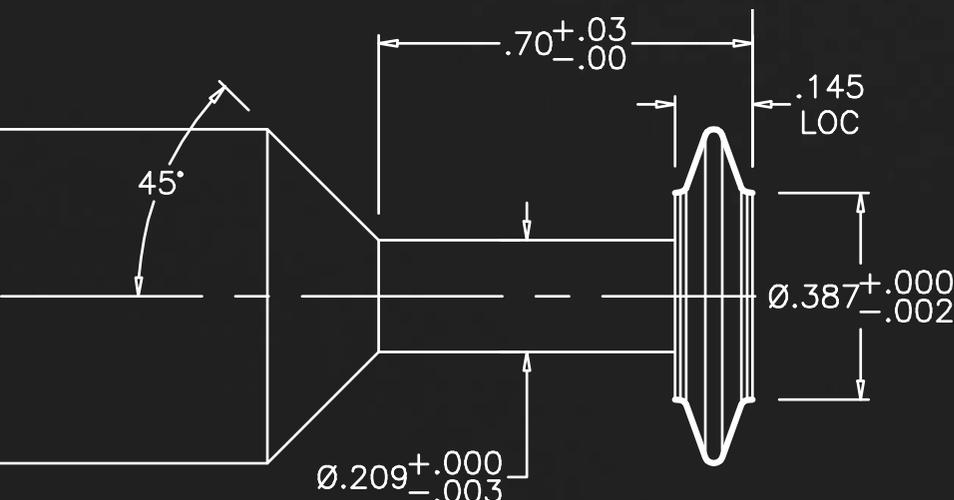
It's as simple as 1, 2, 3 to get an estimate for a custom-made tool from us via our channel partners.

- 1** Please provide us with a tool sketch, a part print (our favorite), a snippet of feature machining, or, if you have one, draw it on a napkin!
- 2** Let us know what material you're cutting, its hardness, and the operations the tool will be expected to perform. We'll utilize all of our resources and let you know if we have any additional questions.
- 3** Let us know how many tools you need quoted and what distributor of ours you would like us to quote through. If your not sure who to buy from, then give us a call and we'll recommend our nearest distributor.

We are not limited to just end mills however! We have designed some of the most intricate & complex tooling in the business. With our experience and highly resourceful engineering staff we can handle your needs quickly and ensure that you will get the best design from us as possible.

Here are some common custom tools we regularly design & manufacturer.

- Ball nose Reamers
- Bore Mills
- Chamber Reamers
- Chamfer Mill
- Circle Segment Cutters
- Compression Router
- Coolant-Fed Tooling
- Double Angle Cutter
- Dovetail Cutters
- Drill Mills
- Drills
- Feed Mills
- Flat-Bottom Drills
- Form Drill
- Form Reamer
- Form Tooling
- Key seat Cutters
- Lollipop Cutters
- Plunge Tool
- Porting Tools
- Radius Cutters
- Reamers
- Router
- Spherical Cutters
- Step Drills
- Step Reamers
- Tapered End Mills
- Thread mills
- Torpedo Reamers
- Trepan Tools



MODIFIED STANDARD TOOLING

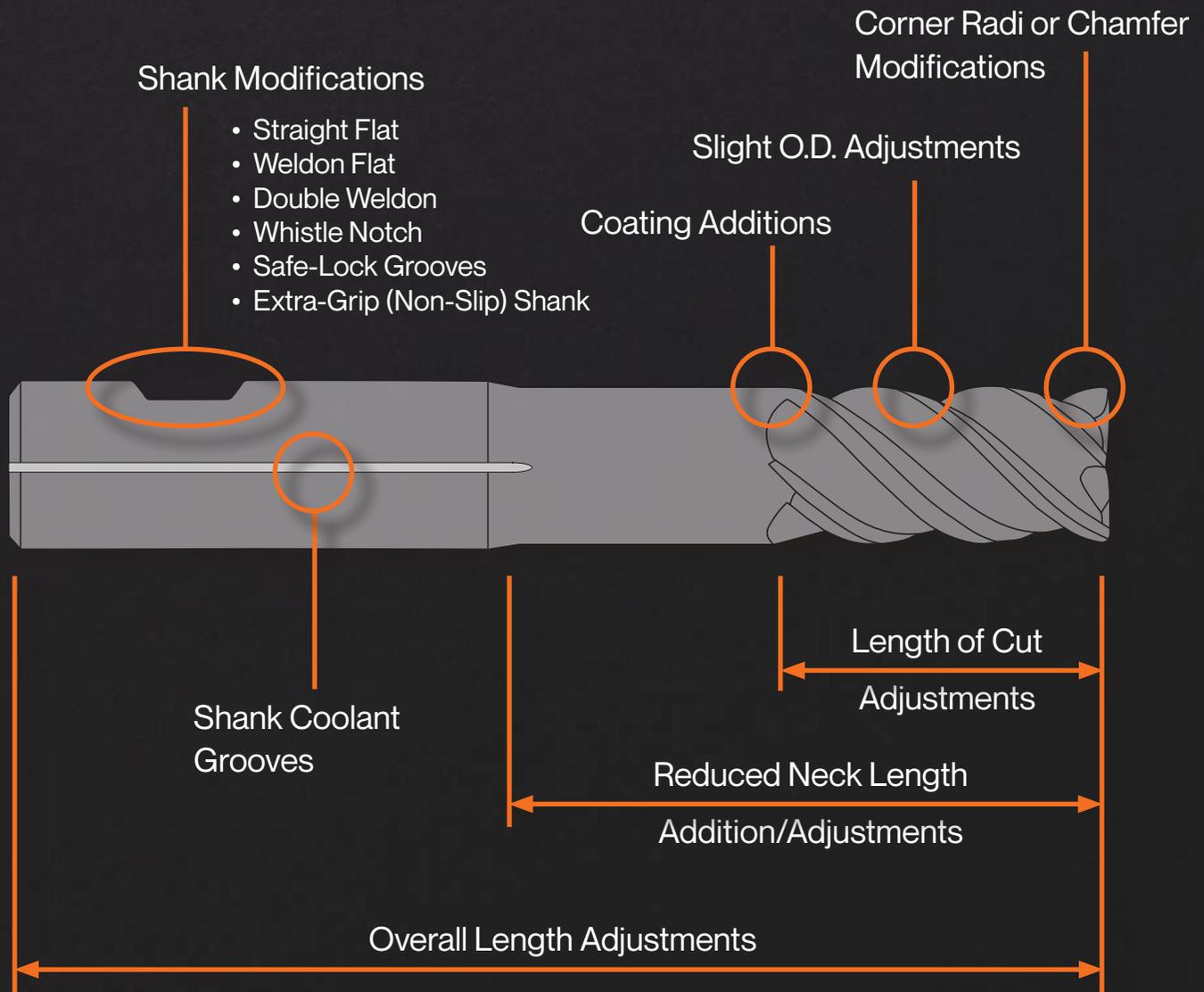
Do you ever need that one little adjustment to a standard tool?

Although we may not always be able to implement all your required modifications to an existing tool, we will evaluate and subsequently decide on the most effective approach to provide you with a tool. We acknowledge that standard tools may not always provide the full range of geometric options required for your component and that you are unable to spare the time to await the production of a tailor-made tool.

While the utmost caution is used to preserve the integrity of the cutting edges throughout the modification process, it is important to note that tools with pre-existing geometry might provide difficulties in incorporating certain changes in specific situations. Upon receiving your request, we will assess if the alteration can be carried out securely and with the utmost confidence.

If, in the event that the update cannot be securely included in an already existing tool, we will search our database for any tooling that may be shelved for other clients with your needed attributes, or, lastly, we can quote a tailored solution.

The figure below shows some of the changes we now make for our clients on a regular basis.



TOOL RECONDITIONING



Want to get more ROI out of your solid carbide tooling?

The cost of cutting tools can and will rise as your business expands and production increases. Tools become much more costly when you start using diameters of 3/4" and larger. Reusing a tool two to three times, depending on its condition upon arrival, can significantly reduce costs and maximize its useful life.

Get the most out of your solid carbide tooling and optimize your return on investment (ROI) with Core Cutter's reconditioning program. Whether it's a drill, reamer, endmill, or form tool, we've got you covered. We're also open to helping you recondition other brands you may own.

Tooling we commonly recondition.

- **Dovetail Cutters**
- **Drills**
- **End mills**
- **Form Tools**
- **Key seat Cutters**
- **Lollipop Cutters**
- **Radius Cutters**
- **Reamers**
- **Step Drills**
- **Tapered Ball nose**
- **Etc...**



Program Guidelines

- We regrind solid carbide tooling only.
- Program allows 1/4" tool diameters and greater.
- Any brand name accepted.
- Please return all tools in their original, well-protected tubes. If not available, please protect them to prevent additional damage during transit (i.e. wax dipping).
- Pricing is determined by exact item quantity (i.e. based on the same EDP tooling). Stated differently, we will aggregate all identical tooling in order to construct the final quantity breakdown pricing for you.
- Reconditioned tooling shipping costs to and from Core Cutter are the customer's responsibility.
- Please let us know if you want un-reconditionable product sent back to you, or for us to scrap here.

Our New Reconditioning Brochure is now available!

The program's steps are as simple as 1-2-3!



COLLECT & SEND

Once you contact our distributor partner, they will take care of the quoting, billing, and logistics. Please inform them of the precise tool list, quantities, and any special instructions or requirements (e.g., minimum diameter reduction, end work only, min. loc, etc.) that you may have. Our tool reconditioning form can be found within this catalog on page 103 (PDF also available). If you require assistance finding the closest distributor, please give us a call.



EVALUATE & QUOTE

As soon as the tools arrive at our facility, we will inspect them thoroughly and provide a quote to our distributor partner. After that, they will get in touch with you. Please note that any non-reconditionable tooling in the shipment will be marked as "no work done" and isolated. Please let us know if you want us to scrap it or for us to send it back to you, which will include a shipping fee.



RECONDITION & RETURN

Tools will be re-packaged (if received in this way) or re-wax dipped, have new fresh geometry, and include a new pristine coating (if coated originally). Be ready to welcome your revitalized tooling upon the quoted delivery date. It is important note, that the delivery timer officially begins once the order has been authorized to proceed.

SHANK CONFIGURATIONS

Getting the shank properly prepared is an essential part of your setup

Though it's not a very exciting or engaging concept, the tool's shank plays a crucial role in defining its performance, strength, and accuracy. All modern high-precision tool holders, including shrink fit, milling chucks, and hydraulic systems, are compatible with our standard tooling (h6) cylindrical shanks. We are aware, however, that a large number of tool-holding connections call for other configurations, which we can and will provide.

Here are some of the other shank configurations we regularly offer.

- **Straight Flats**
- **Whistle Notch**
- **Weldon Flats**
- **Haimer Safe-Lock®**
- **Double Weldon Flats**
- **Extra-Grip (aka Non-Slip)**

WELDON FLAT

Currently, the HP endmill market does not adhere to any current ANSI tool standards, which means that utilizing an outdated HSS standard may cause the Weldon location to deviate from the ideal position. Many manufacturers still use the traditional HSS ANSI Weldon flat specification, which measures from the tool's back to its front, leading to a pull-back or push-out condition (Fig. 1).

In order to account for this, we have created our own Weldon flat positioning method (Table 1), which is based on the flute washing out of the tool and will maintain a perfect distance from the tool holder's nose (Fig. 1, middle image).

TIP Of course, if you have a specific location that you want your Weldon flats on our tools, just provide us the "B" dimension and we'll be glad to accommodate.

The table below represents the Weldon flat specifications that will be used when ordering this particular shank flat configuration from us, unless directed otherwise.

Shank Dia. (D2)	Dim. "A" (+/- .004)	Dim. "B" (+/- .015)	Dim. "C"	Dim. "D"
1/4	.155	.500	.017 (+.005/- .000)	-
5/16	.295	.750	.020 (+.005/- .000)	-
3/8	.295	.750	.050 (+.015/- .000)	-
7/16	.345	.835	.060 (+.015/- .000)	-
1/2	.345	.835	.060 (+.015/- .000)	-
5/8	.415	.900	.065 (+.015/- .000)	-
3/4	.470	.900	.075 (+.015/- .000)	-
1.0"	.530	1.000	.075 (+.015/- .000)	.900
1-1/4	.530	1.000	.095 (+.005/- .000)	.900

Table 1 - Weldon Flat Specifications

Find more detailed information pertaining to tool holders on p. 76

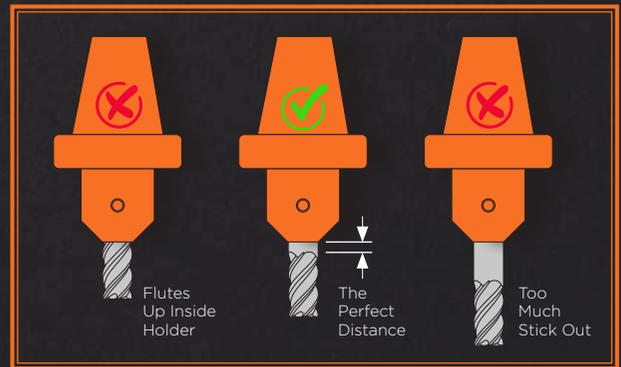
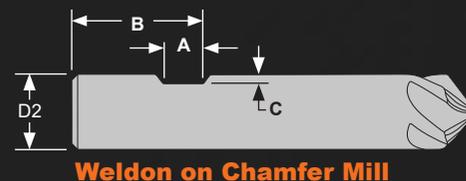
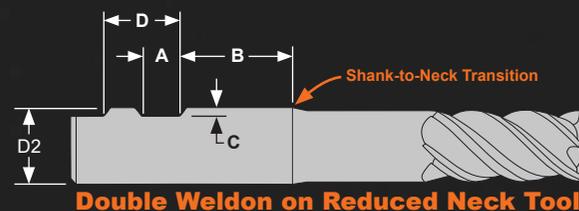
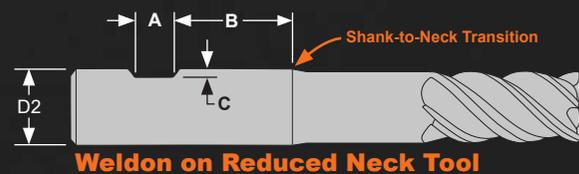
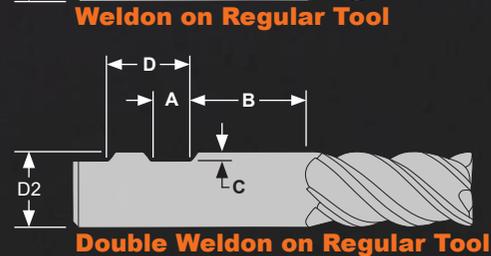
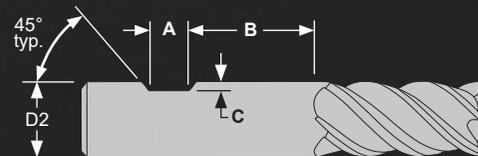


Fig. 1 - Tool Projection w/Weldon Flat



ROUGHING PROFILES

What exactly is the difference between a chip breaker and a serrated rougher?

The length of cut (L1) of an endmill represents the edges that make contact with the material during cutting. To mitigate the cutting forces, we instinctively use geometry elements like rake and relief. However, there are additional enhancements that might also prove advantageous. In heavy milling operations, roughing grooves are a crucial geometric feature that help remove vast amounts of material more effectively.

The primary purpose of a rougher is to prevent the chips from becoming excessively lengthy or entangled, as this could potentially cause harm to both the workpiece and the cutting tool. Rougher's can also alleviate strain on the tool and workpiece, enabling the tool to cut more easily due to reduced edge contact (friction). Leading to greater feed rates, velocities, and cutting depths, all of which contribute to an increased material removal rate (MRR).

Chipbreakers (aka Chip Splitters, Semi-Finishers)

In comparison to the conventional standard corn cob roughers, the offset design of the chipbreaker grooves (Fig. 3) along the cutting edge ensures that the flutes of each chipbreaker overlap each other (Fig. 3), producing a significantly superior finish as shown in figure 1. Additionally, as a result of fragmentation, the chip breaks into tiny pieces and becomes much more controllable. Please head to pages 9 - 20 of our catalog to find our chip-breaker product selection(s).

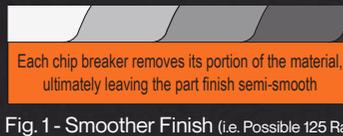
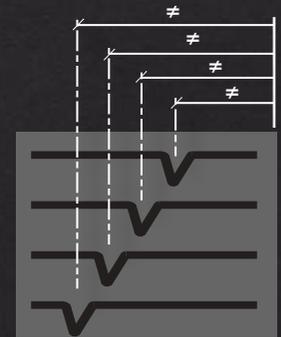


Fig. 1 - Smoother Finish (i.e. Possible 125 Ra)

Chip breakers are offset flute-to-flute. Here's a "flat" layout of a 4-flute chipbreaker tool for optical reference.



Should you be using a chipbreaker style?

People often inquire when they should use a chip-breaker-type tool. Because we begin placing our chipbreakers at the front of the tool and work our way back, the depth of cut will determine relevancy.

If your ADOC (A_p) is less than $1.0 \times \text{diameter}$, you will probably not be able to engage enough of them to be relevant. Instead, save the money on this feature and just secure a non-chip breaker tool.

Chip Breaker Style



Fig. 3 - Chip Breaker Style

Serration Roughers (aka Fine-Pitch, Low-Profile, Hog Mill, Corncob Rougher, Knuckle Rougher etc.)

In our industry, roughing end mills are nothing new; most of us are familiar with corn cob roughers (Fig. 4), which are typically made of cobalt or HSS. However, research indicates that solid carbide is not as forgiving as cobalt or HSS, and the tops of the serrations in ferrous materials are particularly susceptible to failure. Typically, non-ferrous roughing uses these extreme knuckle designs. As a result, there is a push (on solid carbide tooling) to flatten out the serrations' peaks, making the roughing portion of the solid carbide tool much more durable; this process is known as truncation (Fig. 5).

These are also excellent roughers; the main distinction is that the part will undoubtedly show roughing grooves, necessitating the use of a finisher after the roughing operation. These designs are typically slightly more expensive as well, primarily due to the use of special-profile grinding wheels and the longer grinding times required to produce each serration.

See pages 21 and 22 for our new low-profile serrated rougher alternative for your tough ferrous (& Titanium) applications.



Fig. 4 - Knuckle Rougher Style
(*D1 = Tool Cutting Diameter)



Fig. 5 - Low-Profile Serrated Style
(*D1 = Tool Cutting Diameter)



ROUGHING TOOLS

	Available Surface Treatment	ISO Mat'l Group	Catalog Page(s)
AL3-CB 3-Flute High-Performance Chipbreaker Endmill 	<ul style="list-style-type: none"> ✓ Uncoated ✓ D-Max Coating 	N	10 - 12
VST4-CB 4-Flute High-Performance Chipbreaker Endmill 	<ul style="list-style-type: none"> ✓ A-Max Coating 	P M K S	13 - 14
VST5-CB 5-Flute High-Performance Chipbreaker Endmill 	<ul style="list-style-type: none"> ✓ P-Max Coating 	P M K S	15 - 16
VST6-CB 6-Flute High-Performance Chipbreaker Endmill 	<ul style="list-style-type: none"> ✓ T-Max Coating 	P M K S	17 - 18
VMF-CB 7, 9, and 11 Flute High-Performance Chipbreaker Endmill 	<ul style="list-style-type: none"> ✓ C-Max Coating 	P M K S	19 - 20
VXR 4 & 5 Flute High-Performance Low-Profile Serrated Roughing Endmill 	<ul style="list-style-type: none"> ✓ T-Max Coating 	P M K S H	21 - 22

NEW Series

NEW Series



Cutting Parameters, pages 23 - 24



AL3-CB

Our Proven High-Performance 3-Flute Chipbreaker Geometry



With Corner Radius Only

Center-Cutting End Geometry

Extra-Fine Grain Cemented Carbide

-.0001/-.0004 Cutting Diameter Tolerance with Cylindrical Margin

37° Helix

Offset "Flute-to-Flute" Chipbreaker Design

Uncoated (p. 11)
D-Max Coated (p. 12)

Strengthened Core Diameter

CNC Ground in the 

Serialization of every tool on shank by lot#

h6 Shank Tolerance

Cutting Parameters Found on pp. 23 - 24



Material Group

- N** Aluminum/Copper/Brass
- P** Carbon/Alloy Steel
- M** Stainless Steel
- K** Cast Iron
- S** Hi-Temp Alloys
- H** Hardened Steel

Process

- HEM Roughing Wall Finishing
- Heavy Peripheral Floor Finishing
- Light Peripheral Interpolation
- Contouring Chamfering
- Slotting Countersinking
- Ramping Deburring
- Plunging Beveling

AL3-CB (Uncoated)

3-Flute High-Performance Uncoated Endmill w/Chipbreakers

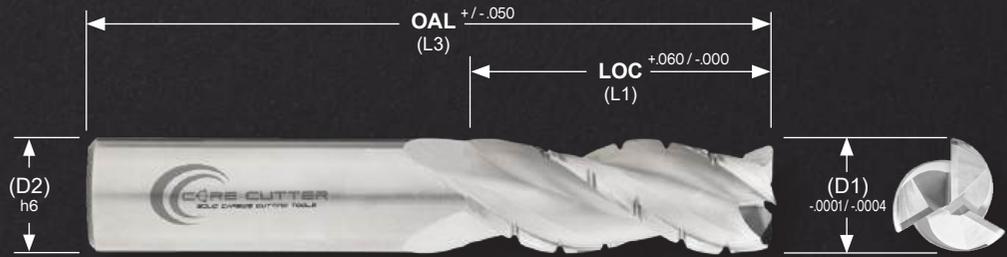
Custom made configurations of the AL3-CB style are available upon request

Cutting Parameters
pp. 23 - 24



Permittable ISO Material Categories

N



Tool Geometry						EDP #'s by Corner Condition	
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	.015R	.030R
1/8	1/8	.250	1.50	3	AL3-S-0125-CB	310010C	
		.375	2.00	3	AL3-SR-0125-CB	310110C	
		.500	2.50	3	AL3-R-0125-CB	310210C	
3/16	3/16	.313	2.00	3	AL3-S-0187-CB	300010C	
		.438	2.00	3	AL3-SR-0187-CB	300110C	
		.563	2.50	3	AL3-R-0187-CB	300210C	
1/4	1/4	.375	2.00	3	AL3-S-0250-CB		301020C
		.500	2.50	3	AL3-SR-0250-CB		301120C
		.750	2.50	3	AL3-R-0250-CB		301220C
		1.000	3.00	3	AL3-SP-0250-CB		391220C
5/16	5/16	1.250	3.00	3	AL3-M-0250-CB		301320C
		.500	2.00	3	AL3-SR-0312-CB		302120C
		.750	2.50	3	AL3-R-0312-CB		302220C
		1.250	3.00	3	AL3-M-0312-CB		302320C
3/8	3/8	.500	2.00	3	AL3-S-0375-CB		303020C
		.750	2.50	3	AL3-SR-0375-CB		303120C
		.875	3.00	3	AL3-SP-0375-CB		393220C
		1.000	3.00	3	AL3-R-0375-CB		303220C
		1.250	3.00	3	AL3-M-0375-CB		303320C
1/2	1/2	1.500	4.00	3	AL3-L-0375-CB		303420C
		.625	2.50	3	AL3-S-0500-CB		305020C
		1.000	3.00	3	AL3-SR-0500-CB		305120C
		1.250	3.00	3	AL3-R-0500-CB		305220C
		1.500	4.00	3	AL3-M-0500-CB		305320C
5/8	5/8	1.625	4.00	3	AL3-SP-0500-CB		395320C
		2.000	4.00	3	AL3-L-0500-CB		305420C
		.750	3.00	3	AL3-S-0625-CB		306010C
		1.250	3.50	3	AL3-SR-0625-CB		306110C
		1.500	3.50	3	AL3-R-0625-CB		306210C
3/4	3/4	1.625	3.50	3	AL3-SP-0625-CB		396210C
		2.000	4.00	3	AL3-M-0625-CB		306310C
		2.500	5.00	3	AL3-L-0625-CB		306410C
		1.000	3.00	3	AL3-S-0750-CB		307010C
		1.500	4.00	3	AL3-SR-0750-CB		307110C
1.0	1.0	1.625	4.00	3	AL3-SP-0750-CB		397110C
		2.000	5.00	3	AL3-R-0750-CB		307210C
		2.250	5.00	3	AL3-RM-0750-CB		387210C
		2.500	5.00	3	AL3-M-0750-CB		307310C
		3.000	6.00	3	AL3-L-0750-CB		307410C
1.0	1.0	1.750	4.00	3	AL3-SR-1000-CB		308110C
		2.500	5.00	3	AL3-R-1000-CB		308210C
		3.000	6.00	3	AL3-M-1000-CB		308310C
		3.500	6.00	3	AL3-L-1000-CB		308410C

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

AL3-CB (Coated)

3-Flute High-Performance D-Max Coated Endmill w/Chipbreakers

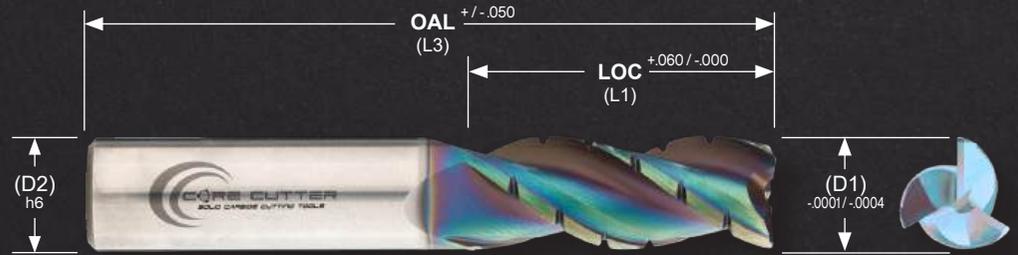
Custom made configurations of the AL3-CB style are available upon request

Cutting Parameters pp. 23 - 24



Permittable ISO Material Categories

N



Tool Geometry

EDP #'s by Corner Condition

Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	EDP #'s by Corner Condition	
						.015R	.030R
1/8	1/8	.250	1.500	3	AL3-S-0125-CB	310011C	
		.375	2.000	3	AL3-SR-0125-CB	310111C	
		.500	2.500	3	AL3-R-0125-CB	310211C	
3/16	3/16	.313	2.000	3	AL3-S-0187-CB	300011C	
		.438	2.000	3	AL3-SR-0187-CB	300111C	
		.563	2.500	3	AL3-R-0187-CB	300211C	
1/4	1/4	.375	2.000	3	AL3-S-0250-CB		301021C
		.500	2.500	3	AL3-SR-0250-CB		301121C
		.750	2.500	3	AL3-R-0250-CB		301221C
		1.000	3.000	3	AL3-SP-0250-CB		391221C
5/16	5/16	1.250	3.000	3	AL3-M-0250-CB		301321C
		.500	2.000	3	AL3-SR-0312-CB		302121C
		.750	2.500	3	AL3-R-0312-CB		302221C
3/8	3/8	1.250	3.000	3	AL3-M-0312-CB		302321C
		.500	2.000	3	AL3-S-0375-CB		303021C
		.750	2.500	3	AL3-SR-0375-CB		303121C
1/2	1/2	.875	3.000	3	AL3-SP-0375-CB		393221C
		1.000	3.000	3	AL3-R-0375-CB		303221C
		1.250	3.000	3	AL3-M-0375-CB		303321C
		1.500	4.000	3	AL3-L-0375-CB		303421C
5/8	5/8	.625	2.500	3	AL3-S-0500-CB		305021C
		1.000	3.000	3	AL3-SR-0500-CB		305121C
		1.250	3.000	3	AL3-R-0500-CB		305221C
		1.500	4.000	3	AL3-M-0500-CB		305321C
		1.625	4.000	3	AL3-SP-0500-CB		395321C
3/4	3/4	2.000	4.000	3	AL3-L-0500-CB		305421C
		.750	3.000	3	AL3-S-0625-CB		306011C
		1.250	3.500	3	AL3-SR-0625-CB		306111C
		1.500	3.500	3	AL3-R-0625-CB		306211C
		1.625	3.500	3	AL3-SP-0625-CB		396211C
1.0	1.0	2.000	4.000	3	AL3-M-0625-CB		306311C
		2.500	5.000	3	AL3-L-0625-CB		306411C
		1.000	3.000	3	AL3-S-0750-CB		307011C
		1.500	4.000	3	AL3-SR-0750-CB		307111C
		1.625	4.000	3	AL3-SP-0750-CB		397111C
		2.000	5.000	3	AL3-R-0750-CB		307211C
		2.250	5.00	3	AL3-RM-0750-CB		387211C
2.500	5.000	3	AL3-M-0750-CB		307311C		
1.0	1.0	3.000	6.000	3	AL3-L-0750-CB		307411C
		1.750	4.000	3	AL3-SR-1000-CB		308111C
		2.500	5.000	3	AL3-R-1000-CB		308211C
		3.000	6.000	3	AL3-M-1000-CB		308311C
		3.500	6.000	3	AL3-L-1000-CB		308411C

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

VST4-CB



Our Proven High-Performance 4-Flute Chipbreaker Geometry

Center-Cutting End Geometry

With Corner Radius Only

Extra-Fine Grain Cemented Carbide

Variable Flute Indexing

A-Max Coated

Serialization of every tool on shank by lot#

+ .000/- .002 Cutting Diameter Tolerance with Eccentric Relief

Offset "Flute-to-Flute" Chipbreaker Design

Strengthened Core Diameter

CNC Ground in the **USA**

h6 Shank Tolerance

Cutting Parameters Found on pp. 23 - 24 

Material Group	Process
<ul style="list-style-type: none"> ✗ N Aluminum/Copper/Brass ✓ P Carbon/Alloy Steel ✓ M Stainless Steel ✓ K Cast Iron ✓ S Hi-Temp Alloys ✗ H Hardened Steel 	<ul style="list-style-type: none"> HEM Roughing ✗ ✗ Wall Finishing Heavy Peripheral ✓ ✓ Floor Finishing Light Peripheral ✓ ✓ Interpolation Contouring ✓ ✗ Chamfering Slotting ✓ ✗ Countersinking Ramping ✓ ✗ Deburring Plunging ✓ ✗ Beveling

VST4-CB

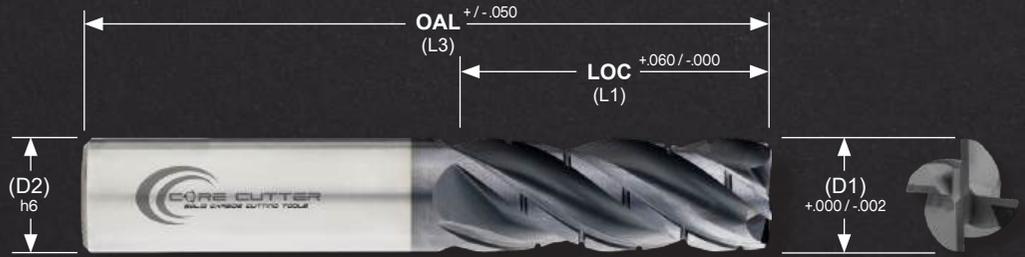
4-Flute High-Performance A-Max Coated Endmill w/Chipbreakers

Custom made configurations of the VST4-CB style are available upon request

Cutting Parameters
pp. 23 - 24



Permittable ISO Material Categories



Tool Geometry

EDP #'s by Corner Condition

Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	EDP #'s by Corner Condition	
						.015R	.030R
1/8	1/8	.250	1.50	4	VST4-S-0125-CB	410011C	
		.375	2.00	4	VST4-SR-0125-CB	410111C	
		.500	2.50	4	VST4-R-0125-CB	410211C	
3/16	3/16	.313	2.00	4	VST4-S-0187-CB	400011C	
		.438	2.00	4	VST4-SR-0187-CB	400111C	
		.563	2.50	4	VST4-R-0187-CB	400211C	
1/4	1/4	.375	2.00	4	VST4-S-0250-CB		401021C
		.500	2.50	4	VST4-SR-0250-CB		401121C
		.750	2.50	4	VST4-R-0250-CB		401221C
		1.000	3.00	4	VST4-SP-0250-CB		491221C
		1.250	3.00	4	VST4-M-0250-CB		401321C
5/16	5/16	.500	2.00	4	VST4-SR-0312-CB		402121C
		.750	2.50	4	VST4-R-0312-CB		402221C
		1.250	3.00	4	VST4-M-0312-CB		402321C
3/8	3/8	.500	2.00	4	VST4-S-0375-CB		403021C
		.750	2.50	4	VST4-SR-0375-CB		403121C
		.875	3.00	4	VST4-SP-0375-CB		493221C
		1.000	3.00	4	VST4-R-0375-CB		403221C
		1.250	3.00	4	VST4-M-0375-CB		403321C
		1.500	4.00	4	VST4-L-0375-CB		403421C
1/2	1/2	.625	2.50	4	VST4-S-0500-CB		405021C
		1.000	3.00	4	VST4-SR-0500-CB		405121C
		1.250	3.00	4	VST4-R-0500-CB		405221C
		1.500	4.00	4	VST4-M-0500-CB		405321C
		1.625	4.00	4	VST4-SP-0500-CB		495321C
		2.000	4.00	4	VST4-L-0500-CB		405421C
5/8	5/8	.750	3.00	4	VST4-S-0625-CB		406011C
		1.250	3.50	4	VST4-SR-0625-CB		406111C
		1.500	3.50	4	VST4-R-0625-CB		406211C
		1.625	3.50	4	VST4-SP-0625-CB		496211C
		2.000	4.00	4	VST4-M-0625-CB		406311C
		2.500	5.00	4	VST4-L-0625-CB		406411C
3/4	3/4	1.000	3.00	4	VST4-S-0750-CB		407011C
		1.500	4.00	4	VST4-SR-0750-CB		407111C
		1.625	4.00	4	VST4-SP-0750-CB		497111C
		2.000	5.00	4	VST4-R-0750-CB		407211C
		2.250	5.00	4	VST4-RM-0750-CB		487211C
		2.500	5.00	4	VST4-M-0750-CB		407311C
		3.000	6.00	4	VST4-L-0750-CB		407411C
1.0	1.0	1.750	4.00	4	VST4-SR-1000-CB		408111C
		2.500	5.00	4	VST4-R-1000-CB		408211C
		3.000	6.00	4	VST4-M-1000-CB		408311C
		3.500	6.00	4	VST4-L-1000-CB		408411C

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

VST5-CB



Our Proven High-Performance 5-Flute Chipbreaker Geometry

Center-Cutting End Geometry

With Corner Radius Only

Extra-Fine Grain Cemented Carbide

Variable Flute Indexing

P-Max Coated

Serialization of every tool on shank by lot#

+0.000/-0.002 Cutting Diameter Tolerance with Eccentric Relief

Offset "Flute-to-Flute" Chipbreaker Design

Strengthened Core Diameter

CNC Ground in the **USA**

h6 Shank Tolerance

Cutting Parameters
Found on pp. 23 - 24

Material Group	Process
<ul style="list-style-type: none"> ✗ N Aluminum/Copper/Brass ✔ P Carbon/Alloy Steel ✔ M Stainless Steel ✔ K Cast Iron ✔ S Hi-Temp Alloys ✗ H Hardened Steel 	<ul style="list-style-type: none"> HEM Roughing ✔ ✗ Wall Finishing Heavy Peripheral ✔ ✔ Floor Finishing Light Peripheral ✔ ✔ Interpolation Contouring ✔ ✗ Chamfering Slotting ✔ ✗ Countersinking Ramping ✔ ✗ Deburring Plunging ✔ ✗ Beveling

VST5-CB

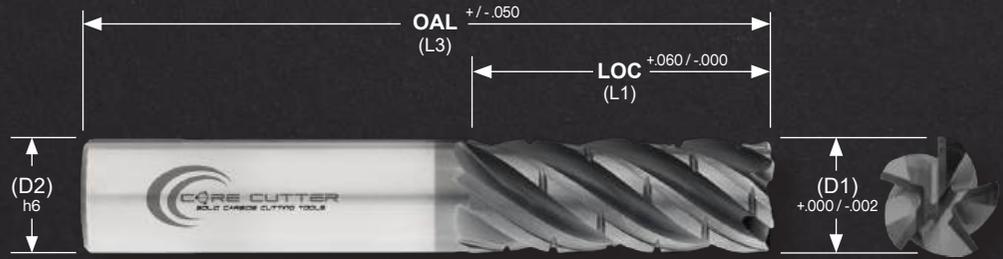
5-Flute High-Performance P-Max Coated Endmill w/Chipbreakers

Custom made configurations of the VST5-CB style are available upon request

Cutting Parameters pp. 23 - 24



Permittable ISO Material Categories



Tool Geometry

EDP #'s by Corner Condition

Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	EDP #'s by Corner Condition	
						.015R	.030R
1/8	1/8	.250	1.50	5	VST5-S-0125-CB	510011C	
		.375	2.00	5	VST5-SR-0125-CB	510111C	
		.500	2.50	5	VST5-R-0125-CB	510211C	
3/16	3/16	.313	2.00	5	VST5-S-0187-CB	500011C	
		.438	2.00	5	VST5-SR-0187-CB	500111C	
		.563	2.50	5	VST5-R-0187-CB	500211C	
1/4	1/4	.375	2.00	5	VST5-S-0250-CB		501021C
		.500	2.50	5	VST5-SR-0250-CB		501121C
		.750	2.50	5	VST5-R-0250-CB		501221C
		1.000	3.00	5	VST5-SP-0250-CB		591221C
		1.250	3.00	5	VST5-M-0250-CB		501321C
5/16	5/16	.500	2.00	5	VST5-SR-0312-CB		502121C
		.750	2.50	5	VST5-R-0312-CB		502221C
		1.250	3.00	5	VST5-M-0312-CB		502321C
3/8	3/8	.500	2.00	5	VST5-S-0375-CB		503021C
		.750	2.50	5	VST5-SR-0375-CB		503121C
		.875	3.00	5	VST5-SP-0375-CB		593221C
		1.000	3.00	5	VST5-R-0375-CB		503221C
		1.250	3.00	5	VST5-M-0375-CB		503321C
1/2	1/2	1.500	4.00	5	VST5-L-0375-CB		503421C
		.625	2.50	5	VST5-S-0500-CB		505021C
		1.000	3.00	5	VST5-SR-0500-CB		505121C
		1.250	3.00	5	VST5-R-0500-CB		505221C
		1.500	4.00	5	VST5-M-0500-CB		505321C
5/8	5/8	1.625	4.00	5	VST5-SP-0500-CB		595321C
		2.000	4.00	5	VST5-L-0500-CB		505421C
		.750	3.00	5	VST5-S-0625-CB		506011C
		1.250	3.50	5	VST5-SR-0625-CB		506111C
		1.500	3.50	5	VST5-R-0625-CB		506211C
		1.625	3.50	5	VST5-SP-0625-CB		596211C
3/4	3/4	2.000	4.00	5	VST5-M-0625-CB		506311C
		2.500	5.00	5	VST5-L-0625-CB		506411C
		1.000	3.00	5	VST5-S-0750-CB		507011C
		1.500	4.00	5	VST5-SR-0750-CB		507111C
		1.625	4.00	5	VST5-SP-0750-CB		597111C
		2.000	5.00	5	VST5-R-0750-CB		507211C
		2.250	5.00	5	VST5-RM-0750-CB		587211C
1.0	1.0	2.500	5.00	5	VST5-M-0750-CB		507311C
		3.000	6.00	5	VST5-L-0750-CB		507411C
		1.750	4.00	5	VST5-SR-1000-CB		508111C
		2.500	5.00	5	VST5-R-1000-CB		508211C
1.0	1.0	3.000	6.00	5	VST5-M-1000-CB		508311C
		3.500	6.00	5	VST5-L-1000-CB		508411C

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

NEW Series

VST6-CB



Our Proven High-Performance 6-Flute Chipbreaker Geometry

- Center-Cutting End Geometry
- With Corner Radius Only
- Extra-Fine Grain Cemented Carbide
- Variable Flute Indexing
- T-Max Coated
- Serialization of every tool on shank by lot#
- Strengthened Core Diameter
- CNC Ground in the **USA**
- h6 Shank Tolerance
- + .000/- .002 Cutting Diameter Tolerance with Eccentric Relief
- Offset "Flute-to-Flute" Chipbreaker Design

Cutting Parameters
Found on pp. 23 - 24



Material Group

- N** Aluminum/Copper/Brass
- P** Carbon/Alloy Steel
- M** Stainless Steel
- K** Cast Iron
- S** Hi-Temp Alloys
- H** Hardened Steel

Process

- HEM Roughing Wall Finishing
- Heavy Peripheral Floor Finishing
- Light Peripheral Interpolation
- Contouring Chamfering
- Slotting Countersinking
- Ramping Deburring
- Plunging Beveling



6-Flute High-Performance T-Max Coated Endmill w/Chipbreakers

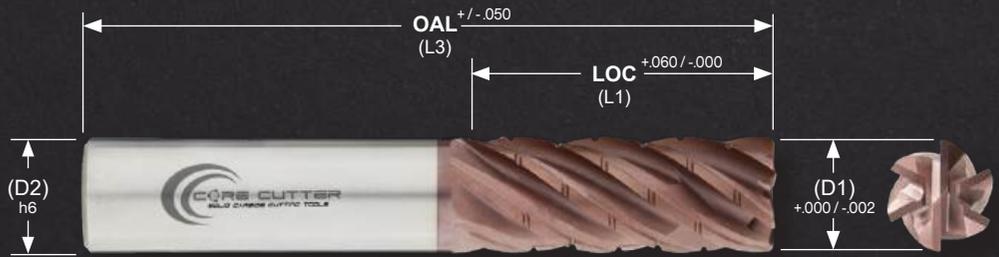
Custom made configurations of the VST6-CB style are available upon request

Cutting Parameters
pp. 23 - 24



Permittable ISO Material Categories

P M K S



Tool Geometry						EDP #'s by Corner Condition	
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	.015R	.030R
3/16	3/16	.313	2.00	6	VST6-S-0187-CB	600011C	
		.438	2.00	6	VST6-SR-0187-CB	600111C	
		.563	2.50	6	VST6-R-0187-CB	600211C	
1/4	1/4	.375	2.00	6	VST6-S-0250-CB		601021C
		.500	2.50	6	VST6-SR-0250-CB		601121C
		.750	2.50	6	VST6-R-0250-CB		601221C
		1.000	3.00	6	VST6-SP-0250-CB		691221C
		1.250	3.00	6	VST6-M-0250-CB		601321C
5/16	5/16	.500	2.00	6	VST6-SR-0312-CB		602121C
		.750	2.50	6	VST6-R-0312-CB		602221C
		1.250	3.00	6	VST6-M-0312-CB		602321C
3/8	3/8	.500	2.00	6	VST6-S-0375-CB		603021C
		.750	2.50	6	VST6-SR-0375-CB		603121C
		.875	3.00	6	VST6-SP-0375-CB		693221C
		1.000	3.00	6	VST6-R-0375-CB		603221C
		1.250	3.00	6	VST6-M-0375-CB		603321C
1/2	1/2	1.500	4.00	6	VST6-L-0375-CB		603421C
		.625	2.50	6	VST6-S-0500-CB		605021C
		1.000	3.00	6	VST6-SR-0500-CB		605121C
		1.250	3.00	6	VST6-R-0500-CB		605221C
		1.500	4.00	6	VST6-M-0500-CB		605321C
5/8	5/8	1.625	4.00	6	VST6-SP-0500-CB		695321C
		2.000	4.00	6	VST6-L-0500-CB		605421C
		.750	3.00	6	VST6-S-0625-CB		606011C
		1.250	3.50	6	VST6-SR-0625-CB		606111C
		1.500	3.50	6	VST6-R-0625-CB		606211C
3/4	3/4	1.625	3.50	6	VST6-SP-0625-CB		696211C
		2.000	4.00	6	VST6-M-0625-CB		606311C
		2.500	5.00	6	VST6-L-0625-CB		606411C
		1.000	3.00	6	VST6-S-0750-CB		607011C
		1.500	4.00	6	VST6-SR-0750-CB		607111C
1.0	1.0	1.625	4.00	6	VST6-SP-0750-CB		697111C
		2.000	5.00	6	VST6-R-0750-CB		607211C
		2.250	5.00	6	VST6-RM-0750-CB		687211C
		2.500	5.00	6	VST6-M-0750-CB		607311C
		3.000	6.00	6	VST6-L-0750-CB		607411C
1.0	1.0	1.750	4.00	6	VST6-SR-1000-CB		608111C
		2.500	5.00	6	VST6-R-1000-CB		608211C
		3.000	6.00	6	VST6-M-1000-CB		608311C
		3.500	6.00	6	VST6-L-1000-CB		608411C

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

VMF-CB



Our Proven High-Performance 7, 9, and 11 Flute Chipbreaker Geometry

With Corner Radius Only

Center-Cutting End Geometry
(Except the 11 flute configuration)

Extra-Fine Grain Cemented Carbide

+0.000/-0.002 Cutting Diameter Tolerance with Eccentric Relief

Variable Flute Indexing
(7, 9 & 11 Flutes Available)

Offset "Flute-to-Flute" Chipbreaker Design

C-Max Coated

Strengthened Core Diameter

Serialization of every tool on shank by lot#

CNC Ground in the **USA**

h6 Shank Tolerance

Cutting Parameters
Found on pp. 23 - 24



Material Group

- N** Aluminum/Copper/Brass
- P** Carbon/Alloy Steel
- M** Stainless Steel
- K** Cast Iron
- S** Hi-Temp Alloys
- H** Hardened Steel

Process

- HEM Roughing Wall Finishing
- Heavy Peripheral Floor Finishing
- Light Peripheral Interpolation
- Contouring Chamfering
- Slotting Countersinking
- Ramping Deburring
- Plunging Beveling



VMF-CB

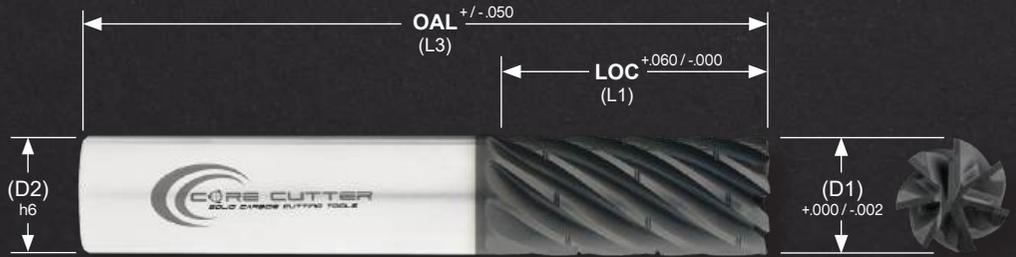
Multi-Flute High-Performance C-Max Coated Endmill w/Chipbreakers

Custom made configurations of the VMF-CB style are available upon request

Cutting Parameters
pp. 23 - 24



Permittable ISO Material Categories



Tool Geometry						EDP #'s by Corner Condition	
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	.015R	.030R
3/8	3/8	.750	2.50	7	VMF7-SR-0375-CB	703112	
		1.000	3.00	7	VMF7-R-0375-CB	703212	
1/2	1/2	1.000	3.00	7	VMF7-SR-0500-CB		705122
		1.250	3.00	7	VMF7-R-0500-CB		705222
		1.500	4.00	7	VMF7-M-0500-CB		705322
5/8	5/8	1.250	3.50	7	VMF7-SR-0625-CB		706112
		2.000	4.00	7	VMF7-M-0625-CB		706312
3/4	3/4	1.500	4.00	7	VMF7-SR-0750-CB		707112
		1.500	4.00	9	VMF9-SR-0750-CB		907112
		1.625	4.00	7	VMF7-SP-0750-CB		797112
		2.500	5.00	7	VMF7-M-0750-CB		707312
		2.500	5.00	9	VMF9-M-0750-CB		907312
		3.000	6.00	7	VMF7-L-0750-CB		707412
1.0	1.0	3.000	6.00	9	VMF9-L-0750-CB		907412
		1.750	4.00	7	VMF7-SR-1000-CB		708112
		1.750	4.00	9	VMF9-SR-1000-CB		908112
		1.750	4.00	11	VMF11-SR-1000-CB		118112
		2.500	5.00	7	VMF7-R-1000-CB		708212
		2.500	5.00	9	VMF9-R-1000-CB		908212
		2.500	5.00	11	VMF11-R-1000-CB		118212
		3.000	6.00	7	VMF7-M-1000-CB		708312
3.000	6.00	9	VMF9-M-1000-CB		908312		
		3.000	6.00	11	VMF11-M-1000-CB		118312

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

Multiple Flute Count Options Available.

NEW Series

VXR



Our Proven High-Performance 4 & 5 Flute Low-Profile Serrated Rougher

- With Corner Radius Only
- Center-Cutting End Geometry
- Extra-Fine Grain Cemented Carbide
- + .000 / - .002 Cutting Diameter Tolerance with Eccentric Relief
- Variable Flute Indexing (4 & 5 Flutes Available)
- Offset "Flute-to-Flute" Chipbreaker Design
- T-Max Coated
- Strengthened Core Diameter
- Serialization of every tool on shank by lot#
- CNC Ground in the **USA**
- h6 Shank Tolerance

Cutting Parameters Found on pp. 23 - 24 

Material Group

- N** Aluminum/Copper/Brass
- P** Carbon/Alloy Steel
- M** Stainless Steel
- K** Cast Iron
- S** Hi-Temp Alloys
- H** Hardened Steel

Process

- HEM Roughing Wall Finishing
- Heavy Peripheral Floor Finishing
- Light Peripheral Interpolation
- Contouring Chamfering
- Slotting Countersinking
- Ramping Deburring
- Plunging Beveling



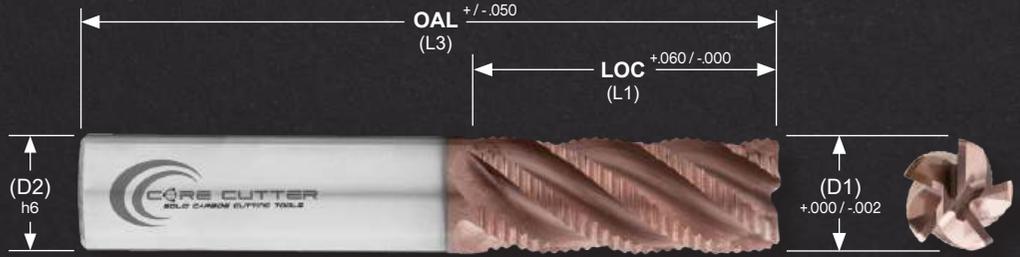
High-Performance T-Max Coated Low-Profile Serrated Rougher

Custom made configurations of the VXR style are available upon request

Cutting Parameters pp. 23 - 24



Permittable ISO Material Categories



Tool Geometry						EDP #'s by Corner Condition	
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	.040R	.060R
3/8	3/8	.750	2.50	4	VXR4-SR-0375-R040	473121	
		.750	2.50	5	VXR5-SR-0375-R040	573121	
		1.000	3.00	4	VXR4-R-0375-R040	473221	
		1.000	3.00	5	VXR5-R-0375-R040	573221	
1/2	1/2	1.250	3.00	4	VXR4-R-0500-R040	475221	
		1.250	3.00	5	VXR5-R-0500-R040	575221	
		1.625	4.00	4	VXR4-SP-0500-R040	475326	
		1.625	4.00	5	VXR5-SP-0500-R040	575326	
3/4	3/4	1.625	4.00	4	VXR4-SP-0750-R060		477126
		1.625	4.00	5	VXR5-SP-0750-R060		577126
		2.250	5.00	4	VXR4-RM-0750-R060		477226
		2.250	5.00	5	VXR5-RM-0750-R060		577226

Our part numbers highlighted in **ORANGE** are declared factory stocked items, please call for availability on all other part numbers.

Multiple Flute Count Options Available.

SPEEDS & FEEDS

Suggested Initial cut values for all roughing tools.

ISO Material Categories		SFM	Roughing Tools Feed Table (f _z)																											
			D1 ≤ 1/8				D1 ≤ 1/4				D1 ≤ 3/8				D1 ≤ 1/2				D1 ≤ 5/8				D1 ≤ 3/4				D1 ≤ 1"			
			S	HP	LP	*HEM	S	HP	LP	*HEM	S	HP	LP	*HEM	S	HP	LP	*HEM	S	HP	LP	*HEM	S	HP	LP	*HEM	S	HP	LP	*HEM
N	Wrought Aluminum Alloys 1100, 2024, 6061, 7075	1200 2000	.0008	.0008	.0009	.0014	.0015	.0017	.0018	.0028	.0023	.0025	.0027	.0041	.0031	.0033	.0036	.0055	.0039	.0041	.0044	.0069	.0046	.0050	.0053	.0083	.0062	.0066	.0071	.0110
	Cast Aluminum Alloys A356, A360, A380, A390	550 800	.0007	.0008	.0008	.0014	.0014	.0017	.0016	.0028	.0021	.0025	.0024	.0041	.0028	.0033	.0032	.0055	.0034	.0041	.0040	.0069	.0041	.0050	.0048	.0083	.0055	.0066	.0064	.0110
	Brass, Bronze, Copper 101, 110, 260, 360, 932	435 750	.0006	.0009	.0007	.0015	.0012	.0018	.0014	.0029	.0018	.0026	.0021	.0044	.0024	.0035	.0028	.0059	.0030	.0044	.0035	.0073	.0036	.0053	.0042	.0088	.0048	.0070	.0056	.0117
P	Free Machining Steels 1018, 1215, 12L14	300 500	.0008	.0009	.0009	.0015	.0015	.0018	.0018	.0030	.0023	.0027	.0027	.0045	.0031	.0036	.0036	.0061	.0039	.0045	.0044	.0076	.0046	.0054	.0053	.0091	.0062	.0073	.0071	.0121
	Alloys Steels 4130 (Chrome Moly), 4140, 4340, 8620	250 350	.0007	.0009	.0009	.0014	.0015	.0017	.0017	.0028	.0022	.0026	.0026	.0043	.0030	.0034	.0034	.0057	.0037	.0043	.0043	.0071	.0045	.0051	.0051	.0085	.0059	.0068	.0069	.0114
	Tool & Die Steels A2, D2, H13, P20, S7	110 225	.0007	.0008	.0008	.0013	.0014	.0015	.0016	.0026	.0021	.0023	.0024	.0039	.0028	.0031	.0032	.0051	.0034	.0039	.0040	.0064	.0041	.0046	.0048	.0077	.0055	.0062	.0064	.0103
M	Martensitic Stainless Steel 410, 416, 420, 440C, 440F	275 380	.0007	.0008	.0008	.0013	.0013	.0015	.0015	.0026	.0020	.0023	.0023	.0039	.0026	.0031	.0030	.0051	.0033	.0039	.0038	.0064	.0040	.0046	.0046	.0077	.0053	.0062	.0061	.0103
	Austenitic Stainless Steel 303, 304, 316, 321	200 300	.0007	.0008	.0009	.0014	.0015	.0017	.0017	.0028	.0022	.0025	.0026	.0041	.0030	.0033	.0034	.0055	.0037	.0041	.0043	.0069	.0045	.0050	.0051	.0083	.0059	.0066	.0069	.0110
	PH Stainless Steel 13-8, 15-5, 17-4	180 275	.0008	.0009	.0009	.0015	.0015	.0018	.0018	.0029	.0023	.0026	.0027	.0044	.0031	.0035	.0036	.0059	.0039	.0044	.0044	.0073	.0046	.0053	.0053	.0088	.0062	.0070	.0071	.0117
K	Gray Cast Iron GG10, GG20, GG30	325 450	.0007	.0007	.0008	.0012	.0014	.0014	.0016	.0024	.0021	.0021	.0024	.0036	.0028	.0029	.0032	.0048	.0034	.0036	.0040	.0060	.0041	.0043	.0048	.0072	.0055	.0057	.0064	.0095
	Ductile Cast Iron A536 Grade 60-40-18	275 375	.0007	.0007	.0008	.0011	.0013	.0014	.0015	.0023	.0020	.0021	.0023	.0034	.0026	.0028	.0030	.0046	.0033	.0034	.0038	.0057	.0040	.0041	.0046	.0069	.0053	.0055	.0061	.0092
	Malleable Cast Iron 310M8, 22010, M4504	250 325	.0006	.0007	.0007	.0011	.0012	.0013	.0014	.0022	.0018	.0020	.0021	.0033	.0024	.0026	.0028	.0044	.0030	.0033	.0035	.0055	.0036	.0040	.0042	.0066	.0048	.0053	.0056	.0088
S	Titanium Ti-3AL, Ti-4AL, Ti-5AL, Ti-6AL	175 280	.0006	.0006	.0006	.0010	.0011	.0012	.0013	.0020	.0017	.0018	.0019	.0030	.0022	.0024	.0025	.0040	.0028	.0030	.0032	.0050	.0033	.0036	.0038	.0061	.0044	.0048	.0051	.0081
	HRSA (Co) Rene 41, HS-188, X-40, AirResist 13, Stellite	110 165	.0003	.0005	.0003	.0008	.0006	.0009	.0007	.0015	.0009	.0014	.0010	.0023	.0012	.0018	.0014	.0030	.0015	.0023	.0017	.0038	.0018	.0027	.0021	.0045	.0024	.0036	.0028	.0060
	HRSA (Fe) A286, Incoloy, Udimet, Discaloy	100 150	.0003	.0004	.0003	.0006	.0005	.0008	.0006	.0013	.0008	.0011	.0009	.0019	.0010	.0015	.0012	.0025	.0013	.0019	.0014	.0031	.0015	.0023	.0017	.0038	.0020	.0030	.0023	.0050
	HRSA (Ni) Inconel, MAR-M-247, Udimet-700, Haynes, Monel, Rene 150, Waspaloy	75 125	.0005	.0006	.0006	.0010	.0010	.0011	.0013	.0018	.0015	.0017	.0019	.0028	.0020	.0022	.0025	.0037	.0025	.0028	.0031	.0047	.0030	.0033	.0038	.0055	.0040	.0044	.0050	.0073
H	Hardened Steel (<55 HRC)	80 115	.0003	.0005	.0005	.0008	.0006	.0009	.0011	.0015	.0009	.0014	.0016	.0023	.0012	.0018	.0022	.0030	.0015	.0023	.0027	.0038	.0018	.0027	.0032	.0045	.0024	.0036	.0043	.0060
	Hardened Steel (>55 HRC)	70 100	.0003	.0004	.0005	.0007	.0005	.0008	.0009	.0013	.0008	.0011	.0014	.0018	.0010	.0015	.0018	.0025	.0013	.0019	.0023	.0032	.0015	.0023	.0027	.0038	.0020	.0030	.0036	.0050

Speeds and Feeds suggested within the table are only estimated starting parameters and may require increase/decrease adjustments based on your particular application and/or setup - Core Cutter LLC, assumes no liability.
*For HEM applications, the "HEM" column within the feed table is for your feed (fz) based on chip thinning at ≤10% step over, and for SFM, you can take our recommendations x 1.5 - 1.8

KEY

Co	Cobalt (Chemical Element - see p. 79)	HEM	High Efficiency Milling (see pp. 84-86)	S	Slotting (a _e = 100% of Dia.)
D1	Tool Cutting Diameter	LP	Light Peripheral (a _e = 18%-to-29% of Dia.)	HRC	Rockwell Hardness "C" Scale
F _z	Feed per Tooth	Ni	Nickel (Metallic Element - see p. 79)		
F _a	Iron (Chemical Element - see p. 79)	ISO	International Organization for Standardization		
HP	Heavy Peripheral (a _e = 30%-to-50% of Dia.)	SFM	Surface Feet per Minute		

DEPTH OF CUT GUIDELINES

Suggested Initial Depth of Cut Values for all Roughing Tools

Roughing Tools (Depth of Cut Chart)										
Tool Series	Light Peripheral (LP)		Heavy Peripheral (HP)		Slotting (S)		Ramping		High Efficiency Milling (see pp. 84-86)	
	a_e	a_p	a_e	a_p	a_e	a_p	Angle	Feed	a_e	a_p
	AL3-CB	20% - 35% of D1	Up to 2.5 x D1	35% - 50% of D1	Up to 2.0 x D1	100% of D1	Up to 1.0 x D1	5° - 10°	Use (LP) in Feed Chart on p.23	12% - 30% of D1
VST4-CB	18% - 30% of D1	Up to 3.0 x D1	30% - 50% of D1	Up to 2.5 x D1	100% of D1	Up to 1.0 x D1	1° - 5°	Use (LP) in Feed Chart on p.23	Upgrade to a 5-flute tool to get higher Material Removal Rate (MRR)	
VXR4-CB	18% - 30% of D1	Up to 3.0 x D1	30% - 50% of D1	Up to 2.5 x D1	100% of D1	Up to 1.0 x D1	1° - 5°	Use (LP) in Feed Chart on p.23	Upgrade to a 5-flute tool to get higher Material Removal Rate (MRR)	
VST5-CB	18% - 30% of D1	Up to 3.0 x D1	30% - 50% of D1	Up to 2.5 x D1	100% of D1	Up to .50 x D1	1° - 5°	Use (LP) in Feed Chart on p.23	8% - 15% of D1	Up to 3.5 x D1
VXR5-CB	18% - 30% of D1	Up to 3.0 x D1	30% - 50% of D1	Up to 2.5 x D1	100% of D1	Up to .50 x D1	1° - 5°	Use (LP) in Feed Chart on p.23	8% - 15% of D1	Up to 3.5 x D1
VST6-CB	18% - 30% of D1	Up to 3.0 x D1	25% - 50% of D1	Up to 2.75 x D1	100% of D1	Up to .35 x D1	1° - 5°	Use (LP) in Feed Chart on p.23	8% - 20% of D1	Up to 3.75 x D1
VMF7-CB	8% - 13% of D1	Up to 3.0 x D1	Not Recommended		Not Recommended		1° - 5°	Use (LP) in Feed Chart on p.23	8% - 13% of D1	Up to 3.75 x D1
VMF9-CB	7% - 12% of D1	Up to 3.5 x D1	Not Recommended		Not Recommended		1° - 5°	Use (LP) in Feed Chart on p.23	7% - 12% of D1	Up to 4.0 x D1
VMF11-CB	6% - 10% of D1	Up to 3.5 x D1	Not Recommended		Not Recommended		1° - 5°	Use (LP) in Feed Chart on p.23	6% - 10% of D1	Up to 4.0 x D1

*Note: The depth of cut numbers supplied in this table are estimates only and may need to be changed higher/lower based on your specific application and setup - Core Cutter LLC, assumes no liability.

KEY

Angle	Ramping angle to utilize	FEED	F_z to use for this operation	LOC	Length of Cut (L1)
D1	Tool Cutting Diameter	HP	Heavy Peripheral ($a_e = 30\%$ -to- 50% of Dia.)	MRR	Metal Removal Rate (See p. 87)
a_e	Radial Depth of Cut	HEM	High Efficiency Milling (See pp. 84-86)	Ramping	Tool plunges gradually
a_p	Axial Depth of Cut	LP	Light Peripheral ($a_e = 18\%$ -to- 29% of Dia.)	Slotting	Slotting ($a_e = 100\%$ of Dia.)



Miniature Tooling

	Available Surface Treatment	ISO Mat'l Group	Catalog Page(s)						
QTR3 3-Flute High-Performance Endmill with 1/4" Shank Diameter	 P-Max Coating	<table border="1"><tr><td>N</td></tr><tr><td>P</td></tr><tr><td>M</td></tr><tr><td>K</td></tr><tr><td>S</td></tr><tr><td>H</td></tr></table>	N	P	M	K	S	H	26 - 27
N									
P									
M									
K									
S									
H									
									
QTR3-RN 3-Flute High-Performance (Reduced Neck) Endmill w/ 1/4" Shank Diameter	 P-Max Coating	<table border="1"><tr><td>N</td></tr><tr><td>P</td></tr><tr><td>M</td></tr><tr><td>K</td></tr><tr><td>S</td></tr><tr><td>H</td></tr></table>	N	P	M	K	S	H	28
N									
P									
M									
K									
S									
H									
									



Cutting Parameters, pages 29 - 30



QTR3

Our Proven High-Performance 3-Flute Miniature Tool Geometry

End Construction Options:

- Square Corner
- Corner Radii
- Ball Nose

Extra-Fine Grain Cemented Carbide

Series Contains all 1/4" Shank Diameters

P-Max Coated

Serialization of every tool on shank by lot#

Center-Cutting End Geometry

Variable Flute Indexing & Variable Helix

Cutting Diameter Tolerance
< 3/16" = .000/-0.001
3/16" to 1/4" = .000/-0.002

Need Long Reach? See p. 28

CNC Ground in the 

h6 Shank Tolerance

Cutting Parameters Found on pp. 29 - 30



Material Group

- ✓ **N** Aluminum/Copper/Brass
- ✓ **P** Carbon/Alloy Steel
- ✓ **M** Stainless Steel
- ✓ **K** Cast Iron
- ✓ **S** Hi-Temp Alloys
- ✓ **H** Hardened Steel

Process

- | | | | |
|------------------|---|---|-----------------|
| HEM Roughing | ✓ | ✓ | Wall Finishing |
| Heavy Peripheral | ✓ | ✓ | Floor Finishing |
| Light Peripheral | ✓ | ✓ | Interpolation |
| Contouring | ✓ | ✗ | Chamfering |
| Slotting | ✓ | ✗ | Countersinking |
| Ramping | ✓ | ✗ | Deburring |
| Plunging | ✓ | ✗ | Beveling |



3-Flute High-Performance P-Max Coated Miniature Endmill

Custom made configurations of the QTR3 style are available upon request

Cutting Parameters
pp. 29 - 30



Permittable ISO Material Categories

N P M K S H



Tool Geometry						EDP #'s by Corner Condition				
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Cut Depth Ratio	Tool Description	Square Corner	.010R	.015R	Ball Nose
1/16	1/4"	.125	2.500	3	2xD	QTR3-0062-2XD	Q0622S	Q0622R		Q0622B
		.188	2.500	3	3xD	QTR3-0062-3XD	Q0623S	Q0623R		Q0623B
		.250	2.500	3	4xD	QTR3-0062-4XD	Q0624S	Q0624R		
5/64		.156	2.500	3	2xD	QTR3-0078-2XD	Q0782S	Q0782R		Q0782B
		.234	2.500	3	3xD	QTR3-0078-3XD	Q0783S	Q0783R		Q0783B
		.313	2.500	3	4xD	QTR3-0078-4XD	Q0784S	Q0784R		
3/32		.188	2.500	3	2xD	QTR3-0093-2XD	Q0932S	Q0932R		Q0932B
		.281	2.500	3	3xD	QTR3-0093-3XD	Q0933S	Q0933R		Q0933B
		.375	2.500	3	4xD	QTR3-0093-4XD	Q0934S	Q0934R		
7/64		.219	2.500	3	2xD	QTR3-0109-2XD	Q1092S	Q1092R		Q1092B
		.328	2.500	3	3xD	QTR3-0109-3XD	Q1093S	Q1093R		Q1093B
		.438	2.500	3	4xD	QTR3-0109-4XD	Q1094S	Q1094R		
1/8	.250	2.500	3	2xD	QTR3-0125-2XD	Q1252S		Q1252R	Q1252B	
	.375	2.500	3	3xD	QTR3-0125-3XD	Q1253S		Q1253R	Q1253B	
	.500	2.500	3	4xD	QTR3-0125-4XD	Q1254S		Q1254R		
5/32	.313	2.500	3	2xD	QTR3-0156-2XD	Q1562S		Q1562R	Q1562B	
	.469	2.500	3	3xD	QTR3-0156-3XD	Q1563S		Q1563R	Q1563B	
	.625	2.500	3	4xD	QTR3-0156-4XD	Q1564S		Q1564R		
3/16	.375	2.500	3	2xD	QTR3-0187-2XD	Q1872S		Q1872R	Q1872B	
	.563	2.500	3	3xD	QTR3-0187-3XD	Q1873S		Q1873R	Q1873B	
	.625	2.500	3	3.3xD	QTR3-0187-3.3XD	Q18733S		Q18733R	Q18733B	
7/32	.750	2.500	3	4xD	QTR3-0187-4XD	Q1874S		Q1874R		
	.438	2.500	3	2xD	QTR3-0218-2XD	Q2182S		Q2182R	Q2182B	
	.656	2.500	3	3xD	QTR3-0218-3XD	Q2183S		Q2183R	Q2183B	
1/4	.875	2.500	3	4xD	QTR3-0218-4XD	Q2184S		Q2184R		
	.500	2.500	3	2xD	QTR3-0250-2XD	Q2502S		Q2502R	Q2502B	
	.750	2.500	3	3xD	QTR3-0250-3XD	Q2503S		Q2503R	Q2503B	
		1.000	2.500	3	4xD	QTR3-0250-4XD	Q2504S		Q2504R	

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

* Dynamic Tolerancing for QTR3 Series

Tool Cut Diameter	Cutting Dia. Tolerance (D1)	Length of Cut Tolerance (L1)
1/16" -to- 5/32"	+0.00 / -.001	+0.010 / -.000
3/16" -to- 1/4"	+0.000 / -.002	+0.060 / -.000

QTR3-RN

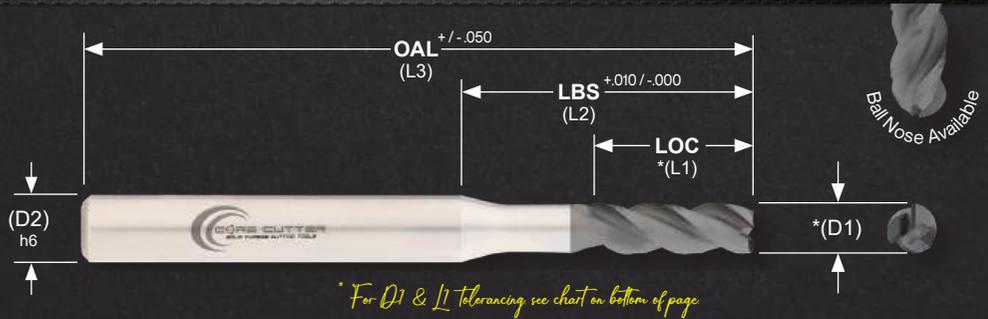
3-Flute High-Performance P-Max Coated (Reduced Neck) Miniature Endmill

Custom made configurations of the QTR3-RN style are available upon request

Cutting Parameters pp. 29 - 30



Permittable ISO Material Categories



Tool Geometry							EDP #'s by Corner Condition				
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	LBS (L2)	OAL (L3)	Flute Count	REACH Ratio	Tool Description	Square Corner	.010R	.015R	Ball Nose
1/16	1/4"	.188	.313	2.500	3	5xd	QTR3-RN-0062-5XD	Q0623SN	Q0623RN		Q0623BN
5/64		.234	.390	2.500	3	5xd	QTR3-RN-0078-5XD	Q0783SN	Q0783RN		Q0783BN
3/32		.281	.469	2.500	3	5xd	QTR3-RN-0093-5XD	Q0933SN	Q0933RN		Q0933BN
7/64		.328	.547	2.500	3	5xd	QTR3-RN-0109-5XD	Q1093SN	Q1093RN		Q1093BN
1/8		.375	.625	2.500	3	5xd	QTR3-RN-0125-5XD	Q1253SN		Q1253RN	Q1253BN
5/32		.469	.781	2.500	3	5xd	QTR3-RN-0156-5XD	Q1563SN		Q1563RN	Q1563BN
3/16		.563	.937	2.500	3	5xd	QTR3-RN-0187-5XD	Q1873SN		Q1873RN	Q1873BN
7/32		.656	1.093	2.500	3	5xd	QTR3-RN-0218-5XD	Q2183SN		Q2183RN	Q2183BN
1/4		.750	1.250	2.500	3	5xd	QTR3-RN-0250-5XD	Q2503SN		Q2503RN	Q2503BN

Our part numbers highlighted in **ORANGE** are declared factory stocked items, please call for availability on all other part numbers.

* Dynamic Tolerancing for QTR3 Series

Tool Cut Diameter	Cutting Dia. Tolerance (D1)	Length of Cut Tolerance (L1)
1/16" -to- 5/32"	+ .000 / - .001	+ .010 / - .000
3/16" -to- 1/4"	+ .000 / - .002	+ .060 / - .000

Suggested Initial Cutting Parameters for Miniature Tooling

ISO Material Categories		SFM	Dynamic (QTR3) - Miniature Tooling Feed Table (f_z)																								
			D1 ≤ 1/16					D1 ≤ 3/32					D1 ≤ 1/8					D1 ≤ 3/16					D1 ≤ 1/4				
			S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM
N	Wrought Aluminum Alloys 1100, 2024, 6061, 7075	1200 to 2000	.00045	.00050	.00048	.00034	.00083	.00068	.00075	.00072	.00051	.00125	.00090	.00100	.00095	.00067	.00167	.00135	.00150	.00143	.00101	.00250	.00180	.00200	.00190	.00135	.00333
	Cast Aluminum Alloys A356, A360, A380, A390	550 to 800	.00040	.00045	.00042	.00030	.00075	.00060	.00068	.00064	.00045	.00113	.00080	.00090	.00085	.00060	.00150	.00120	.00135	.00127	.00090	.00225	.00160	.00180	.00169	.00120	.00299
	Brass, Bronze, Copper 101, 110, 260, 360, 932	435 to 750	.00035	.00040	.00037	.00026	.00067	.00053	.00060	.00056	.00039	.00100	.00070	.00080	.00074	.00052	.00133	.00105	.00120	.00111	.00079	.00200	.00140	.00160	.00148	.00105	.00266
P	Free Machining Steels 1018, 1215, 12L14	300 to 500	.00040	.00040	.00042	.00030	.00067	.00060	.00060	.00064	.00045	.00100	.00080	.00080	.00085	.00060	.00133	.00120	.00120	.00127	.00090	.00200	.00160	.00160	.00169	.00120	.00266
	Alloys Steels 4130 (Chrome Moly), 4140, 4340, 8620	250 to 350	.00035	.00040	.00037	.00026	.00067	.00053	.00060	.00056	.00039	.00100	.00070	.00080	.00074	.00052	.00133	.00105	.00120	.00111	.00079	.00200	.00140	.00160	.00148	.00105	.00266
	Tool & Die Steels A2, D2, H13, P20, S7	110 to 225	.00030	.00035	.00032	.00022	.00058	.00045	.00053	.00048	.00034	.00088	.00060	.00070	.00064	.00045	.00117	.00090	.00105	.00095	.00068	.00175	.00120	.00140	.00127	.00090	.00233
M	Martensitic Stainless Steel 410, 416, 420, 440C, 440F	275 to 380	.00030	.00035	.00032	.00022	.00058	.00045	.00053	.00048	.00034	.00088	.00060	.00070	.00064	.00045	.00117	.00090	.00105	.00095	.00068	.00175	.00120	.00140	.00127	.00090	.00233
	Austenitic Stainless Steel 303, 304, 316, 321	200 to 300	.00030	.00035	.00032	.00022	.00058	.00045	.00053	.00048	.00034	.00088	.00060	.00070	.00064	.00045	.00117	.00090	.00105	.00095	.00068	.00175	.00120	.00140	.00127	.00090	.00233
	PH Stainless Steel 13-8, 15-5, 17-4	180 to 275	.00025	.00030	.00027	.00019	.00050	.00038	.00045	.00040	.00028	.00075	.00050	.00060	.00053	.00037	.00100	.00075	.00090	.00080	.00056	.00150	.00100	.00120	.00106	.00075	.00200
K	Gray Cast Iron GG10, GG20, GG30	325 to 450	.00080	.00095	.00085	.00060	.00158	.00120	.00143	.00127	.00090	.00238	.00160	.00190	.00170	.00120	.00316	.00240	.00285	.00255	.00180	.00475	.00319	.00379	.00339	.00239	.00632
	Ductile Cast Iron A536 Grade 60-40-18	275 to 375	.00065	.00080	.00069	.00049	.00133	.00098	.00120	.00103	.00073	.00200	.00130	.00160	.00138	.00097	.00266	.00195	.00240	.00207	.00146	.00400	.00259	.00319	.00275	.00195	.00532
	Malleable Cast Iron 310M8, 22010, M4504	250 to 325	.00060	.00070	.00064	.00045	.00117	.00090	.00105	.00095	.00068	.00175	.00120	.00140	.00127	.00090	.00233	.00180	.00210	.00191	.00135	.00350	.00239	.00279	.00254	.00180	.00466
S	Titanium Ti-3AL, Ti-4AL, Ti-5AL, Ti-6AL	175 to 280	.00030	.00040	.00032	.00022	.00067	.00045	.00060	.00048	.00034	.00100	.00060	.00080	.00064	.00045	.00133	.00090	.00120	.00095	.00068	.00200	.00120	.00160	.00127	.00090	.00266
	HRSA (Co) Rene 41, HS-188, X-40, AirResist 13, Stellite	110 to 165	.00030	.00035	.00032	.00022	.00058	.00045	.00053	.00048	.00034	.00088	.00060	.00070	.00064	.00045	.00117	.00090	.00105	.00095	.00068	.00175	.00120	.00140	.00127	.00090	.00233
	HRSA (Fe) A286, Incoloy, Udimet, Discaloy	100 to 150	.00030	.00030	.00032	.00022	.00050	.00045	.00045	.00048	.00034	.00075	.00060	.00060	.00064	.00045	.00100	.00090	.00090	.00095	.00068	.00150	.00120	.00120	.00127	.00090	.00200
	HRSA (Ni) Inconel, MAR-M-247, Udimet-700, Haynes, Monel, Rene 150, Waspaloy	75 to 125	.00025	.00030	.00027	.00019	.00050	.00038	.00045	.00040	.00028	.00075	.00050	.00060	.00053	.00037	.00100	.00075	.00090	.00080	.00056	.00150	.00100	.00120	.00106	.00075	.00200
H	Hardened Steel (<55 HRC)	80 to 115	.00015	.00025	.00016	.00011	.00042	.00023	.00038	.00024	.00017	.00063	.00030	.00050	.00032	.00022	.00083	.00045	.00075	.00048	.00034	.00125	.00060	.00100	.00063	.00045	.00166
	Hardened Steel (>55 HRC)	70 to 100	.00015	.00020	.00016	.00011	.00033	.00023	.00030	.00024	.00017	.00050	.00030	.00040	.00032	.00022	.00067	.00045	.00060	.00048	.00034	.00100	.00060	.00080	.00063	.00045	.00133

Speeds and Feeds suggested within the table are only estimated starting parameters and may require increase/decrease adjustments based on your particular application and/or setup - Core Cutter LLC, assumes no liability.
 *For HEM applications, the "HEM" column within the feed table is for your feed (f_z) based on chip thinning at ≤10% step over, and for SFM, you can take our recommendations x 1.5 - 1.8

KEY

Co	Cobalt (Chemical Element - see p. 79)	HP	Heavy Peripheral ($a_e = 30\%$ -to- 50% of Dia.)	SFM	Surface Feet per Minute
D1	Tool Cutting Diameter	HEM	High Efficiency Milling (see pp. 84-86)	S	Slotting ($a_e = 100\%$ of Dia.)
F	Finishing (see p. 93)	LP	Light Peripheral ($a_e = 18\%$ -to- 29% of Dia.)	HRC	Rockwell Hardness "C" Scale
f_z	Feed per Tooth	Ni	Nickel (Metallic Element - see pg. 79)		
F_e	Iron (Chemical Element - see p. 79)	ISO	International Organization for Standardization		

DEPTH OF CUT GUIDELINES

Suggested Initial Depth of Cut Parameters for Miniature Tooling

Dynamic (QTR3) - Miniature Tooling (Depth of Cut Chart)												
Tool Series	Light Peripheral (LP)		Heavy Peripheral (HP)		Slotting (S)		Finishing (F)		Ramping		High Efficiency Milling (HEM) <i>(see pp. 84-86)</i>	
	a_e	a_p	a_e	a_p	a_e	a_p	a_e	a_p	Angle	Feed	a_e	a_p
	QTR3	12% - 20% of D1	Up to 1.0 x D1	20% - 35% of D1	Up to .50 x D	100% of D1	.25 x D	3% - 5% of D1	Up to 1.0 x D1	3° - 5°	Use (LP) in Feed Chart on p.29	7% - 10% of D1
QTR3-RN	12% - 18% of D1	Up to Full LOC (L1)	15% - 20% of D1	Up to 1.0 x D1	100% of D1	.10 - .15 x D	3% - 5% of D1	Up to Full LOC (L1)	3° - 5°	Use (LP) in Feed Chart on p.29	8% - 10% of D1	Up to Full LOC (L1)

*Note: The depth of cut numbers supplied in this table are estimates only and may need to be changed higher/lower based on your specific application and setup - Core Cutter LLC, assumes no liability.

KEY

Angle	Ramping angle to utilize	FEED	F_z to use for this operation	MRR	Metal Removal Rate (See p. 87)
D1	Tool Cutting Diameter	HP	Heavy Peripheral ($a_e = 30\%$ -to- 50% of Dia.) High	Ramping	Tool plunges gradually
a_e	Radial Depth of Cut	HEM	Efficiency Milling (See pp. 84-86) Light	Slotting	Slotting ($a_e = 100\%$ of Dia.)
a_p	Axial Depth of Cut	LP	Peripheral ($a_e = 18\%$ -to- 29% of Dia.) Length of Cut		
F	Finishing (see p. 93)	LOC	(L1)		



Non-Ferrous Tooling

	Available Surface Treatment	ISO Mat'l Group	Catalog Page(s)
AL2 2-Flute High-Performance Endmill 	<input checked="" type="checkbox"/> Uncoated <input checked="" type="checkbox"/> D-Max Coating	N	32 - 34
AL2-RN 2-Flute High-Performance (Reduced Neck) Endmill 	<input checked="" type="checkbox"/> Uncoated <input checked="" type="checkbox"/> D-Max Coating	N	35 - 36
AL3 3-Flute High-Performance Endmill 	<input checked="" type="checkbox"/> Uncoated <input checked="" type="checkbox"/> D-Max Coating	N	37 - 39
AL3-RN 3-Flute High-Performance (Reduced Neck) Endmill 	<input checked="" type="checkbox"/> Uncoated <input checked="" type="checkbox"/> D-Max Coating	N	40 - 41



Cutting Parameters, pages 42 - 43



AL2

Our Proven High-Performance 2-Flute Geometry

Center-Cutting End Geometry

End Construction Options:

- Square Corner
- Corner Radii
- Ball Nose

Extra-Fine Grain Cemented Carbide

-.0001/-.0004 Cutting Diameter Tolerance with Cylindrical Margin

45° Helix

*Need Long Reach?
See pp. 35-36*

Uncoated (pp. 33 & 35)
D-Max Coated (pp. 34 & 36)

CNC Ground in the **USA**

h6 Shank Tolerance

Serialization of every tool on shank by lot#

Cutting Parameters Found on pp. 42 - 43



Material Group

- N** Aluminum/Copper/Brass
- P** Carbon/Alloy Steel
- M** Stainless Steel
- K** Cast Iron
- S** Hi-Temp Alloys
- H** Hardened Steel

Process

- HEM Roughing Wall Finishing
- Heavy Peripheral Floor Finishing
- Light Peripheral Interpolation
- Contouring Chamfering
- Slotting Countersinking
- Ramping Deburring
- Plunging Beveling



AL2 (Uncoated)

2-Flute High-Performance Uncoated Endmill

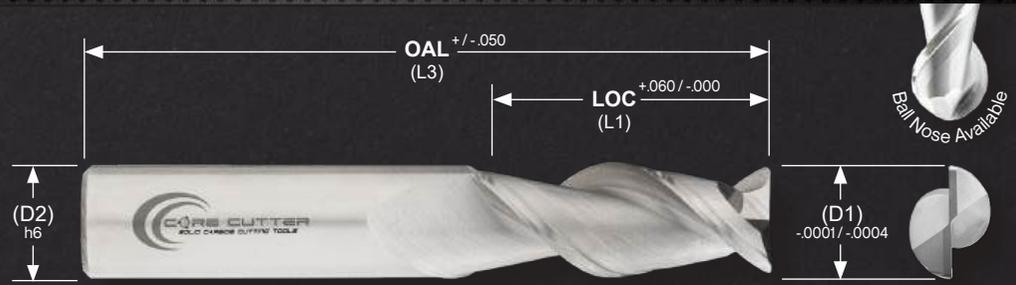
Custom made configurations of the AL2 style are available upon request

Cutting Parameters
pp. 42 - 43



Permittable ISO Material Categories

N



Tool Geometry						EDP #'s by Corner Condition					
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.030R	.060R	.125R	Ball Nose
1/8	1/8	.250	1.50	2	AL2-S-0125	210000	210010				210040
		.375	2.00	2	AL2-SR-0125	210100	210110				210140
		.500	2.50	2	AL2-R-0125	210200	210210				210240
3/16	3/16	.313	2.00	2	AL2-S-0187	200000	200010				200040
		.438	2.00	2	AL2-SR-0187	200100	200110				200140
		.563	2.50	2	AL2-R-0187	200200	200210				200240
1/4	1/4	.375	2.00	2	AL2-S-0250	201000	201010	201020	201030		201040
		.500	2.50	2	AL2-SR-0250	201100	201110	201120	201130		201140
		.750	2.50	2	AL2-R-0250	201200	201210	201220	201230		201240
		1.250	3.00	2	AL2-M-0250	201300	201310	201320	201330		201340
5/16	5/16	.500	2.00	2	AL2-SR-0312	202100	202110	202120			202140
		.750	2.50	2	AL2-R-0312	202200	202210	202220			202240
		1.250	3.00	2	AL2-M-0312	202300	202310	202320			202340
3/8	3/8	.500	2.00	2	AL2-S-0375	203000	203010	203020	203030		203040
		.750	2.50	2	AL2-SR-0375	203100	203110	203120	203130		203140
		.875	3.00	2	AL2-SP-0375	293200	293210	293220	293230		293240
		1.000	3.00	2	AL2-R-0375	203200	203210	203220	203230		203240
		1.250	3.00	2	AL2-M-0375	203300	203310	203320	203330		203340
1/2	1/2	1.500	4.00	2	AL2-L-0375	203400	203410	203420	203430		203440
		.625	2.50	2	AL2-S-0500	205000	205010	205020	205030	205040	205050
		1.000	3.00	2	AL2-SR-0500	205100	205110	205120	205130	205140	205150
		1.250	3.00	2	AL2-R-0500	205200	205210	205220	205230	205240	205250
		1.500	4.00	2	AL2-M-0500	205300	205310	205320	205330	205340	205350
		1.625	4.00	2	AL2-SP-0500	295300	295310	295320	295330	295340	295350
5/8	5/8	2.000	4.00	2	AL2-L-0500	205400	205410	205420	205430	205440	205450
		.750	3.00	2	AL2-S-0625	206000	206010	206020	206030	206040	206050
		1.250	3.50	2	AL2-SR-0625	206100	206110	206120	206130	206140	206150
		1.500	3.50	2	AL2-R-0625	206200	206210	206220	206230	206240	206250
		1.625	3.50	2	AL2-SP-0625	296200	296210	296220	296230	296240	296250
		2.000	4.00	2	AL2-M-0625	206300	206310	206320	206330	206340	206350
3/4	3/4	2.500	5.00	2	AL2-L-0625	206400	206410	206420	206430	206440	206450
		1.000	3.00	2	AL2-S-0750	207000	207010	207020	207030	207040	207050
		1.500	4.00	2	AL2-SR-0750	207100	207110	207120	207130	207140	207150
		1.625	4.00	2	AL2-SP-0750	297100	297110	297120	297130	297140	297150
		2.000	5.00	2	AL2-R-0750	207200	207210	207220	207230	207240	207250
		2.500	5.00	2	AL2-M-0750	207300	207310	207320	207330	207340	207350
1.0	1.0	3.000	6.00	2	AL2-L-0750	207400	207410	207420	207430	207440	207450
		1.750	4.00	2	AL2-SR-1000	208100	208110	208120	208130	208140	208150
		2.500	5.00	2	AL2-R-1000	208200	208210	208220	208230	208240	208250
		3.000	6.00	2	AL2-M-1000	208300	208310	208320	208330	208340	208350
										208400	

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

AL2 (Coated)

2-Flute High-Performance D-Max Coated Endmill

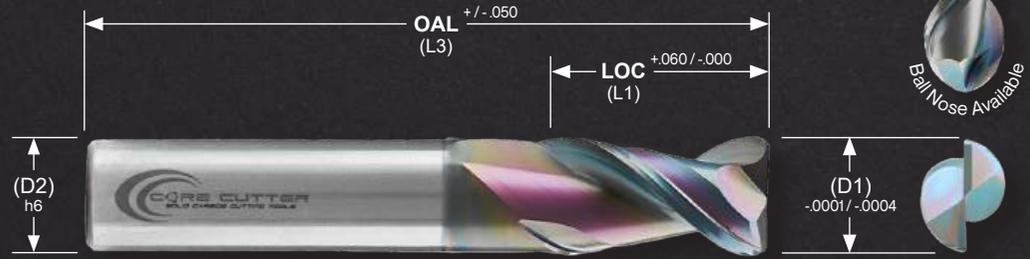
Custom made configurations of the AL2 style are available upon request

Cutting Parameters
pp. 42 - 43



Permittable ISO Material Categories

N



Tool Geometry

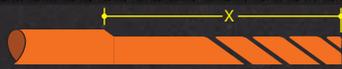
EDP #'s by Corner Condition

Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	EDP #'s by Corner Condition					Ball Nose	
						Square Corner	.015R	.030R	.060R	.125R		
1/8	1/8	.250	1.50	2	AL2-S-0125	210001	210011				210041	
		.375	2.00	2	AL2-SR-0125	210101	210111				210141	
		.500	2.50	2	AL2-R-0125	210201	210211				210241	
3/16	3/16	.313	2.00	2	AL2-S-0187	200001	200011				200041	
		.438	2.00	2	AL2-SR-0187	200101	200111				200141	
		.563	2.50	2	AL2-R-0187	200201	200211				200241	
1/4	1/4	.375	2.00	2	AL2-S-0250	201001	201011	201021	201031		201041	
		.500	2.50	2	AL2-SR-0250	201101	201111	201121	201131		201141	
		.750	2.50	2	AL2-R-0250	201201	201211	201221	201231		201241	
		1.250	3.00	2	AL2-M-0250	201301	201311	201321	201331		201341	
5/16	5/16	.500	2.00	2	AL2-SR-0312	202101	202111	202121			202141	
		.750	2.50	2	AL2-R-0312	202201	202211	202221			202241	
		1.250	3.00	2	AL2-M-0312	202301	202311	202321			202341	
3/8	3/8	.500	2.00	2	AL2-S-0375	203001	203011	203021	203031		203041	
		.750	2.50	2	AL2-SR-0375	203101	203111	203121	203131		203141	
		.875	3.00	2	AL2-SP-0375	293201	293211	293221	293231		293241	
		1.000	3.00	2	AL2-R-0375	203201	203211	203221	203231		203241	
		1.250	3.00	2	AL2-M-0375	203301	203311	203321	203331		203341	
1/2	1/2	1.500	4.00	2	AL2-L-0375	203401	203411	203421	203431		203441	
		.625	2.50	2	AL2-S-0500	205001	205011	205021	205031	205041	205051	
		1.000	3.00	2	AL2-SR-0500	205101	205111	205121	205131	205141	205151	
		1.250	3.00	2	AL2-R-0500	205201	205211	205221	205231	205241	205251	
		1.500	4.00	2	AL2-M-0500	205301	205311	205321	205331	205341	205351	
		1.625	4.00	2	AL2-SP-0500	295301	295311	295321	295331	295341	295351	
5/8	5/8	2.000	4.00	2	AL2-L-0500	205401	205411	205421	205431	205441	205451	
		.750	3.00	2	AL2-S-0625	206001		206011	206021	206031	206041	
		1.250	3.50	2	AL2-SR-0625	206101		206111	206121	206131	206141	
		1.500	3.50	2	AL2-R-0625	206201		206211	206221	206231	206241	
		1.625	3.50	2	AL2-SP-0625	296201		296211	296221	296231	296241	
		2.000	4.00	2	AL2-M-0625	206301		206311	206321	206331	206341	
3/4	3/4	2.500	5.00	2	AL2-L-0625	206401		206411	206421	206431	206441	
		1.000	3.00	2	AL2-S-0750	207001		207011	207021	207031	207041	
		1.500	4.00	2	AL2-SR-0750	207101		207111	207121	207131	207141	
		1.625	4.00	2	AL2-SP-0750	297101		297111	297121	297131	297141	
		2.000	5.00	2	AL2-R-0750	207201		207211	207221	207231	207241	
		2.500	5.00	2	AL2-M-0750	207301		207311	207321	207331	207341	
1.0	1.0	3.000	6.00	2	AL2-L-0750	207401		207411	207421	207431	207441	
		1.750	4.00	2	AL2-SR-1000	208101		208111	208121	208131	208141	
		2.500	5.00	2	AL2-R-1000	208201		208211	208221	208231	208241	
		3.000	6.00	2	AL2-M-1000	208301		208311	208321	208331	208341	
			3.500	6.00	2	AL2-L-1000	208401		208411	208421	208431	208441

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

AL2-RN (Uncoated)

2-Flute High-Performance Uncoated (Reduced Neck) Endmill



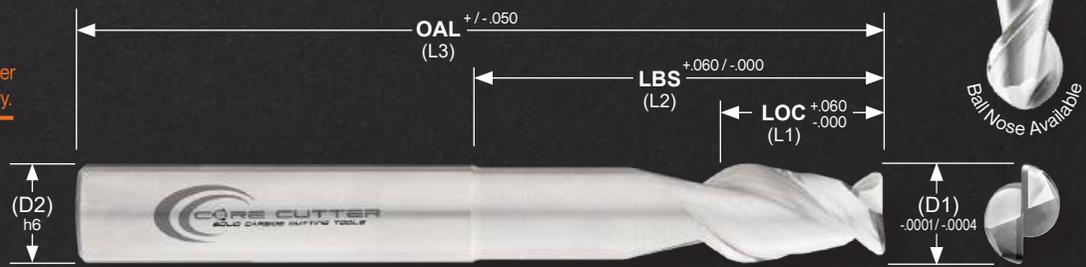
Check out "Un-Necked" in the table below for longer OALs and a custom LBS length you want to specify.

Cutting Parameters
pp. 42 - 43



Permittable ISO Material Categories

N

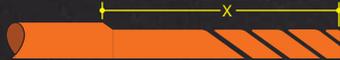


Tool Geometry							EDP #'s by Corner Condition					
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	LBS (L2)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.030R	.060R	.125R	Ball Nose
1/8	1/8	.188	.500	2.00	2	AL2-RN-R-0125	210700	210710				210740
		.188	.750	2.50	2	AL2-RN-M-0125	210800	210810				210840
3/16	3/16	.250	.500	2.50	2	AL2-RN-R-0187	200700	200710				200740
		.250	.750	3.00	2	AL2-RN-M-0187	200800	200810				200840
		.250	1.000	3.00	2	AL2-RN-L-0187	200900	200910				200940
1/4	1/4	.375	.750	2.50	2	AL2-RN-S-0250	201600	201610	201620	201630		201640
		.375	1.000	3.00	2	AL2-RN-SR-0250	201600N	201610N	201620N	201630N		201640N
		.375	1.250	4.00	2	AL2-RN-R-0250	201700	201710	201720	201730		201740
		.375	1.500	4.00	2	AL2-RN-SP-0250	201800	201810	201820	201830		201840
5/16	5/16	.500	1.250	3.00	2	AL2-RN-SR-0312	202600N	202610N	202620N			202640N
		.500	2.000	4.00	2	AL2-RN-M-0312	202800	202810	202820			202840
3/8	3/8	.625	1.625	3.00	2	AL2-RN-SR-0375	203600N	203610N	203620N	203630N		203640N
		.625	2.000	4.00	2	AL2-RN-R-0375	203700	203710	203720	203730		203740
		.625	2.500	4.00	2	AL2-RN-M-0375	203800	203810	203820	203830		203840
		.625	3.000	5.00	2	AL2-RN-L-0375	203900	203910	203920	203930		203940
1/2	1/2	.750	1.250	3.00	2	AL2-RN-S-0500	205600	205610	205620	205630	205640	205650
		.750	1.750	3.00	2	AL2-RN-SR-0500	205600N	205610N	205620N	205630N	205640N	205650N
		.750	2.000	4.00	2	AL2-RN-R-0500	205700	205710	205720	205730	205740	205750
		.750	2.250	4.00	2	AL2-RN-SP-0500	205700N	205710N	205720N	205730N	205740N	205750N
		.750	2.500	5.00	2	AL2-RN-M-0500	205800	205810	205820	205830	205840	205850
		.750	3.500	6.00	2	AL2-RN-L-0500	205900	205910	205920	205930	205940	205950
		.750	Un-Necked	7.00	2	AL2-RN-7-0500	205700-BLK	205710-BLK	205720-BLK	205730-BLK	205740-BLK	205750-BLK
		.750	Un-Necked	8.00	2	AL2-RN-8-0500	205800-BLK	205810-BLK	205820-BLK	205830-BLK	205840-BLK	205850-BLK
5/8	5/8	1.000	2.000	4.00	2	AL2-RN-R-0625	206700		206710	206720	206730	206740
		1.000	2.500	5.00	2	AL2-RN-M-0625	206800		206810	206820	206830	206840
		1.000	3.500	5.00	2	AL2-RN-L-0625	206900		206910	206920	206930	206940
		1.000	Un-Necked	7.00	2	AL2-RN-7-0625	206700-BLK		206710-BLK	206720-BLK	206730-BLK	206740-BLK
		1.000	Un-Necked	8.00	2	AL2-RN-8-0625	206800-BLK		206810-BLK	206820-BLK	206830-BLK	206840-BLK
3/4	3/4	1.125	1.750	4.00	2	AL2-RN-SR-0750	207600N		207610N	207620N	207630N	207640N
		1.125	2.000	4.00	2	AL2-RN-R-0750	207700		207710	207720	207730	207740
		1.125	2.500	5.00	2	AL2-RN-SP-0750	207700N		207710N	207720N	207730N	207740N
		1.125	3.000	6.00	2	AL2-RN-M-0750	207800		207810	207820	207830	207840
		1.125	4.000	6.00	2	AL2-RN-X-0750	207900N		207910N	207920N	207930N	207940N
		1.125	Un-Necked	7.00	2	AL2-RN-7-0750	207700-BLK		207710-BLK	207720-BLK	207730-BLK	207740-BLK
		1.125	Un-Necked	8.00	2	AL2-RN-8-0750	207800-BLK		207810-BLK	207820-BLK	207830-BLK	207840-BLK
1.0	1.0	1.500	2.500	5.00	2	AL2-RN-R-1000	208700		208710	208720	208730	208740
		1.500	3.500	6.00	2	AL2-RN-M-1000	208800		208810	208820	208830	208840
		1.500	4.500	7.00	2	AL2-RN-L-1000	208900		208910	208920	208930	208940
		1.500	Un-Necked	7.00	2	AL2-RN-7-1000	208700-BLK		208710-BLK	208720-BLK	208730-BLK	208740-BLK
		1.500	Un-Necked	8.00	2	AL2-RN-8-1000	208800-BLK		208810-BLK	208820-BLK	208830-BLK	208840-BLK

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

AL2-RN (Coated)

2-Flute High-Performance D-Max Coated (Reduced Neck) Endmill



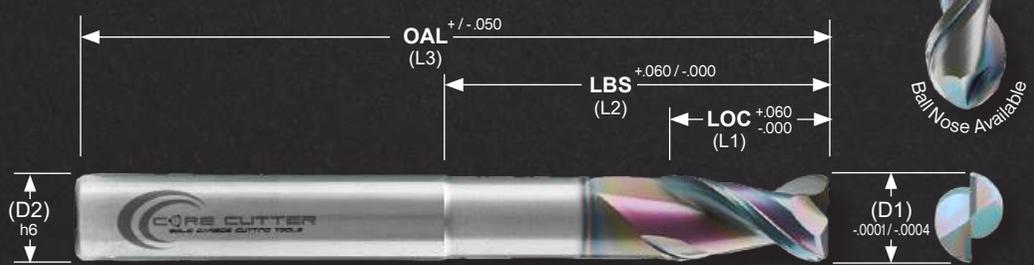
Check out "Un-Necked" in the table below for longer OALs and a custom LBS length you want to specify.

Cutting Parameters
pp. 42 - 43



Permittable ISO Material Categories

N



Tool Geometry							EDP #'s by Corner Condition					
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	LBS (L2)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.030R	.060R	.125R	Ball Nose
1/8	1/8	.188	.500	2.00	2	AL2-RN-R-0125	210701	210711				210741
		.188	.750	2.50	2	AL2-RN-M-0125	210801	210811				210841
3/16	3/16	.250	.500	2.50	2	AL2-RN-R-0187	200701	200711				200741
		.250	.750	3.00	2	AL2-RN-M-0187	200801	200811				200841
		.250	1.000	3.00	2	AL2-RN-L-0187	200901	200911				200941
1/4	1/4	.375	.750	2.50	2	AL2-RN-S-0250	201601	201611	201621	201631		201641
		.375	1.000	3.00	2	AL2-RN-SR-0250	201601N	201611N	201621N	201631N		201641N
		.375	1.250	4.00	2	AL2-RN-R-0250	201701	201711	201721	201731		201741
		.375	1.500	4.00	2	AL2-RN-SP-0250	201801	201811	201821	201831		201841
5/16	5/16	.500	1.250	3.00	2	AL2-RN-SR-0312	202601N	202611N	202621N			202641N
		.500	2.000	4.00	2	AL2-RN-M-0312	202801	202811	202821			202841
3/8	3/8	.625	1.625	3.00	2	AL2-RN-SR-0375	203601N	203611N	203621N	203631N		203641N
		.625	2.000	4.00	2	AL2-RN-R-0375	203701	203711	203721	203731		203741
		.625	2.500	4.00	2	AL2-RN-M-0375	203801	203811	203821	203831		203841
		.625	3.000	5.00	2	AL2-RN-L-0375	203901	203911	203921	203931		203941
1/2	1/2	.750	1.250	3.00	2	AL2-RN-S-0500	205601	205611	205621	205631	205641	205651
		.750	1.750	3.00	2	AL2-RN-SR-0500	205601N	205611N	205621N	205631N	205641N	205651N
		.750	2.000	4.00	2	AL2-RN-R-0500	205701	205711	205721	205731	205741	205751
		.750	2.250	4.00	2	AL2-RN-SP-0500	205701N	205711N	205721N	205731N	205741N	205751N
		.750	2.500	5.00	2	AL2-RN-M-0500	205801	205811	205821	205831	205841	205851
		.750	3.500	6.00	2	AL2-RN-L-0500	205901	205911	205921	205931	205941	205951
		.750	Un-Necked	7.00	2	AL2-RN-7-0500	205701-BLK	205711-BLK	205721-BLK	205731-BLK	205741-BLK	205751-BLK
5/8	5/8	.750	Un-Necked	8.00	2	AL2-RN-8-0500	205801-BLK	205811-BLK	205821-BLK	205831-BLK	205841-BLK	205851-BLK
		1.000	2.000	4.00	2	AL2-RN-R-0625	206701		206711	206721	206731	206741
		1.000	2.500	5.00	2	AL2-RN-M-0625	206801		206811	206821	206831	206841
		1.000	3.500	5.00	2	AL2-RN-L-0625	206901		206911	206921	206931	206941
		1.000	Un-Necked	7.00	2	AL2-RN-7-0625	206701-BLK		206711-BLK	206721-BLK	206731-BLK	206741-BLK
3/4	3/4	1.000	Un-Necked	8.00	2	AL2-RN-8-0625	206801-BLK		206811-BLK	206821-BLK	206831-BLK	206841-BLK
		1.125	1.750	4.00	2	AL2-RN-SR-0750	207601N		207611N	207621N	207631N	207641N
		1.125	2.000	4.00	2	AL2-RN-R-0750	207701		207711	207721	207731	207741
		1.125	2.500	5.00	2	AL2-RN-SP-0750	207701N		207711N	207721N	207731N	207741N
		1.125	3.000	6.00	2	AL2-RN-M-0750	207801		207811	207821	207831	207841
		1.125	4.000	6.00	2	AL2-RN-X-0750	207901N		207911N	207921N	207931N	207941N
		1.125	Un-Necked	7.00	2	AL2-RN-7-0750	207701-BLK		207711-BLK	207721-BLK	207731-BLK	207741-BLK
1.0	1.0	1.125	Un-Necked	8.00	2	AL2-RN-8-0750	207801-BLK		207811-BLK	207821-BLK	207831-BLK	207841-BLK
		1.500	2.500	5.00	2	AL2-RN-R-1000	208701		208711	208721	208731	208741
		1.500	3.500	6.00	2	AL2-RN-M-1000	208801		208811	208821	208831	208841
		1.500	4.500	7.00	2	AL2-RN-L-1000	208901		208911	208921	208931	208941
		1.500	Un-Necked	7.00	2	AL2-RN-7-1000	208701-BLK		208711-BLK	208721-BLK	208731-BLK	208741-BLK
		1.500	Un-Necked	8.00	2	AL2-RN-8-1000	208801-BLK		208811-BLK	208821-BLK	208831-BLK	208841-BLK

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

AL3



Our Proven High Performance 3-Flute Geometry

End Construction Options:

- Square Corner
- Corner Radii
- Ball Nose

Extra-Fine Grain Cemented Carbide

37° Helix

Uncoated (pp. 38 & 40)
D-Max Coated (pp. 39 & 41)

*Need Chipbreakers?
See pp. 10-12*

Serialization of every tool
on shank by lot#

Center-Cutting End Geometry

-.0001/-.0004 Cutting
Diameter Tolerance
with Cylindrical Margin

*Need Long Reach?
See pp. 40-41*

CNC Ground in the **USA**

h6 Shank Tolerance

Cutting Parameters
Found on pp. 42 - 43



Material Group

- | | | |
|---|----------|-----------------------|
| ✓ | N | Aluminum/Copper/Brass |
| ✗ | P | Carbon/Alloy Steel |
| ✗ | M | Stainless Steel |
| ✗ | K | Cast Iron |
| ✗ | S | Hi-Temp Alloys |
| ✗ | H | Hardened Steel |

Process

- | | | | |
|------------------|---|---|-----------------|
| HEM Roughing | ✓ | ✓ | Wall Finishing |
| Heavy Peripheral | ✓ | ✓ | Floor Finishing |
| Light Peripheral | ✓ | ✓ | Interpolation |
| Contouring | ✓ | ✗ | Chamfering |
| Slotting | ✓ | ✗ | Countersinking |
| Ramping | ✓ | ✗ | Deburring |
| Plunging | ✓ | ✗ | Beveling |

AL3 (Uncoated)

3-Flute High-Performance Uncoated Endmill

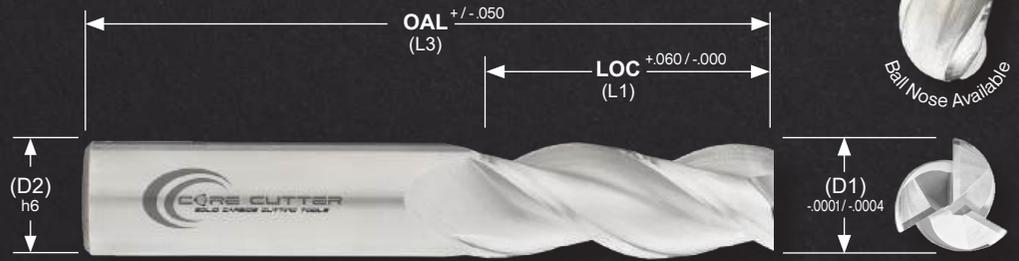
Custom made configurations of the AL3 style are available upon request

Cutting Parameters
pp. 42 - 43



Permittable ISO Material Categories

N



Tool Geometry						EDP #'s by Corner Condition						
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.030R	.060R	.090R	.125R	Ball Nose
1/8	1/8	.250	1.50	3	AL3-S-0125	310000	310010					310040
		.375	2.00	3	AL3-SR-0125	310100	310110					310140
		.500	2.50	3	AL3-R-0125	310200	310210					310240
3/16	3/16	.313	2.00	3	AL3-S-0187	300000	300010					300040
		.438	2.00	3	AL3-SR-0187	300100	300110					300140
		.563	2.50	3	AL3-R-0187	300200	300210					300240
1/4	1/4	.375	2.00	3	AL3-S-0250	301000	301010	301020	301030			301040
		.500	2.50	3	AL3-SR-0250	301100	301110	301120	301130			301140
		.750	2.50	3	AL3-R-0250	301200	301210	301220	301230			301240
		1.000	3.00	3	AL3-SP-0250	391200	391210	391220	391230			391240
5/16	5/16	1.250	3.00	3	AL3-M-0250	301300	301310	301320	301330			301340
		.500	2.00	3	AL3-SR-0312	302100	302110	302120				302140
		.750	2.50	3	AL3-R-0312	302200	302210	302220				302240
3/8	3/8	1.250	3.00	3	AL3-M-0312	302300	302310	302320				302340
		.500	2.00	3	AL3-S-0375	303000	303010	303020	303030	303035		303040
		.750	2.50	3	AL3-SR-0375	303100	303110	303120	303130	303135		303140
		.875	3.00	3	AL3-SP-0375	393200	393210	393220	393230	393235		393240
		1.000	3.00	3	AL3-R-0375	303200	303210	303220	303230	303235		303240
		1.250	3.00	3	AL3-M-0375	303300	303310	303320	303330	303335		303340
1/2	1/2	1.500	4.00	3	AL3-L-0375	303400	303410	303420	303430	303435		303440
		.625	2.50	3	AL3-S-0500	305000	305010	305020	305030	305035	305040	305050
		1.000	3.00	3	AL3-SR-0500	305100	305110	305120	305130	305135	305140	305150
		1.250	3.00	3	AL3-R-0500	305200	305210	305220	305230	305235	305240	305250
		1.500	4.00	3	AL3-M-0500	305300	305310	305320	305330	305335	305340	305350
		1.625	4.00	3	AL3-SP-0500	395300	395310	395320	395330	395335	395340	395350
5/8	5/8	2.000	4.00	3	AL3-L-0500	305400	305410	305420	305430	305435	305440	305450
		.750	3.00	3	AL3-S-0625	306000		306010	306020	306025	306030	306040
		1.250	3.50	3	AL3-SR-0625	306100		306110	306120	306125	306130	306140
		1.500	3.50	3	AL3-R-0625	306200		306210	306220	306225	306230	306240
		1.625	3.50	3	AL3-SP-0625	396200		396210	396220	396225	396230	396240
		2.000	4.00	3	AL3-M-0625	306300		306310	306320	306325	306330	306340
3/4	3/4	2.500	5.00	3	AL3-L-0625	306400		306410	306420	306425	306430	306440
		1.000	3.00	3	AL3-S-0750	307000		307010	307020	307025	307030	307040
		1.500	4.00	3	AL3-SR-0750	307100		307110	307120	307125	307130	307140
		1.625	4.00	3	AL3-SP-0750	397100		397110	397120	397125	397130	397140
		2.000	5.00	3	AL3-R-0750	307200		307210	307220	307225	307230	307240
		2.250	5.00	3	AL3-RM-0750	387200		387210	387220	387225	387230	387240
1.0	1.0	2.500	5.00	3	AL3-M-0750	307300		307310	307320	307325	307330	307340
		3.000	6.00	3	AL3-L-0750	307400		307410	307420	307425	307430	307440
		1.750	4.00	3	AL3-SR-1000	308100		308110	308120	308125	308130	308140
		2.500	5.00	3	AL3-R-1000	308200		308210	308220	308225	308230	308240
1.0	1.0	3.000	6.00	3	AL3-M-1000	308300		308310	308320	308325	308330	308340
		3.500	6.00	3	AL3-L-1000	308400		308410	308420	308425	308430	308440

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

3-Flute High-Performance D-Max Coated Endmill

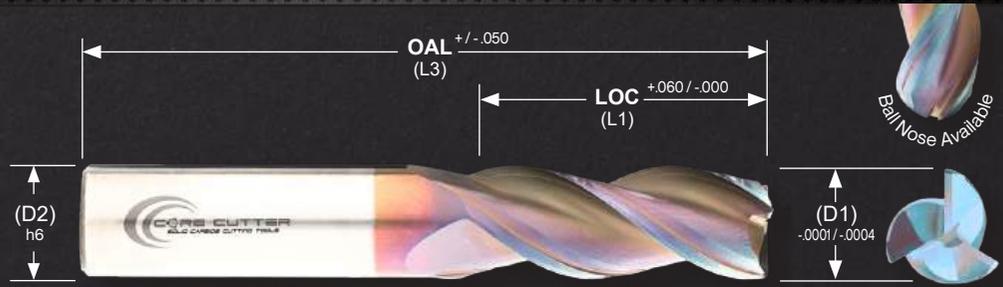
Custom made configurations of the AL3 style are available upon request

Cutting Parameters
pp. 42 - 43



Permittable ISO Material Categories

N

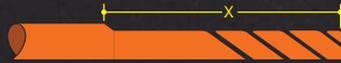


Tool Geometry						EDP #'s by Corner Condition						
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.030R	.060R	.090R	.125R	Ball Nose
1/8	1/8	.250	1.50	3	AL3-S-0125	310001	310011					310041
		.375	2.00	3	AL3-SR-0125	310101	310111					310141
		.500	2.50	3	AL3-R-0125	310201	310211					310241
3/16	3/16	.313	2.00	3	AL3-S-0187	300001	300011					300041
		.438	2.00	3	AL3-SR-0187	300101	300111					300141
		.563	2.50	3	AL3-R-0187	300201	300211					300241
1/4	1/4	.375	2.00	3	AL3-S-0250	301001	301011	301021	301031			301041
		.500	2.50	3	AL3-SR-0250	301101	301111	301121	301131			301141
		.750	2.50	3	AL3-R-0250	301201	301211	301221	301231			301241
		1.000	3.00	3	AL3-SP-0250	391201	391211	391221	391231			391241
5/16	5/16	1.250	3.00	3	AL3-M-0250	301301	301311	301321	301331			301341
		.500	2.00	3	AL3-SR-0312	302101	302111	302121				302141
		.750	2.50	3	AL3-R-0312	302201	302211	302221				302241
3/8	3/8	1.250	3.00	3	AL3-M-0312	302301	302311	302321				302341
		.500	2.00	3	AL3-S-0375	303001	303011	303021	303031	303036		303041
		.750	2.50	3	AL3-SR-0375	303101	303111	303121	303131	303136		303141
		.875	3.00	3	AL3-SP-0375	393201	393211	393221	393231	393236		393241
		1.000	3.00	3	AL3-R-0375	303201	303211	303221	303231	303236		303241
1/2	1/2	1.250	3.00	3	AL3-M-0375	303301	303311	303321	303331	303336		303341
		1.500	4.00	3	AL3-L-0375	303401	303411	303421	303431	303436		303441
		.625	2.50	3	AL3-S-0500	305001	305011	305021	305031	305036	305041	305051
		1.000	3.00	3	AL3-SR-0500	305101	305111	305121	305131	305136	305141	305151
		1.250	3.00	3	AL3-R-0500	305201	305211	305221	305231	305236	305241	305251
		1.500	4.00	3	AL3-M-0500	305301	305311	305321	305331	305336	305341	305351
5/8	5/8	1.625	4.00	3	AL3-SP-0500	395301	395311	395321	395331	395336	395341	395351
		2.000	4.00	3	AL3-L-0500	305401	305411	305421	305431	305436	305441	305451
		.750	3.00	3	AL3-S-0625	306001		306011	306021	306026	306031	306041
		1.250	3.50	3	AL3-SR-0625	306101		306111	306121	306126	306131	306141
		1.500	3.50	3	AL3-R-0625	306201		306211	306221	306226	306231	306241
		1.625	3.50	3	AL3-SP-0625	396201		396211	396221	396226	396231	396241
3/4	3/4	2.000	4.00	3	AL3-M-0625	306301		306311	306321	306326	306331	306341
		2.500	5.00	3	AL3-L-0625	306401		306411	306421	306426	306431	306441
		1.000	3.00	3	AL3-S-0750	307001		307011	307021	307026	307031	307041
		1.500	4.00	3	AL3-SR-0750	307101		307111	307121	307126	307131	307141
		1.625	4.00	3	AL3-SP-0750	397101		397111	397121	397126	397131	397141
		2.000	5.00	3	AL3-R-0750	307201		307211	307221	307226	307231	307241
		2.250	5.00	3	AL3-RM-0750	387201		387211	387221	387226	387231	387241
		2.500	5.00	3	AL3-M-0750	307301		307311	307321	307326	307331	307341
1.0	1.0	3.000	6.00	3	AL3-L-0750	307401		307411	307421	307426	307431	307441
		1.750	4.00	3	AL3-SR-1000	308101		308111	308121	308126	308131	308141
		2.500	5.00	3	AL3-R-1000	308201		308211	308221	308226	308231	308241
		3.000	6.00	3	AL3-M-1000	308301		308311	308321	308326	308331	308341
		3.500	6.00	3	AL3-L-1000	308401		308411	308421	308426	308431	308441

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

AL3-RN (Uncoated)

3-Flute High-Performance Uncoated (Reduced Neck) Endmill

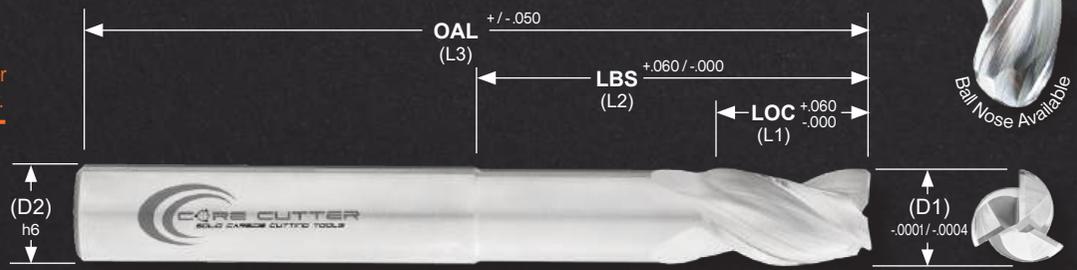


Check out "Un-Necked" in the table below for longer OALs and a custom LBS length you want to specify.

Cutting Parameters
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Permittable ISO Material Categories



Tool Geometry

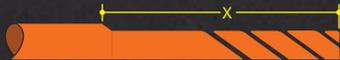
EDP #'s by Corner Condition

Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	LBS (L2)	OAL (L3)	Flute Count	Tool Description	EDP #'s by Corner Condition										
							Square Corner	.015R	.030R	.060R	.090R	.125R	Ball Nose				
1/8	1/8	.188	.500	2.00	3	AL3-RN-R-0125	310700	310710							310740		
		.188	.750	2.50	3	AL3-RN-M-0125	310800	310810							310840		
3/16	3/16	.250	.500	2.50	3	AL3-RN-R-0187	300700	300710							300740		
		.250	.750	3.00	3	AL3-RN-M-0187	300800	300810							300840		
		.250	1.000	3.00	3	AL3-RN-L-0187	300900	300910							300940		
1/4	1/4	.375	.750	2.50	3	AL3-RN-S-0250	301600	301610	301620	301630					301640		
		.375	1.000	3.00	3	AL3-RN-SR-0250	301600N	301610N	301620N	301630N					301640N		
		.375	1.250	4.00	3	AL3-RN-R-0250	301700	301710	301720	301730					301740		
		.375	1.500	4.00	3	AL3-RN-SP-0250	301800	301810	301820	301830					301840		
5/16	5/16	.500	1.250	3.00	3	AL3-RN-SR-0312	302600N	302610N	302620N						302640N		
		.500	2.000	4.00	3	AL3-RN-M-0312	302800	302810	302820						302840		
3/8	3/8	.625	1.625	3.00	3	AL3-RN-SR-0375	303600N	303610N	303620N	303630N	303635N				303640N		
		.625	2.000	4.00	3	AL3-RN-R-0375	303700	303710	303720	303730	303735				303740		
		.625	2.500	4.00	3	AL3-RN-M-0375	303800	303810	303820	303830	303835				303840		
		.625	3.000	5.00	3	AL3-RN-L-0375	303900	303910	303920	303930	303935				303940		
1/2	1/2	.750	1.250	3.00	3	AL3-RN-S-0500	305600	305610	305620	305630	305635	305640	305650		305660		
		.750	1.750	3.00	3	AL3-RN-SR-0500	305600N	305610N	305620N	305630N	305635N	305640N	305650N		305660N		
		.750	2.000	4.00	3	AL3-RN-R-0500	305700	305710	305720	305730	305735	305740	305750		305760		
		.750	2.250	4.00	3	AL3-RN-SP-0500	305700N	305710N	305720N	305730N	305735N	305740N	305750N		305760N		
		.750	2.500	5.00	3	AL3-RN-M-0500	305800	305810	305820	305830	305835	305840	305850		305860		
		.750	3.500	6.00	3	AL3-RN-L-0500	305900	305910	305920	305930	305935	305940	305950		305960		
		.750	Un-Necked	7.00	3	AL3-RN-7-0500	305700-BLK	305710-BLK	305720-BLK	305730-BLK	305735-BLK	305740-BLK	305750-BLK		305760-BLK		
.750	Un-Necked	8.00	3	AL3-RN-8-0500	305800-BLK	305810-BLK	305820-BLK	305830-BLK	305835-BLK	305840-BLK	305850-BLK		305860-BLK				
5/8	5/8	1.000	2.000	4.00	3	AL3-RN-R-0625	306700		306710	306720	306725	306730	306740		306760		
		1.000	2.500	5.00	3	AL3-RN-M-0625	306800		306810	306820	306825	306830	306840		306860		
		1.000	3.500	5.00	3	AL3-RN-L-0625	306900		306910	306920	306925	306930	306940		306960		
		1.000	Un-Necked	7.00	3	AL3-RN-7-0625	306700-BLK		306710-BLK	306720-BLK	306725-BLK	306730-BLK	306740-BLK		306760-BLK		
		1.000	Un-Necked	8.00	3	AL3-RN-8-0625	306800-BLK		306810-BLK	306820-BLK	306825-BLK	306830-BLK	306840-BLK		306860-BLK		
3/4	3/4	1.125	1.750	4.00	3	AL3-RN-SR-0750	307600N		307610N	307620N	307625N	307630N	307640N		307660N		
		1.125	2.000	4.00	3	AL3-RN-R-0750	307700		307710	307720	307725	307730	307740		307760		
		1.125	2.500	5.00	3	AL3-RN-SP-0750	307700N		307710N	307720N	307725N	307730N	307740N		307760N		
		1.125	3.000	6.00	3	AL3-RN-M-0750	307800		307810	307820	307825	307830	307840		307860		
		1.125	4.000	6.00	3	AL3-RN-X-0750	307900N		307910N	307920N	307925N	307930N	307940N		307960N		
		1.125	Un-Necked	7.00	3	AL3-RN-7-0750	307700-BLK		307710-BLK	307720-BLK	307725-BLK	307730-BLK	307740-BLK		307760-BLK		
		1.125	Un-Necked	8.00	3	AL3-RN-8-0750	307800-BLK		307810-BLK	307820-BLK	307825-BLK	307830-BLK	307840-BLK		307860-BLK		
1.0	1.0	1.500	2.500	5.00	3	AL3-RN-R-1000	308700		308710	308720	308725	308730	308740		308760		
		1.500	3.500	6.00	3	AL3-RN-M-1000	308800		308810	308820	308825	308830	308840		308860		
		1.500	4.500	7.00	3	AL3-RN-L-1000	308900		308910	308920	308925	308930	308940		308960		
		1.500	Un-Necked	7.00	3	AL3-RN-7-1000	308700-BLK		308710-BLK	308720-BLK	308725-BLK	308730-BLK	308740-BLK		308760-BLK		
		1.500	Un-Necked	8.00	3	AL3-RN-8-1000	308800-BLK		308810-BLK	308820-BLK	308825-BLK	308830-BLK	308840-BLK		308860-BLK		

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

AL3-RN (Coated)

3-Flute High-Performance D-Max Coated (Reduced Neck) Endmill



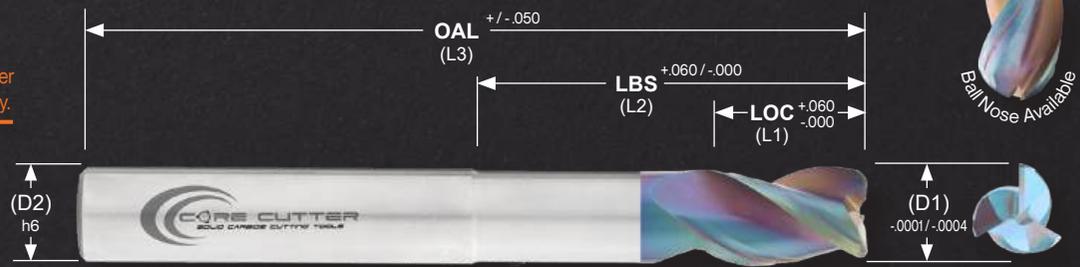
Check out "Un-Necked" in the table below for longer OALs and a custom LBS length you want to specify.

Cutting Parameters
pp. 42 - 43



Permittable ISO Material Categories

N



Tool Geometry							EDP #'s by Corner Condition						
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	LBS (L2)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.030R	.060R	.090R	.125R	Ball Nose
1/8	1/8	.188	.500	2.00	3	AL3-RN-R-0125	310701	310711					310741
		.188	.750	2.50	3	AL3-RN-M-0125	310801	310811					310841
3/16	3/16	.250	.500	2.50	3	AL3-RN-R-0187	300701	300711					300741
		.250	.750	3.00	3	AL3-RN-M-0187	300801	300811					300841
		.250	1.000	3.00	3	AL3-RN-L-0187	300901	300911					300941
1/4	1/4	.375	.750	2.50	3	AL3-RN-S-0250	301601	301611	301621	301631			301641
		.375	1.000	3.00	3	AL3-RN-SR-0250	301601N	301611N	301621N	301631N			301641N
		.375	1.250	4.00	3	AL3-RN-R-0250	301701	301711	301721	301731			301741
		.375	1.500	4.00	3	AL3-RN-SP-0250	301801	301811	301821	301831			301841
5/16	5/16	.500	1.250	3.00	3	AL3-RN-SR-0312	302601N	302611N	302621N				302641N
		.500	2.000	4.00	3	AL3-RN-M-0312	302801	302811	302821				302841
3/8	3/8	.625	1.625	3.00	3	AL3-RN-SR-0375	303601N	303611N	303621N	303631N	303636N		303641N
		.625	2.000	4.00	3	AL3-RN-R-0375	303701	303711	303721	303731	303736		303741
		.625	2.500	4.00	3	AL3-RN-M-0375	303801	303811	303821	303831	303836		303841
		.625	3.000	5.00	3	AL3-RN-L-0375	303901	303911	303921	303931	303936		303941
1/2	1/2	.750	1.250	3.00	3	AL3-RN-S-0500	305601	305611	305621	305631	305636	305641	305651
		.750	1.750	3.00	3	AL3-RN-SR-0500	305601N	305611N	305621N	305631N	305636N	305641N	305651N
		.750	2.000	4.00	3	AL3-RN-R-0500	305701	305711	305721	305731	305736	305741	305751
		.750	2.250	4.00	3	AL3-RN-SP-0500	305701N	305711N	305721N	305731N	305736N	305741N	305751N
		.750	2.500	5.00	3	AL3-RN-M-0500	305801	305811	305821	305831	305836	305841	305851
		.750	3.500	6.00	3	AL3-RN-L-0500	305901	305911	305921	305931	305936	305941	305951
		.750	Un-Necked	7.00	3	AL3-RN-7-0500	305701-BLK	305711-BLK	305721-BLK	305731-BLK	305736-BLK	305741-BLK	305751-BLK
5/8	5/8	1.000	2.000	4.00	3	AL3-RN-R-0625	306701		306711	306721	306726	306731	306741
		1.000	2.500	5.00	3	AL3-RN-M-0625	306801		306811	306821	306826	306831	306841
		1.000	3.500	5.00	3	AL3-RN-L-0625	306901		306911	306921	306926	306931	306941
		1.000	Un-Necked	7.00	3	AL3-RN-7-0625	306701-BLK		306711-BLK	306721-BLK	306726-BLK	306731-BLK	306741-BLK
		1.000	Un-Necked	8.00	3	AL3-RN-8-0625	306801-BLK		306811-BLK	306821-BLK	306826-BLK	306831-BLK	306841-BLK
3/4	3/4	1.125	1.750	4.00	3	AL3-RN-SR-0750	307601N		307611N	307621N	307626N	307631N	307641N
		1.125	2.000	4.00	3	AL3-RN-R-0750	307701		307711	307721	307726	307731	307741
		1.125	2.500	5.00	3	AL3-RN-SP-0750	307701N		307711N	307721N	307726N	307731N	307741N
		1.125	3.000	6.00	3	AL3-RN-M-0750	307801		307811	307821	307826	307831	307841
		1.125	4.000	6.00	3	AL3-RN-X-0750	307901N		307911N	307921N	307926N	307931N	307941N
		1.125	Un-Necked	7.00	3	AL3-RN-7-0750	307701-BLK		307711-BLK	307721-BLK	307726-BLK	307731-BLK	307741-BLK
		1.125	Un-Necked	8.00	3	AL3-RN-8-0750	307801-BLK		307811-BLK	307821-BLK	307826-BLK	307831-BLK	307841-BLK
1.0	1.0	1.500	2.500	5.00	3	AL3-RN-R-1000	308701		308711	308721	308726	308731	308741
		1.500	3.500	6.00	3	AL3-RN-M-1000	308801		308811	308821	308826	308831	308841
		1.500	4.500	7.00	3	AL3-RN-L-1000	308901		308911	308921	308926	308931	308941
		1.500	Un-Necked	7.00	3	AL3-RN-7-1000	308701-BLK		308711-BLK	308721-BLK	308726-BLK	308731-BLK	308741-BLK
		1.500	Un-Necked	8.00	3	AL3-RN-8-1000	308801-BLK		308811-BLK	308821-BLK	308826-BLK	308831-BLK	308841-BLK

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

SPEEDS & FEEDS

Suggested Initial Cut Values for all Non-Ferrous Series Tooling

ISO Material Categories		Ferrous (& Titanium) Tooling																																			
		Feed Table (f_z)																																			
		SFM	D1 ≤ 1/8					D1 ≤ 1/4					D1 ≤ 3/8					D1 ≤ 1/2					D1 ≤ 5/8					D1 ≤ 3/4					D1 ≤ 1"				
S	HP		LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM		
N	Wrought Aluminum Alloys 1100, 2024, 6061, 7075	1200 2000	.0016	.0019	.0018	.0012	.0031	.0031	.0038	.0036	.0023	.0063	.0047	.0056	.0054	.0035	.0094	.0062	.0075	.0072	.0047	.0125	.0078	.0094	.0089	.0058	.0156	.0093	.0113	.0107	.0070	.0188	.0124	.0150	.0143	.0093	.0375
	Cast Aluminum Alloys A356, A360, A380, A390	550 800	.0013	.0016	.0015	.0010	.0026	.0027	.0031	.0031	.0020	.0052	.0040	.0047	.0046	.0030	.0078	.0053	.0062	.0061	.0040	.0103	.0066	.0078	.0076	.0050	.0129	.0080	.0093	.0092	.0060	.0155	.0106	.0124	.0122	.0080	.0310
	Brass, Bronze, Copper 101, 110, 260, 360, 932	435 750	.0012	.0014	.0014	.0009	.0023	.0024	.0027	.0028	.0018	.0045	.0036	.0041	.0042	.0027	.0068	.0048	.0054	.0055	.0036	.0090	.0060	.0068	.0069	.0045	.0113	.0072	.0081	.0083	.0054	.0135	.0096	.0108	.0111	.0072	.0270

Speeds and Feeds suggested within the table are only estimated starting parameters and may require increase/decrease adjustments based on your particular application and/or setup - Core Cutter LLC, assumes no liability.
 *For HEM applications, the "HEM" column within the feed table is for your feed (fz) based on chip thinning at ≤10% step over, and for SFM, you can take our recommendations x 1.5 - 1.8

KEY

D1	Tool Cutting Diameter	HEM	High Efficiency Milling (see pp. 84-86)	S	Slotting ($a_e = 100\%$ of Dia.)
F	Finishing (see p. 93)	LP	Light Peripheral ($a_e = 18\%$ -to-29% of Dia.)	HRC	Rockwell Hardness "C" Scale
f_z	Feed per Tooth	ISO	International Organization for Standardization		
HP	Heavy Peripheral ($a_e = 30\%$ -to-50% of Dia.)	SFM	Surface Feet per Minute		

DEPTH OF CUT GUIDELINES

Suggested Initial Depth of Cut Values for all Non-Ferrous Series Tooling

Non-Ferrous Tooling (Depth of Cut Chart)

Tool Series	Light Peripheral (LP)		Heavy Peripheral (HP)		Slotting (S)		Finishing (F)		Ramping		High Efficiency Milling (HEM)	
	a_e	a_p	a_e	a_p	a_e	a_p	a_e	a_p	Angle	Feed	a_e	a_p
	AL2	20% - 35% of D1	Up to 2.5 x D1	35% - 50% of D1	Up to 2.0 x D1	100% of D1	Up to 1.5 x D1	3% - 5% of D1	Up to Full LOC (L1)	5° - 10°	Use (LP) in Feed Chart on p.42	Use Higher Flute Count
AL2-RN	10% - 18% of D1	Up to Full LOC (L1)	18% - 25% of D1	Up to Full LOC (L1)	100% of D1	Up to 1.0 x D1	3% - 5% of D1	Up to Full LOC (L1)	5° - 10°	Use (LP) in Feed Chart on p.42	Use Higher Flute Count	
AL3	20% - 35% of D1	Up to 3.0 x D1	35% - 50% of D1	Up to 2.5 x D1	100% of D1	Up to 1.0 x D1	3% - 5% of D1	Up to Full LOC (L1)	5° - 10°	Use (LP) in Feed Chart on p.42	10% - 25% of D1	Up to 3.5 x D1
AL3-RN	12% - 21% of D1	Up to Full LOC (L1)	21% - 30% of D1	Up to Full LOC (L1)	100% of D1	Up to 1.0 x D1	3% - 5% of D1	Up to Full LOC (L1)	5° - 10°	Use (LP) in Feed Chart on p.42	10% - 25% of D1	Up to Full LOC (L1)

*Note: The depth of cut numbers supplied in this table are estimates only and may need to be changed higher/lower based on your specific application and setup - Core Cutter LLC, assumes no liability.

KEY

Angle	Ramping angle to utilize	FEED	F_z to use for this operation	LOC	Length of Cut (L1)
D1	Tool Cutting Diameter	HP	Heavy Peripheral ($a_e = 30\%$ -to- 50% of Dia.)	MRR	Metal Removal Rate (See p. 87)
a_e	Radial Depth of Cut	HEM	High Efficiency Milling (See pp. 84-86)	Ramping	Tool plunges gradually
a_p	Axial Depth of Cut	LP	Light Peripheral ($a_e = 18\%$ -to- 29% of Dia.)	Slotting	Slotting ($a_e = 100\%$ of Dia.)



Ferrous Tooling (& Titanium)

 **Cutting Parameters, pages 58 - 59**

Catalog Page(s)	ISO Mat'l Group	Available Surface Treatment	
45 - 46	P M K S H	✓ A-Max Coating	VST4 4-Flute High-Performance Endmill 
47	P M K S H	✓ A-Max Coating	VST4-RN 4-Flute High-Performance (Reduced Neck) Endmill 
48 - 49	P M K S H	✓ A-Max Coating	FEM5 5-Flute High-Performance Finishing Endmill 
50 - 51	P M K S H	✓ P-Max Coating	VST5 5-Flute High-Performance Endmill 
52	P M K S H	✓ P-Max Coating	VST5-RN 5-Flute High-Performance (Reduced Neck) Endmill 
53 - 54	P M K S H	✓ T-Max Coating	VST6 6-Flute High-Performance Endmill  <i>NEW Series</i>
55	P M K S H	✓ T-Max Coating	VST6-RN 6-Flute High-Performance (Reduced Neck) Endmill  <i>NEW Series</i>
56 - 57	P M K S H	✓ C-Max Coating	VMF 7, 9, and 11 flute High-Performance Endmill 

VST4



Our Proven High-Performance 4-Flute Geometry

End Construction Options:

- Square Corner
- Corner Radii
- Ball Nose

Extra-Fine Grain Cemented Carbide

Variable Flute Indexing

A-Max Coated

*Need Chipbreakers?
See pp. 13-14*

Serialization of every tool on shank by lot#

Center-Cutting End Geometry

+0.000/-0.002 Cutting Diameter Tolerance with Eccentric Relief

Need Long Reach? See p. 47

Strengthened Core Diameter

CNC Ground in the **USA**

h6 Shank Tolerance

Cutting Parameters Found on pp. 58 - 59



Material Group

- N** Aluminum/Copper/Brass
- P** Carbon/Alloy Steel
- M** Stainless Steel
- K** Cast Iron
- S** Hi-Temp Alloys
- H** Hardened Steel

Process

- HEM Roughing Wall Finishing
- Heavy Peripheral Floor Finishing
- Light Peripheral Interpolation
- Contouring Chamfering
- Slotting Countersinking
- Ramping Deburring
- Plunging Beveling



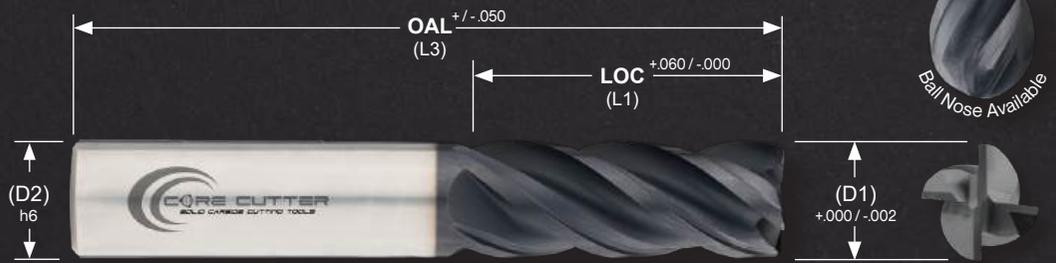
4-Flute High-Performance A-Max Coated Endmill

Custom made configurations of the VST4 style are available upon request

Cutting Parameters
pp. 58 - 59



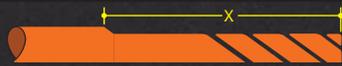
Permittable ISO Material Categories



Tool Geometry						EDP #'s by Corner Condition							
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.020R	.030R	.060R	.090R	.125R	Ball Nose
1/8	1/8	.250	1.50	4	VST4-S-0125	410001	410011						410041
		.375	2.00	4	VST4-SR-0125	410101	410111						410141
		.500	2.50	4	VST4-R-0125	410201	410211						410241
3/16	3/16	.313	2.00	4	VST4-S-0187	400001	400011						400041
		.438	2.00	4	VST4-SR-0187	400101	400111						400141
		.563	2.50	4	VST4-R-0187	400201	400211						400241
1/4	1/4	.375	2.00	4	VST4-S-0250	401001	401011	401016	401021	401031			401041
		.500	2.50	4	VST4-SR-0250	401101	401111	401116	401121	401131			401141
		.750	2.50	4	VST4-R-0250	401201	401211	401216	401221	401231			401241
		1.000	3.00	4	VST4-SP-0250	491201	491211	491216	491221	491231			491241
		1.250	3.00	4	VST4-M-0250	401301	401311	401316	401321	401331			401341
5/16	5/16	.500	2.00	4	VST4-SR-0312	402101	402111		402121				402141
		.750	2.50	4	VST4-R-0312	402201	402211		402221				402241
		1.250	3.00	4	VST4-M-0312	402301	402311		402321				402341
3/8	3/8	.500	2.00	4	VST4-S-0375	403001	403011	403016	403021	403031	403036		403041
		.750	2.50	4	VST4-SR-0375	403101	403111	403116	403121	403131	403136		403141
		.875	3.00	4	VST4-SP-0375	493201	493211	493216	493221	493231	493236		493241
		1.000	3.00	4	VST4-R-0375	403201	403211	403216	403221	403231	403236		403241
		1.250	3.00	4	VST4-M-0375	403301	403311	403316	403321	403331	403336		403341
1/2	1/2	1.500	4.00	4	VST4-L-0375	403401	403411	403416	403421	403431	403436		403441
		.625	2.50	4	VST4-S-0500	405001	405011		405021	405031	405036	405041	405051
		1.000	3.00	4	VST4-SR-0500	405101	405111		405121	405131	405136	405141	405151
		1.250	3.00	4	VST4-R-0500	405201	405211		405221	405231	405236	405241	405251
		1.500	4.00	4	VST4-M-0500	405301	405311		405321	405331	405336	405341	405351
		1.625	4.00	4	VST4-SP-0500	495301	495311		495321	495331	495336	495341	495351
5/8	5/8	2.000	4.00	4	VST4-L-0500	405401	405411		405421	405431	405436	405441	405451
		.750	3.00	4	VST4-S-0625	406001			406011	406021	406026	406031	406041
		1.250	3.50	4	VST4-SR-0625	406101			406111	406121	406126	406131	406141
		1.500	3.50	4	VST4-R-0625	406201			406211	406221	406226	406231	406241
		1.625	3.50	4	VST4-SP-0625	496201			496211	496221	496226	496231	496241
		2.000	4.00	4	VST4-M-0625	406301			406311	406321	406326	406331	406341
3/4	3/4	2.500	5.00	4	VST4-L-0625	406401			406411	406421	406426	406431	406441
		1.000	3.00	4	VST4-S-0750	407001			407011	407021	407026	407031	407041
		1.500	4.00	4	VST4-SR-0750	407101			407111	407121	407126	407131	407141
		1.625	4.00	4	VST4-SP-0750	497101			497111	497121	497126	497131	497141
		2.000	5.00	4	VST4-R-0750	407201			407211	407221	407226	407231	407241
		2.250	5.00	4	VST4-RM-0750	487201			487211	487221	487226	487231	487241
		2.500	5.00	4	VST4-M-0750	407301			407311	407321	407326	407331	407341
1.0	1.0	3.000	6.00	4	VST4-L-0750	407401			407411	407421	407426	407431	407441
		1.750	4.00	4	VST4-SR-1000	408101			408111	408121	408126	408131	408141
		2.500	5.00	4	VST4-R-1000	408201			408211	408221	408226	408231	408241
		3.000	6.00	4	VST4-M-1000	408301			408311	408321	408326	408331	408341
		3.500	6.00	4	VST4-L-1000	408401			408411	408421	408426	408431	408441

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

4-Flute High-Performance A-Max Coated (Reduced Neck) Endmill



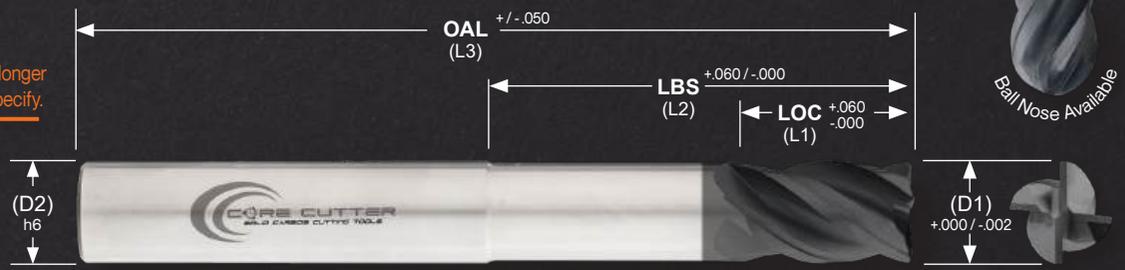
Check out "Un-Necked" in the table below for longer OALs and a custom LBS length you want to specify.

Cutting Parameters
pp. 58 - 59



Permittable ISO Material Categories

P M K S H



Tool Geometry							Corner Condition / EDP #'s							
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	LBS (L2)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.020R	.030R	.060R	.090R	.125R	Ball Nose
1/8	1/8	.188	.500	2.00	4	VST4-RN-R-0125	410701	410711						410741
		.188	.750	2.50	4	VST4-RN-M-0125	410801	410811						410841
3/16	3/16	.250	.500	2.50	4	VST4-RN-R-0187	400701	400711						400741
		.250	.750	3.00	4	VST4-RN-M-0187	400801	400811						400841
		.250	1.000	3.00	4	VST4-RN-L-0187	400901	400911						400941
1/4	1/4	.375	.750	2.50	4	VST4-RN-S-0250	401601	401611	401616	401621	401631			401641
		.375	1.000	3.00	4	VST4-RN-SR-0250	401601N	401611N	401616N	401621N	401631N			401641N
		.375	1.250	4.00	4	VST4-RN-R-0250	401701	401711	401716	401721	401731			401741
		.375	1.500	4.00	4	VST4-RN-SP-0250	401801	401811	401816	401821	401831			401841
5/16	5/16	.500	1.250	3.00	4	VST4-RN-SR-0312	402601N	402611N		402621N				402641N
		.500	2.000	4.00	4	VST4-RN-M-0312	402801	402811		402821				402841
3/8	3/8	.625	1.625	3.00	4	VST4-RN-SR-0375	403601N	403611N	403616N	403621N	403631N	403636N		403641N
		.625	2.000	4.00	4	VST4-RN-R-0375	403701	403711	403716	403721	403731	403736		403741
		.625	2.500	4.00	4	VST4-RN-M-0375	403801	403811	403816	403821	403831	403836		403841
		.625	3.000	5.00	4	VST4-RN-L-0375	403901	403911	403916	403921	403931	403936		403941
1/2	1/2	.750	1.250	3.00	4	VST4-RN-S-0500	405601	405611		405621	405631	405636	405641	405651
		.750	1.750	3.00	4	VST4-RN-SR-0500	405601N	405611N		405621N	405631N	405636N	405641N	405651N
		.750	2.000	4.00	4	VST4-RN-R-0500	405701	405711		405721	405731	405736	405741	405751
		.750	2.250	4.00	4	VST4-RN-SP-0500	405701N	405711N		405721N	405731N	405736N	405741N	405751N
		.750	2.500	5.00	4	VST4-RN-M-0500	405801	405811		405821	405831	405836	405841	405851
		.750	3.500	6.00	4	VST4-RN-L-0500	405901	405911		405921	405931	405936	405941	405951
		.750	Un-Necked	7.00	4	VST4-RN-7-0500	405701-BLK	405711-BLK		405721-BLK	405731-BLK	405736-BLK	405741-BLK	405751-BLK
		.750	Un-Necked	8.00	4	VST4-RN-8-0500	405801-BLK	405811-BLK		405821-BLK	405831-BLK	405836-BLK	405841-BLK	405851-BLK
5/8	5/8	1.000	2.000	4.00	4	VST4-RN-R-0625	406701			406711	406721	406726	406731	406741
		1.000	2.500	5.00	4	VST4-RN-M-0625	406801			406811	406821	406826	406831	406841
		1.000	3.500	5.00	4	VST4-RN-L-0625	406901			406911	406921	406926	406931	406941
		1.000	Un-Necked	7.00	4	VST4-RN-7-0625	406701-BLK		406711-BLK	406721-BLK	406726-BLK	406731-BLK	406741-BLK	
		1.000	Un-Necked	8.00	4	VST4-RN-8-0625	406801-BLK		406811-BLK	406821-BLK	406826-BLK	406831-BLK	406841-BLK	
3/4	3/4	1.125	1.750	4.00	4	VST4-RN-SR-0750	407601N			407611N	407621N	407626N	407631N	407641N
		1.125	2.000	4.00	4	VST4-RN-R-0750	407701			407711	407721	407726	407731	407741
		1.125	2.500	5.00	4	VST4-RN-SP-0750	407701N			407711N	407721N	407726N	407731N	407741N
		1.125	3.000	6.00	4	VST4-RN-M-0750	407801			407811	407821	407826	407831	407841
		1.125	4.000	6.00	4	VST4-RN-X-0750	407901N			407911N	407921N	407926N	407931N	407941N
		1.125	Un-Necked	7.00	4	VST4-RN-7-0750	407701-BLK		407711-BLK	407721-BLK	407726-BLK	407731-BLK	407741-BLK	
		1.125	Un-Necked	8.00	4	VST4-RN-8-0750	407801-BLK		407811-BLK	407821-BLK	407826-BLK	407831-BLK	407841-BLK	
1.0	1.0	1.500	2.500	6.00	4	VST4-RN-R-1000	408701			408711	408721	408726	408731	408741
		1.500	3.500	6.00	4	VST4-RN-M-1000	408801			408811	408821	408826	408831	408841
		1.500	4.500	7.00	4	VST4-RN-L-1000	408901			408911	408921	408926	408931	408941
		1.500	Un-Necked	7.00	4	VST4-RN-7-1000	408701-BLK		408711-BLK	408721-BLK	408726-BLK	408731-BLK	408741-BLK	
		1.500	Un-Necked	8.00	4	VST4-RN-8-1000	408801-BLK		408811-BLK	408821-BLK	408826-BLK	408831-BLK	408841-BLK	

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.



FEM5

Our Proven High-Performance 5-Flute Finishing Geometry

End Construction Options:
• Square Corner Only

Center-Cutting End Geometry

Extra-Fine Grain Cemented Carbide

+0.000/-0.002 Cutting Diameter Tolerance

A-Max Coated

Strengthened Core Diameter

Serialization of every tool on shank by lot#

CNC Ground in the 

h6 Shank Tolerance

Cutting Parameters Found on pp. 58 - 59



Material Group

-  **N** Aluminum/Copper/Brass
-  **P** Carbon/Alloy Steel
-  **M** Stainless Steel
-  **K** Cast Iron
-  **S** Hi-Temp Alloys
-  **H** Hardened Steel

Process

- HEM Roughing   Wall Finishing
- Heavy Peripheral   Floor Finishing
- Light Peripheral   Interpolation
- Contouring   Chamfering
- Slotting   Countersinking
- Ramping   Deburring
- Plunging   Beveling

5-Flute High-Performance A-Max Coated Finishing Endmill

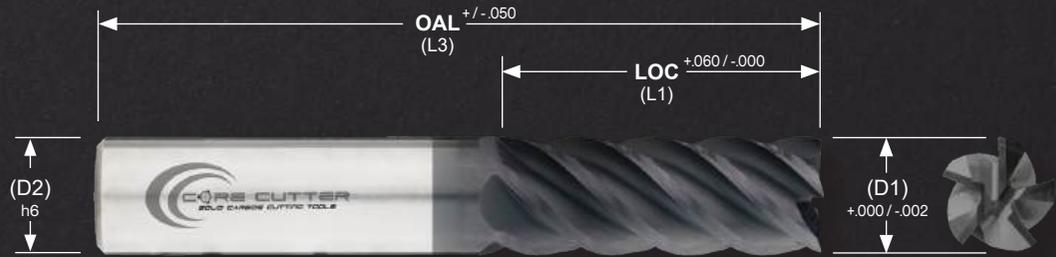
Custom made configurations of the FEM5 style are available upon request

Cutting Parameters
pp. 58 - 59



Permittable ISO Material Categories

P M K S H



Tool Geometry						EDP #'s by Corner Condition	
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	Square Corner	
1/8	1/8	.250	1.50	5	FEM5-S-0125	540001	
		.500	2.50	5	FEM5-R-0125	540201	
3/16	3/16	.313	2.00	5	FEM5-S-0187	550001	
		.563	2.50	5	FEM5-R-0187	550201	
1/4	1/4	.375	2.00	5	FEM5-S-0250	551001	
		.500	2.50	5	FEM5-SR-0250	551101	
		.750	2.50	5	FEM5-R-0250	551201	
5/16	5/16	.500	2.00	5	FEM5-S-0312	552101	
		.750	2.50	5	FEM5-R-0312	552201	
3/8	3/8	.500	2.00	5	FEM5-S-0375	553001	
		1.000	3.00	5	FEM5-R-0375	553201	
		1.250	3.00	5	FEM5-M-0375	553301	
1/2	1/2	.625	2.50	5	FEM5-S-0500	555001	
		1.000	3.00	5	FEM5-SR-0500	555101	
		1.250	3.00	5	FEM5-R-0500	555201	
		1.625	4.00	5	FEM5-SP-0500	545301	
		2.000	4.00	5	FEM5-L-0500	555401	
5/8	5/8	.750	3.00	5	FEM5-S-0625	556001	
		1.250	3.50	5	FEM5-SR-0625	556101	
		1.625	3.50	5	FEM5-SP-0625	546201	
		2.000	4.00	5	FEM5-M-0625	556301	
		2.500	5.00	5	FEM5-L-0625	556401	
3/4	3/4	1.000	3.00	5	FEM5-S-0750	557001	
		1.625	4.00	5	FEM5-SP-0750	547101	
		2.000	5.00	5	FEM5-R-0750	557201	
		2.500	5.00	5	FEM5-M-0750	557301	

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.



VST5

Our Proven High Performance 5-Flute Geometry

End Construction Options:

- Square Corner
- Corner Radii
- Ball Nose

Extra-Fine Grain Cemented Carbide

Variable Flute Indexing

P-Max Coated

*Need Chipbreakers?
See pp. 15-16*

Serialization of every tool on shank by lot#

Center-Cutting End Geometry

+0.000/-0.002 Cutting Diameter Tolerance with Eccentric Relief

Need Long Reach? See p. 52

Strengthened Core Diameter

CNC Ground in the **USA**

h6 Shank Tolerance

Cutting Parameters Found on pp. 58 - 59

Material Group

- N** Aluminum/Copper/Brass
- P** Carbon/Alloy Steel
- M** Stainless Steel
- K** Cast Iron
- S** Hi-Temp Alloys
- H** Hardened Steel

Process

- HEM Roughing Wall Finishing
- Heavy Peripheral Floor Finishing
- Light Peripheral Interpolation
- Contouring Chamfering
- Slotting Countersinking
- Ramping Deburring
- Plunging Beveling



5-Flute High-Performance P-Max Coated Endmill

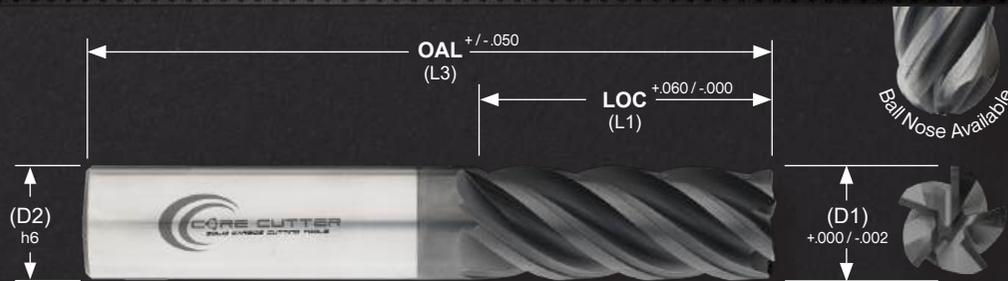
Custom made configurations of the VST5 style are available upon request

Cutting Parameters
pp. 58 - 59



Permittable ISO Material Categories

P M K S H

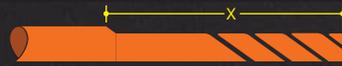


Tool Geometry						EDP #'s by Corner Condition							
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.020R	.030R	.060R	.090R	.125R	Ball Nose
1/8	1/8	0.250	1.50	5	VST5-S-0125	510001	510011						510041
		0.375	2.00	5	VST5-SR-0125	510101	510111						510141
		0.500	2.50	5	VST5-R-0125	510201	510211						510241
3/16	3/16	0.313	2.00	5	VST5-S-0187	500001	500011						500041
		0.438	2.00	5	VST5-SR-0187	500101	500111						500141
		0.563	2.50	5	VST5-R-0187	500201	500211						500241
1/4	1/4	0.375	2.00	5	VST5-S-0250	501001	501011	501016	501021	501031			501041
		0.500	2.50	5	VST5-SR-0250	501101	501111	501116	501121	501131			501141
		0.750	2.50	5	VST5-R-0250	501201	501211	501216	501221	501231			501241
		1.000	3.00	5	VST5-SP-0250	591201	591211	591216	591221	591231			591241
5/16	5/16	1.250	3.00	5	VST5-M-0250	501301	501311	501316	501321	501331			501341
		0.500	2.00	5	VST5-SR-0312	502101	502111	502121				502141	
		0.750	2.50	5	VST5-R-0312	502201	502211	502221				502241	
3/8	3/8	1.250	3.00	5	VST5-M-0312	502301	502311	502321					502341
		0.500	2.00	5	VST5-S-0375	503001	503011	503016	503021	503031	503036		503041
		0.750	2.50	5	VST5-SR-0375	503101	503111	503116	503121	503131	503136		503141
		0.875	3.00	5	VST5-SP-0375	593201	593211	593216	593221	593231	593236		593241
		1.000	3.00	5	VST5-R-0375	503201	503211	503216	503221	503231	503236		503241
1/2	1/2	1.250	3.00	5	VST5-M-0375	503301	503311	503316	503321	503331	503336		503341
		1.500	4.00	5	VST5-L-0375	503401	503411	503416	503421	503431	503436		503441
		0.625	2.50	5	VST5-S-0500	505001	505011	505021	505031	505036	505041	505051	
		1.000	3.00	5	VST5-SR-0500	505101	505111	505121	505131	505136	505141	505151	
		1.250	3.00	5	VST5-R-0500	505201	505211	505221	505231	505236	505241	505251	
5/8	5/8	1.500	4.00	5	VST5-M-0500	505301	505311	505321	505331	505336	505341	505351	
		1.625	4.00	5	VST5-SP-0500	595301	595311	595321	595331	595336	595341	595351	
		2.000	4.00	5	VST5-L-0500	505401	505411	505421	505431	505436	505441	505451	
		0.750	3.00	5	VST5-S-0625	506001		506011	506021	506026	506031	506041	
		1.250	3.50	5	VST5-SR-0625	506101		506111	506121	506126	506131	506141	
		1.500	3.50	5	VST5-R-0625	506201		506211	506221	506226	506231	506241	
3/4	3/4	1.625	3.50	5	VST5-SP-0625	596201		596211	596221	596226	596231	596241	
		2.000	4.00	5	VST5-M-0625	506301		506311	506321	506326	506331	506341	
		2.500	5.00	5	VST5-L-0625	506401		506411	506421	506426	506431	506441	
		1.000	3.00	5	VST5-S-0750	507001		507011	507021	507026	507031	507041	
		1.500	4.00	5	VST5-SR-0750	507101		507111	507121	507126	507131	507141	
		1.625	4.00	5	VST5-SP-0750	597101		597111	597121	597126	597131	597141	
1.0	1.0	2.000	5.00	5	VST5-R-0750	507201		507211	507221	507226	507231	507241	
		2.250	5.00	5	VST5-RM-0750	587201		587211	587221	587226	587231	587241	
		2.500	5.00	5	VST5-M-0750	507301		507311	507321	507326	507331	507341	
		3.000	6.00	5	VST5-L-0750	507401		507411	507421	507426	507431	507441	
		1.750	4.00	5	VST5-SR-1000	508101		508111	508121	508126	508131	508141	
1.0	1.0	2.500	5.00	5	VST5-R-1000	508201		508211	508221	508226	508231	508241	
		3.000	6.00	5	VST5-M-1000	508301		508311	508321	508326	508331	508341	
		3.500	6.00	5	VST5-L-1000	508401		508411	508421	508426	508431	508441	

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

VST5-RN

5-Flute High-Performance P-Max Coated (Reduced Neck) Endmill

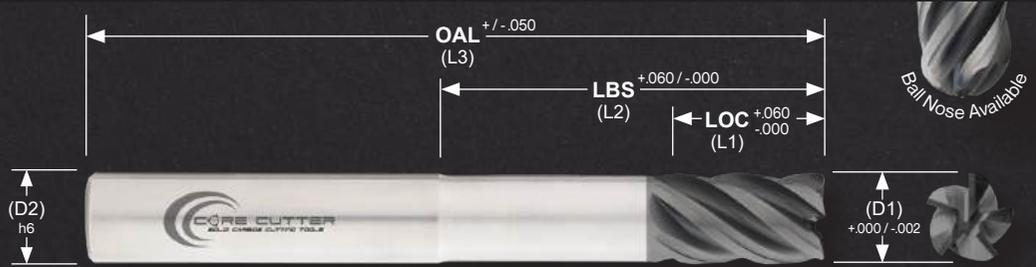


Check out "Un-Necked" in the table below for longer OALs and a custom LBS length you want to specify.

Cutting Parameters
pp. 58 - 59



Permittable ISO Material Categories



Tool Geometry							EDP #'s by Corner Condition							
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	LBS (L2)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.020R	.030R	.060R	.090R	.125R	Ball Nose
1/8	1/8	.188	.500	2.00	5	VST5-RN-R-0125	510701	510711						510741
		.188	.750	2.50	5	VST5-RN-M-0125	510801	510811						510841
3/16	3/16	.250	.500	2.50	5	VST5-RN-R-0187	500701	500711						500741
		.250	.750	3.00	5	VST5-RN-M-0187	500801	500811						500841
		.250	1.000	3.00	5	VST5-RN-L-0187	500901	500911						500941
1/4	1/4	.375	.750	2.50	5	VST5-RN-S-0250	501601	501611	501616	501621	501631			501641
		.375	1.000	3.00	5	VST5-RN-SR-0250	501601N	501611N	501616N	501621N	501631N			501641N
		.375	1.250	4.00	5	VST5-RN-R-0250	501701	501711	501716	501721	501731			501741
		.375	1.500	4.00	5	VST5-RN-SP-0250	501801	501811	501816	501821	501831			501841
5/16	5/16	.500	1.250	3.00	5	VST5-RN-SR-0312	502601N	502611N		502621N				502641N
		.500	2.000	4.00	5	VST5-RN-M-0312	502801	502811		502821				502841
3/8	3/8	.625	1.625	3.00	5	VST5-RN-SR-0375	503601N	503611N	503616N	503621N	503631N	503636N		503641N
		.625	2.000	4.00	5	VST5-RN-R-0375	503701	503711	503716	503721	503731	503736		503741
		.625	2.500	4.00	5	VST5-RN-M-0375	503801	503811	503816	503821	503831	503836		503841
		.625	3.000	5.00	5	VST5-RN-L-0375	503901	503911	503916	503921	503931	503936		503941
1/2	1/2	.750	1.250	3.00	5	VST5-RN-S-0500	505601	505611		505621	505631	505636	505641	505651
		.750	1.750	3.00	5	VST5-RN-SR-0500	505601N	505611N		505621N	505631N	505636N	505641N	505651N
		.750	2.000	4.00	5	VST5-RN-R-0500	505701	505711		505721	505731	505736	505741	505751
		.750	2.250	4.00	5	VST5-RN-SP-0500	505701N	505711N		505721N	505731N	505736N	505741N	505751N
		.750	2.500	5.00	5	VST5-RN-M-0500	505801	505811		505821	505831	505836	505841	505851
		.750	3.500	6.00	5	VST5-RN-L-0500	505901	505911		505921	505931	505936	505941	505951
		.750	Un-Necked	7.00	5	VST5-RN-7-0500	505701-BLK	505711-BLK		505721-BLK	505731-BLK	505736-BLK	505741-BLK	505751-BLK
		.750	Un-Necked	8.00	5	VST5-RN-8-0500	505801-BLK	505811-BLK		505821-BLK	505831-BLK	505836-BLK	505841-BLK	505851-BLK
5/8	5/8	1.000	2.000	4.00	5	VST5-RN-R-0625	506701			506711	506721	506726	506731	506741
		1.000	2.500	5.00	5	VST5-RN-M-0625	506801			506811	506821	506826	506831	506841
		1.000	3.500	5.00	5	VST5-RN-L-0625	506901			506911	506921	506926	506931	506941
		1.000	Un-Necked	7.00	5	VST5-RN-7-0625	506701-BLK			506711-BLK	506721-BLK	506726-BLK	506731-BLK	506741-BLK
		1.000	Un-Necked	8.00	5	VST5-RN-8-0625	506801-BLK			506811-BLK	506821-BLK	506826-BLK	506831-BLK	506841-BLK
3/4	3/4	1.125	1.750	4.00	5	VST5-RN-SR-0750	507601N			507611N	507621N	507626N	507631N	507641N
		1.125	2.000	4.00	5	VST5-RN-R-0751	507701			507711	507721	507726	507731	507741
		1.125	2.500	5.00	5	VST5-RN-SP-0752	507701N			507711N	507721N	507726N	507731N	507741N
		1.125	3.000	6.00	5	VST5-RN-M-0753	507801			507811	507821	507826	507831	507841
		1.125	4.000	6.00	5	VST5-RN-X-0754	507901N			507911N	507921N	507926N	507931N	507941N
		1.125	Un-Necked	7.00	5	VST5-RN-7-0755	507701-BLK			507711-BLK	507721-BLK	507726-BLK	507731-BLK	507741-BLK
		1.125	Un-Necked	8.00	5	VST5-RN-8-0756	507801-BLK			507811-BLK	507821-BLK	507826-BLK	507831-BLK	507841-BLK
1.0	1.0	1.500	2.500	6.00	5	VST5-RN-R-1000	508701			508711	508721	508726	508731	508741
		1.500	3.500	6.00	5	VST5-RN-M-1000	508801			508811	508821	508826	508831	508841
		1.500	4.500	7.00	5	VST5-RN-L-1000	508901			508911	508921	508926	508931	508941
		1.500	Un-Necked	7.00	5	VST5-RN-7-1000	508701-BLK			508711-BLK	508721-BLK	508726-BLK	508731-BLK	508741-BLK
		1.500	Un-Necked	8.00	5	VST5-RN-8-1000	508801-BLK			508811-BLK	508821-BLK	508826-BLK	508831-BLK	508841-BLK

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

NEW!

VST6



Our Proven High Performance 6-Flute Geometry

End Construction Options:

- Square Corner
- Corner Radii
- Ball Nose

Extra-Fine Grain Cemented Carbide

Variable Flute Indexing

T-Max Coated

*Need Chipbreakers?
See pp. 17-18*

Serialization of every tool on shank by lot#

Center-Cutting End Geometry

+ .000/- .002 Cutting Diameter Tolerance with Eccentric Relief

Need Long Reach? See p. 55

Strengthened Core Diameter

CNC Ground in the **USA**

h6 Shank Tolerance

Cutting Parameters Found on pp. 58 - 59



Material Group

- N** Aluminum/Copper/Brass
- P** Carbon/Alloy Steel
- M** Stainless Steel
- K** Cast Iron
- S** Hi-Temp Alloys
- H** Hardened Steel

Process

- HEM Roughing Wall Finishing
- Heavy Peripheral Floor Finishing
- Light Peripheral Interpolation
- Contouring Chamfering
- Slotting Countersinking
- Ramping Deburring
- Plunging Beveling



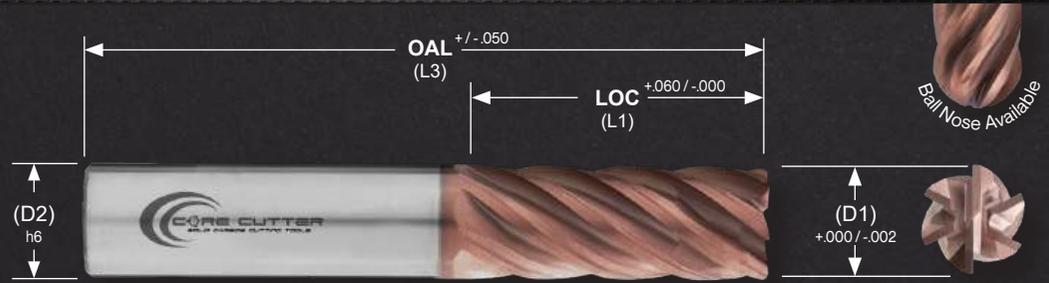
6-Flute High-Performance T-Max Coated Endmill

Custom made configurations of the VST6 style are available upon request

Cutting Parameters
pp. 58 - 59



Permittable ISO Material Categories



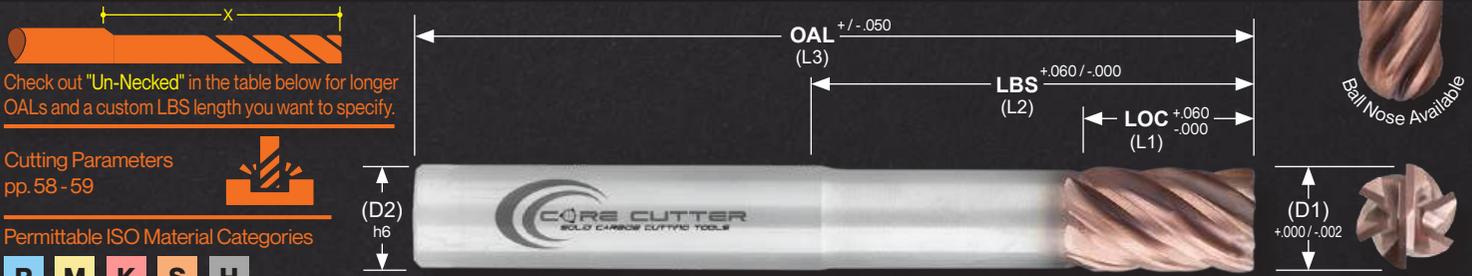
Tool Geometry

EDP #'s by Corner Condition

Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	EDP #'s by Corner Condition							
						Square Corner	.015R	.020R	.030R	.060R	.090R	.125R	Ball Nose
3/16	3/16	.313	2.00	6	VST6-S-0187	600001	600011						600041
		.438	2.00	6	VST6-SR-0187	600101	600111						600141
		.563	2.50	6	VST6-R-0187	600201	600211						600241
1/4	1/4	.375	2.00	6	VST6-S-0250	601001	601011	601016	601021	601031			601041
		.500	2.50	6	VST6-SR-0250	601101	601111	601116	601121	601131			601141
		.750	2.50	6	VST6-R-0250	601201	601211	601216	601221	601231			601241
		1.000	3.00	6	VST6-SP-0250	691201	691211	691216	691221	691231			691241
5/16	5/16	1.250	3.00	6	VST6-M-0250	601301	601311	601316	601321	601331			601341
		.500	2.00	6	VST6-SR-0312	602101	602111		602121				602141
		.750	2.50	6	VST6-R-0312	602201	602211		602221				602241
3/8	3/8	1.250	3.00	6	VST6-M-0312	602301	602311		602321				602341
		.500	2.00	6	VST6-S-0375	603001	603011	603016	603021	603031	603036		603041
		.750	2.50	6	VST6-SR-0375	603101	603111	603116	603121	603131	603136		603141
1/2	1/2	.875	3.00	6	VST6-SP-0375	693201	693211	693216	693221	693231	693236		693241
		1.000	3.00	6	VST6-R-0375	603201	603211	603216	603221	603231	603236		603241
		1.250	3.00	6	VST6-M-0375	603301	603311	603316	603321	603331	603336		603341
		1.500	4.00	6	VST6-L-0375	603401	603411	603416	603421	603431	603436		603441
5/8	5/8	.625	2.50	6	VST6-S-0500	605001	605011		605021	605031	605036	605041	605051
		1.000	3.00	6	VST6-SR-0500	605101	605111		605121	605131	605136	605141	605151
		1.250	3.00	6	VST6-R-0500	605201	605211		605221	605231	605236	605241	605251
		1.500	4.00	6	VST6-M-0500	605301	605311		605321	605331	605336	605341	605351
		1.625	4.00	6	VST6-SP-0500	695301	695311		695321	695331	695336	695341	695351
3/4	3/4	2.000	4.00	6	VST6-L-0500	605401	605411		605421	605431	605436	605441	605451
		.750	3.00	6	VST6-S-0625	606001			606011	606021	606026	606031	606041
		1.250	3.50	6	VST6-SR-0625	606101			606111	606121	606126	606131	606141
		1.500	3.50	6	VST6-R-0625	606201			606211	606221	606226	606231	606241
		1.625	3.50	6	VST6-SP-0625	696201			696211	696221	696226	696231	696241
1.0	1.0	2.000	4.00	6	VST6-M-0625	606301			606311	606321	606326	606331	606341
		2.500	5.00	6	VST6-L-0625	606401			606411	606421	606426	606431	606441
		1.000	3.00	6	VST6-S-0750	607001			607011	607021	607026	607031	607041
		1.500	4.00	6	VST6-SR-0750	607101			607111	607121	607126	607131	607141
		1.625	4.00	6	VST6-SP-0750	697101			697111	697121	697126	697131	697141
		2.000	5.00	6	VST6-R-0750	607201			607211	607221	607226	607231	607241
1.0	1.0	2.250	5.00	6	VST6-RM-0750	687201			687211	687221	687226	687231	687241
		2.500	5.00	6	VST6-M-0750	607301			607311	607321	607326	607331	607341
		3.000	6.00	6	VST6-L-0750	607401			607411	607421	607426	607431	607441
		1.750	4.00	6	VST6-SR-1000	608101			608111	608121	608126	608131	608141
1.0	1.0	2.500	5.00	6	VST6-R-1000	608201			608211	608221	608226	608231	608241
		3.000	6.00	6	VST6-M-1000	608301			608311	608321	608326	608331	608341
		3.500	6.00	6	VST6-L-1000	608401			608411	608421	608426	608431	608441

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

6-Flute High-Performance T-Max Coated (Reduced Neck) Endmill



Tool Geometry							EDP #'s by Corner Condition							
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	LBS (L2)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.020R	.030R	.060R	.090R	.125R	Ball Nose
3/16	3/16	.250	.500	2.50	6	VST6-RN-R-0187	600701	600711						600741
		.250	.750	3.00	6	VST6-RN-M-0187	600801	600811						600841
		.250	1.000	3.00	6	VST6-RN-L-0187	600901	600911						600941
1/4	1/4	.375	.750	2.50	6	VST6-RN-S-0250	601601	601611	601616	601621	601631			601641
		.375	1.000	3.00	6	VST6-RN-SR-0250	601601N	601611N	601616N	601621N	601631N			601641N
		.375	1.250	4.00	6	VST6-RN-R-0250	601701	601711	601716	601721	601731			601741
		.375	1.500	4.00	6	VST6-RN-SP-0250	601801	601811	601816	601821	601831			601841
5/16	5/16	.500	1.250	3.00	6	VST6-RN-SR-0312	602601N	602611N		602621N				602641N
		.500	2.000	4.00	6	VST6-RN-M-0312	602801	602811		602821				602841
3/8	3/8	.625	1.625	3.00	6	VST6-RN-SR-0375	603601N	603611N	603616N	603621N	603631N	603636N		603641N
		.625	2.000	4.00	6	VST6-RN-R-0375	603701	603711	603716	603721	603731	603736		603741
		.625	2.500	4.00	6	VST6-RN-M-0375	603801	603811	603816	603821	603831	603836		603841
		.625	3.000	5.00	6	VST6-RN-L-0375	603901	603911	603916	603921	603931	603936		603941
1/2	1/2	.750	1.250	3.00	6	VST6-RN-S-0500	605601	605611		605621	605631	605636	605641	605651
		.750	1.750	3.00	6	VST6-RN-SR-0500	605601N	605611N		605621N	605631N	605636N	605641N	605651N
		.750	2.000	4.00	6	VST6-RN-R-0500	605701	605711		605721	605731	605736	605741	605751
		.750	2.250	4.00	6	VST6-RN-SP-0500	605701N	605711N		605721N	605731N	605736N	605741N	605751N
		.750	2.500	5.00	6	VST6-RN-M-0500	605801	605811		605821	605831	605836	605841	605851
		.750	3.500	6.00	6	VST6-RN-L-0500	605901	605911		605921	605931	605936	605941	605951
		.750	Un-Necked	7.00	6	VST6-RN-7-0500	605701-BLK	605711-BLK		605721-BLK	605731-BLK	605736-BLK	605741-BLK	605751-BLK
.750	Un-Necked	8.00	6	VST6-RN-8-0500	605801-BLK	605811-BLK		605821-BLK	605831-BLK	605836-BLK	605841-BLK	605851-BLK		
5/8	5/8	1.000	2.000	4.00	6	VST6-RN-R-0625	606701			606711	606721	606726	606731	606741
		1.000	2.500	5.00	6	VST6-RN-M-0625	606801			606811	606821	606826	606831	606841
		1.000	3.500	5.00	6	VST6-RN-L-0625	606901			606911	606921	606926	606931	606941
		1.000	Un-Necked	7.00	6	VST6-RN-7-0625	606701-BLK			606711-BLK	606721-BLK	606726-BLK	606731-BLK	606741-BLK
		1.000	Un-Necked	8.00	6	VST6-RN-8-0625	606801-BLK			606811-BLK	606821-BLK	606826-BLK	606831-BLK	606841-BLK
3/4	3/4	1.125	1.750	4.00	6	VST6-RN-SR-0750	607601N			607611N	607621N	607626N	607631N	607641N
		1.125	2.000	4.00	6	VST6-RN-R-0750	607701			607711	607721	607726	607731	607741
		1.125	2.500	5.00	6	VST6-RN-SP-0750	607701N			607711N	607721N	607726N	607731N	607741N
		1.125	3.000	6.00	6	VST6-RN-M-0750	607801			607811	607821	607826	607831	607841
		1.125	4.000	6.00	6	VST6-RN-X-0750	607901N			607911N	607921N	607926N	607931N	607941N
		1.125	Un-Necked	7.00	6	VST6-RN-7-0750	607701-BLK			607711-BLK	607721-BLK	607726-BLK	607731-BLK	607741-BLK
		1.125	Un-Necked	8.00	6	VST6-RN-8-0750	607801-BLK			607811-BLK	607821-BLK	607826-BLK	607831-BLK	607841-BLK
1.0	1.0	1.500	2.500	6.00	6	VST6-RN-R-1000	608701			608711	608721	608726	608731	608741
		1.500	3.500	6.00	6	VST6-RN-M-1000	608801			608811	608821	608826	608831	608841
		1.500	4.500	7.00	6	VST6-RN-L-1000	608901			608911	608921	608926	608931	608941
		1.500	Un-Necked	7.00	6	VST6-RN-7-1000	608701-BLK			608711-BLK	608721-BLK	608726-BLK	608731-BLK	608741-BLK
		1.500	Un-Necked	8.00	6	VST6-RN-8-1000	608801-BLK			608811-BLK	608821-BLK	608826-BLK	608831-BLK	608841-BLK

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.



VMF

Our Proven High-Performance 7, 9, and 11 Flute Geometry



Center-Cutting End Geometry
(Except the 11 flute configuration)

End Construction Options:

- Square Corner
- Corner Radii

Extra-Fine Grain Cemented Carbide

+ .000/- .002 Cutting Diameter Tolerance with Eccentric Relief

Variable Flute Indexing

Strong Core Diameter

C-MAX Coated

*Need Chipbreakers?
See pp. 19-20*

CNC Ground in the **USA**

Serialization of every tool on shank by lot#

h6 Shank Tolerance

Cutting Parameters Found on pp. 58 - 59



Material Group

- N** Aluminum/Copper/Brass
- P** Carbon/Alloy Steel
- M** Stainless Steel
- K** Cast Iron
- S** Hi-Temp Alloys
- H** Hardened Steel

Process

- HEM Roughing
- Heavy Peripheral
- Light Peripheral
- Contouring
- Slotting
- Ramping
- Plunging
- Wall Finishing
- Floor Finishing
- Interpolation
- Chamfering
- Countersinking
- Deburring
- Beveling

Multi-Flute (7, 9 and 11 Flutes) High-Performance C-Max Coated Endmill

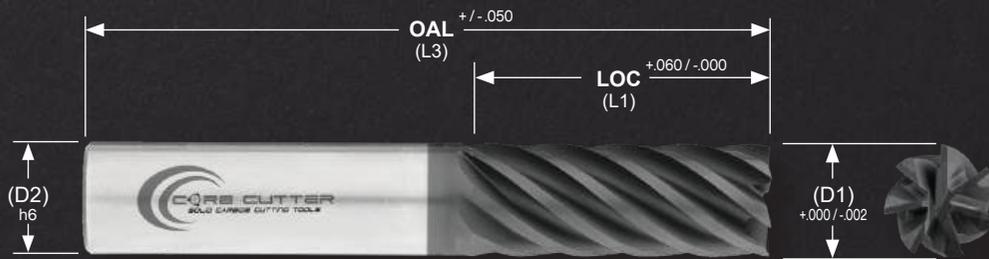
Custom made configurations of the VMF style are available upon request

Cutting Parameters pp. 58 - 59



Permittable ISO Material Categories

P M K S H



Tool Geometry						EDP #'s by Corner Condition		
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.030R
3/8	3/8	.750	2.50	7	VMF7-SR-0375	703101	703111	
		1.000	3.00	7	VMF7-R-0375	703201	703211	
1/2	1/2	1.000	3.00	7	VMF7-SR-0500	705101		705121
		1.250	3.00	7	VMF7-R-0500	705201		705221
		1.500	4.00	7	VMF7-M-0500	705301		705321
5/8	5/8	1.250	3.50	7	VMF7-SR-0625	706101		706111
		2.000	4.00	7	VMF7-M-0625	706301		706311
3/4	3/4	1.500	4.00	7	VMF7-SR-0750	707101		707111
		1.500	4.00	9	VMF9-SR-0750	907101		907111
		1.625	4.00	7	VMF7-SP-0750	797101		797111
		2.500	5.00	7	VMF7-M-0750	707301		707311
		2.500	5.00	9	VMF9-M-0750	907301		907311
		3.000	6.00	7	VMF7-L-0750	707401		707411
		3.000	6.00	9	VMF9-L-0750	907401		907411
1.0	1.0	1.750	4.00	7	VMF7-SR-1000	708101		708111
		1.750	4.00	9	VMF9-SR-1000	908101		908111
		1.750	4.00	11	VMF11-SR-1000	118101		118111
		2.500	5.00	7	VMF7-R-1000	708201		708211
		2.500	5.00	9	VMF9-R-1000	908201		908211
		2.500	5.00	11	VMF11-R-1000	118201		118211
		3.000	6.00	7	VMF7-M-1000	708301		708311
		3.000	6.00	9	VMF9-M-1000	908301		908311
		3.000	6.00	11	VMF11-M-1000	118301		118311

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

Multiple Flute Count Options Available.

SPEEDS & FEEDS

Suggested Initial Cutting Parameters for all Ferrous (& Titanium) Tooling

ISO Material Categories	SFM	Ferrous (& Titanium) Tooling Feed Table (f_z)																																		
		D1 ≤ 1/8					D1 ≤ 1/4					D1 ≤ 3/8					D1 ≤ 1/2					D1 ≤ 5/8					D1 ≤ 3/4					D1 ≤ 1"				
		S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM	S	HP	LP	F	*HEM
P Free Machining Steels 1018, 1215, 12L14 Alloys Steels 4130 (Chrome Moly), 4140, 4340, 8620 Tool & Die Steels A2, D2, H13, P20, S7	300 500	.0007	.0008	.0008	.0005	.0013	.0014	.0015	.0016	.0011	.0025	.0021	.0023	.0024	.0016	.0038	.0028	.0030	.0032	.0021	.0050	.0035	.0038	.0040	.0026	.0063	.0042	.0045	.0048	.0032	.0075	.0056	.0060	.0065	.0042	.0100
	250 350	.0006	.0008	.0007	.0005	.0013	.0013	.0015	.0014	.0009	.0025	.0019	.0023	.0022	.0014	.0038	.0025	.0030	.0029	.0019	.0050	.0031	.0038	.0036	.0023	.0063	.0038	.0045	.0043	.0028	.0075	.0050	.0060	.0058	.0038	.0100
	110 225	.0006	.0008	.0006	.0004	.0013	.0011	.0016	.0013	.0008	.0027	.0017	.0024	.0019	.0012	.0040	.0022	.0032	.0025	.0017	.0053	.0028	.0040	.0032	.0021	.0067	.0033	.0048	.0038	.0025	.0080	.0044	.0064	.0051	.0033	.0107
M Martensitic Stainless Steel 410, 416, 420, 440C, 440F Austenitic Stainless Steel 303, 304, 316, 321 PH Stainless Steel 13-8, 15-5, 17-4	275 380	.0007	.0008	.0008	.0005	.0014	.0014	.0017	.0016	.0011	.0028	.0021	.0025	.0024	.0016	.0041	.0028	.0033	.0032	.0021	.0055	.0035	.0041	.0040	.0026	.0069	.0042	.0050	.0048	.0032	.0083	.0056	.0066	.0065	.0042	.0110
	200 300	.0007	.0008	.0008	.0005	.0013	.0014	.0016	.0016	.0010	.0026	.0020	.0023	.0023	.0015	.0039	.0027	.0031	.0031	.0020	.0052	.0034	.0039	.0039	.0025	.0065	.0041	.0047	.0047	.0030	.0078	.0054	.0062	.0062	.0041	.0103
	180 275	.0006	.0007	.0007	.0005	.0012	.0013	.0014	.0014	.0009	.0023	.0019	.0021	.0022	.0014	.0035	.0025	.0028	.0029	.0019	.0047	.0031	.0035	.0036	.0023	.0058	.0038	.0042	.0043	.0028	.0070	.0050	.0056	.0058	.0038	.0093
K Gray Cast Iron GG10, GG20, GG30 Ductile Cast Iron A536 Grade 60-40-18 Malleable Cast Iron 310M8, 22010, M4304	325 450	.0006	.0007	.0007	.0005	.0012	.0012	.0014	.0014	.0009	.0023	.0018	.0021	.0021	.0014	.0035	.0024	.0028	.0028	.0018	.0047	.0030	.0035	.0035	.0023	.0058	.0036	.0042	.0042	.0027	.0070	.0048	.0056	.0055	.0036	.0093
	275 375	.0007	.0008	.0008	.0005	.0013	.0014	.0015	.0016	.0010	.0025	.0020	.0023	.0023	.0015	.0038	.0027	.0030	.0031	.0020	.0050	.0034	.0038	.0039	.0025	.0063	.0041	.0045	.0047	.0030	.0075	.0054	.0060	.0062	.0041	.0100
	250 325	.0007	.0008	.0008	.0005	.0013	.0014	.0016	.0016	.0011	.0027	.0021	.0024	.0024	.0016	.0040	.0028	.0032	.0032	.0021	.0053	.0035	.0040	.0040	.0026	.0067	.0042	.0048	.0048	.0032	.0080	.0056	.0064	.0065	.0042	.0107
S Titanium Ti-3AL, Ti-4AL, Ti-5AL, Ti-6AL HRSA (Co) Rene 41, HS-188, X-40, AIRResist 13, Stellite HRSA (Fe) A286, Incoloy, Udimet, Discaloy HRSA (Ni) Inconel, MAR-M-247, Udimet-700, Haynes, Monel, Rene 150, Waspaloy	175 280	.0006	.0007	.0007	.0005	.0011	.0013	.0013	.0014	.0009	.0022	.0019	.0020	.0022	.0014	.0033	.0025	.0026	.0029	.0019	.0043	.0031	.0033	.0036	.0023	.0054	.0038	.0039	.0043	.0028	.0065	.0050	.0052	.0058	.0038	.0087
	110 165	.0006	.0006	.0007	.0005	.0010	.0012	.0013	.0014	.0009	.0021	.0018	.0019	.0021	.0014	.0031	.0024	.0025	.0028	.0018	.0042	.0030	.0031	.0035	.0023	.0052	.0036	.0038	.0042	.0027	.0063	.0048	.0050	.0055	.0036	.0083
	100 150	.0006	.0006	.0006	.0004	.0010	.0011	.0012	.0013	.0008	.0020	.0017	.0018	.0019	.0012	.0030	.0022	.0024	.0025	.0017	.0040	.0028	.0030	.0032	.0021	.0050	.0033	.0036	.0038	.0025	.0060	.0044	.0048	.0051	.0033	.0080
	75 125	.0005	.0006	.0006	.0004	.0009	.0010	.0011	.0012	.0008	.0018	.0015	.0017	.0017	.0011	.0028	.0020	.0022	.0023	.0015	.0037	.0025	.0028	.0029	.0019	.0046	.0030	.0033	.0035	.0023	.0055	.0040	.0044	.0046	.0030	.0073
H Hardened Steel (<55 HRC) Hardened Steel (≥55 HRC)	80 115	.0003	.0005	.0003	.0002	.0008	.0006	.0009	.0007	.0005	.0015	.0009	.0014	.0010	.0007	.0023	.0012	.0018	.0014	.0009	.0030	.0015	.0023	.0017	.0011	.0038	.0018	.0027	.0021	.0014	.0045	.0024	.0036	.0028	.0018	.0060
	70 100	.0003	.0004	.0003	.0002	.0006	.0005	.0008	.0006	.0004	.0013	.0008	.0011	.0009	.0006	.0019	.0010	.0015	.0012	.0008	.0025	.0013	.0019	.0014	.0009	.0031	.0015	.0023	.0017	.0011	.0038	.0020	.0030	.0023	.0015	.0050

Speeds and Feeds suggested within the table are only estimated starting parameters and may require increase/decrease adjustments based on your particular application and/or setup - Core Cutter LLC, assumes no liability.
 *For HEM applications, the "HEM" column within the feed table is for your feed (f_z) based on chip thinning at ≤10% step over, and for SFM, you can take our recommendations x 1.5 - 1.8

KEY

Co	Cobalt (Chemical Element - see p. 79)	HP	Heavy Peripheral ($a_p = 30\%$ -to- 50% of Dia.)	SFM	Surface Feet per Minute
D1	Tool Cutting Diameter	HEM	High Efficiency Milling (see pp. 84-86)	S	Slotting ($a_p = 100\%$ of Dia.)
F	Finishing (see p. 93)	LP	Light Peripheral ($a_p = 18\%$ -to- 29% of Dia.)	HRC	Rockwell Hardness "C" Scale
f_z	Feed per Tooth	Ni	Nickel (Metallic Element - see p. 79)		
F_e	Iron (Chemical Element - see p. 79)	ISO	International Organization for Standardization		

DEPTH OF CUT GUIDELINES

Suggested Initial Depth of Cut Guidelines for all Ferrous (& Titanium) Tooling

Ferrous (& Titanium) Tooling (Depth of Cut Chart)												
Tool Series	Light Peripheral (LP)		Heavy Peripheral (HP)		Slotting (S)		Finishing (F)		Ramping		High Efficiency Milling <i>(see pp. 84-86)</i>	
	a_e	a_p	a_e	a_p	a_e	a_p	a_e	a_p	Angle	Feed	a_e	a_p
	VST4	15% - 25% of D1	Up to 2.5 x D1	25% - 50% of D1	Up to 2.0 x D1	100% of D1	Up to 1.0 x D1	3% - 5% of D1	Up to Full LOC (L1)	1° - 5°	Use (LP) in Feed Chart on p.58	Use Higher Flute Count
VST4-RN	9% - 15% of D1	Up to Full LOC (L1)	15% - 30% of D1	Up to 1.0 x D1	100% of D1	Up to 1.0 x D1	3% - 5% of D1	Up to Full LOC (L1)	1° - 5°	Use (LP) in Feed Chart on p.58	Use Higher Flute Count	
FEM5	12% - 15% of D1	Up to 3.0 x D1	15% - 20% of D1	Up to 1.6 x D1	100% of D1	Up to .35 x D1	3% - 5% of D1	Up to Full LOC (L1)	1° - 5°	Use (LP) in Feed Chart on p.58	8% - 15% of D1	Up to 3.5 x D1
VST5	15% - 25% of D1	Up to 2.75 x D1	30% - 50% of D1	Up to 2.25 x D1	100% of D1	Up to .35 x D1	3% - 5% of D1	Up to Full LOC (L1)	1° - 5°	Use (LP) in Feed Chart on p.58	8% - 20% of D1	Up to 3.5 x D1
VST5-RN	9% - 15% of D1	Up to Full LOC (L1)	18% - 30% of D1	Up to Full LOC (L1)	100% of D1	Up to .50 x D1	3% - 5% of D1	Up to Full LOC (L1)	1° - 5°	Use (LP) in Feed Chart on p.58	8% - 10% of D1	Up to Full LOC (L1)
VST6	12% - 25% of D1	Up to 3.0 x D1	25% - 50% of D1	Up to 2.50 x D1	100% of D1	Up to .50 x D1	3% - 5% of D1	Up to Full LOC (L1)	1° - 5°	Use (LP) in Feed Chart on p.58	8% - 20% of D1	Up to 3.75 x D1
VST6-RN	9% - 15% of D1	Up to Full LOC (L1)	18% - 30% of D1	Up to Full LOC (L1)	100% of D1	Up to .35 x D1	3% - 5% of D1	Up to Full LOC (L1)	1° - 5°	Use (LP) in Feed Chart on p.58	8% - 10% of D1	Up to Full LOC (L1)
VMF7	7% - 10% of D1	Up to 3.5 x D1	Not Recommended		Not Recommended		3% - 5% of D1	Up to Full LOC (L1)	1° - 5°	Use (LP) in Feed Chart on p.58	7% - 10% of D1	Up to 4.0 x D1
VMF9	6% - 8% of D1	Up to 3.5 x D1	Not Recommended		Not Recommended		3% - 5% of D1	Up to Full LOC (L1)	1° - 5°	Use (LP) in Feed Chart on p.58	6% - 8% of D1	Up to 4.0 x D1
VMF11	5% - 7% of D1	Up to 3.5 x D1	Not Recommended		Not Recommended		3% - 5% of D1	Up to Full LOC (L1)	1° - 5°	Use (LP) in Feed Chart on p.58	5% - 7% of D1	Up to 4.0 x D1

*Note: The depth of cut numbers supplied in this table are estimates only and may need to be changed higher/lower based on your specific application and setup - Core Cutter LLC, assumes no liability.

KEY

Angle	Ramping angle to utilize	FEED	F_z to use for this operation	LOC	Length of Cut (L1)
D1	Tool Cutting Diameter	HP	Heavy Peripheral (a_e = 30%-to-50% of Dia.)	MRR	Metal Removal Rate (See p. 87)
a_e	Radial Depth of Cut	HEM	High Efficiency Milling (See pp. 84-86)	Ramping	Tool plunges gradually
a_p	Axial Depth of Cut	LP	Light Peripheral (a_e = 18%-to-29% of Dia.)	Slotting	Slotting (a_e = 100% of Dia.)

CHAMFER Tooling



Catalog Page(s)

ISO Mat'l Group

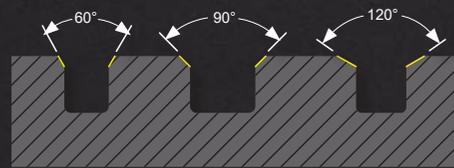
Available Surface Treatment

61 - 62

- N
- P
- M
- K
- S

- ✓ Uncoated
- ✓ P-Max Coating

CMS 2 & 4 Flute (Straight Fluted) Center-Cutting Chamfer Mills



← Standard Incl. Angles found in our lineup

We can custom make the CMS in any configuration you need, just let us know!

63 - 65

- N
- P
- M
- K
- S

- ✓ Uncoated
- ✓ P-Max Coating

CMH 2, 3 & 5 Flute (Helical Fluted) High-Performance Non-Center Cutting Chamfer Mills



→ Standard Incl. Angles found in our lineup



We can custom make the CMH in any configuration you need, just let us know!



Cutting Parameters, pages 66 - 67

Chamfers are useful for a variety of reasons, including smoothing down rough edges, making it easier for pieces to fit together, and improving the look of the finished product.

High-Performance Straight Fluted Chamfer Mills with 2 or 4 Flutes



Center-Cutting End Geometry

60°, 90°, 120° Incl.
Angle Options

2 & 4 Flute Options

P-Max Coated

Extra-Fine Grain Cemented
Carbide

CNC Ground in the 

Serialization of every tool
on shank by lot#

h6 Shank Tolerance

Cutting Parameters
Found on pp. 66 - 67



Material Group

- N** Aluminum/Copper/Brass
- P** Carbon/Alloy Steel
- M** Stainless Steel
- K** Cast Iron
- S** Hi-Temp Alloys
- H** Hardened Steel

Process

- HEM Roughing Wall Finishing
- Heavy Peripheral Floor Finishing
- Light Peripheral Interpolation
- Contouring Chamfering
- Slotting Countersinking
- Ramping Deburring
- Plunging Beveling

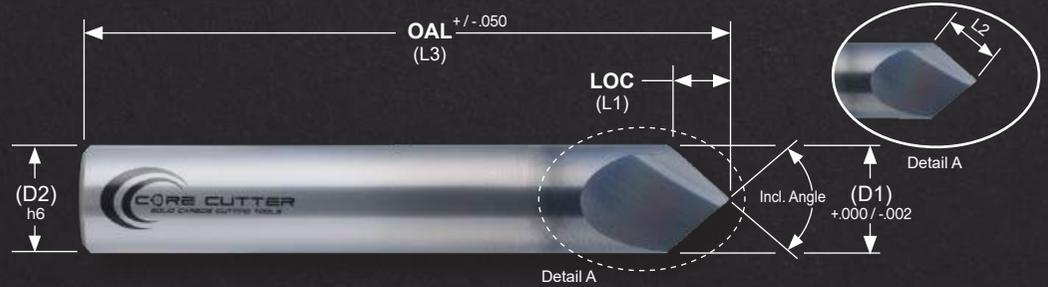
2 & 4 Flute Straight Fluted Chamfer Mills with P-Max Coating

Custom made configurations of the CMS style are available upon request

Cutting Parameters pp. 66 - 67



Permittable ISO Material Categories



Tool Geometry								EDP #'s by Incl. Chamfer Angle		
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	Cutting Edge Length (L2)	OAL (L3)	Web Thickness	Flute Count	Tool Description	60°	90°	120°
1/8	1/8	.108	.125	1.50	.015	2	CMS60-2-0125	S06021		
		.062	.088	1.50	.015	2	CMS90-2-0125		S09021	
		.036	.072	1.50	.015	2	CMS120-2-0125			S012021
3/16	3/16	.162	.187	2.00	.018	2	CMS60-2-0187	S06022		
		.093	.132	2.00	.018	2	CMS90-2-0187		S09022	
		.054	.108	2.00	.018	2	CMS120-2-0187			S12022
1/4	1/4	.216	.249	2.50	.020	2	CMS60-2-0250	S06023		
		.216	.249	2.50	.020	4	CMS60-4-0250	S06043		
		.125	.177	2.50	.020	2	CMS90-2-0250		S09023	
		.125	.177	2.50	.020	4	CMS90-4-0250		S09043	
		.072	.144	2.50	.020	2	CMS120-2-0250			S12023
		.072	.144	2.50	.020	4	CMS120-4-0250			S12043
3/8	3/8	.324	.374	2.50	.035	2	CMS60-2-0375	S06024		
		.324	.374	2.50	.035	4	CMS60-4-0375	S06044		
		.187	.264	2.50	.035	2	CMS90-2-0375		S09024	
		.187	.264	2.50	.035	4	CMS90-4-0375		S09044	
		.108	.217	2.50	.035	2	CMS120-2-0375			S12024
		.108	.217	2.50	.035	4	CMS120-4-0375			S12044
1/2	1/2	.433	.499	3.00	.040	2	CMS60-2-0500	S06025		
		.433	.499	3.00	.040	4	CMS60-4-0500	S06045		
		.250	.353	3.00	.040	2	CMS90-2-0500		S09025	
		.250	.353	3.00	.040	4	CMS90-4-0500		S09045	
		.144	.289	3.00	.040	2	CMS120-2-0500			S12025
		.144	.289	3.00	.040	4	CMS120-4-0500			S12045
5/8	5/8	.541	.624	3.00	.040	2	CMS60-2-0625	S06026		
		.541	.624	3.00	.040	4	CMS60-4-0625	S06046		
		.313	.442	3.00	.040	2	CMS90-2-0625		S09026	
		.313	.442	3.00	.040	4	CMS90-4-0625		S09046	
		.180	.361	3.00	.040	2	CMS120-2-0625			S12026
		.180	.361	3.00	.040	4	CMS120-4-0625			S12046

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

High-Performance Helically Fluted Chamfer Mills with 2, 3, or 5 Flutes

Precision Ground "Tip Diameter" for machine probe touch-off. Find it within our product tables (D3) on pp. 64 & 65, we hold the dia. to $+.000/-0.002$.

Non-Center Cutting

P-Max Coated

High Performance Helical Fluted Design

Extra-Fine Grain Cemented Carbide

2, 3 & 5 Flute Options

Serialization of every tool on shank by lot#

CNC Ground in the 

h6 Shank Tolerance

Cutting Parameters Found on pp. 66 - 67



Material Group

- N** Aluminum/Copper/Brass
- P** Carbon/Alloy Steel
- M** Stainless Steel
- K** Cast Iron
- S** Hi-Temp Alloys
- H** Hardened Steel

Process

- HEM Roughing Wall Finishing
- Heavy Peripheral Floor Finishing
- Light Peripheral Interpolation
- Contouring Chamfering
- Slotting Countersinking
- Ramping Deburring
- Plunging Beveling



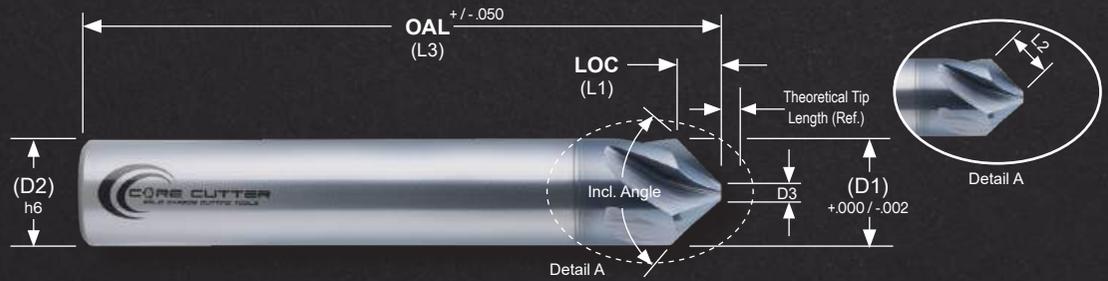
2, 3 or 5 Flute HP Helically Fluted Chamfer Mills with P-Max Coating

Custom made configurations of the CMH style are available upon request

Cutting Parameters
pp. 66 - 67



Permittable ISO Material Categories



Tool Geometry

EDP #'s by Incl. Chamfer Angle

Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	Cutting Edge Length (L2)	OAL (L3)	Tip Diameter (D3)	Theoretical Tip Length (Ref.)	Flute Count	Tool Description	Incl. Chamfer Angle				
									60°	82°	90°	100°	120°
1/8	1/8	.087	.100	1.50	.025	.0220	2	CMH60-2-0125	H06021				
		.058	.076	1.50	.025	.0140	2	CMH82-2-0125		H08221			
		.050	.071	1.50	.025	.0125	2	CMH90-2-0125			H09021		
		.042	.065	1.50	.025	.0100	2	CMH100-2-0125				H10021	
		.029	.058	1.50	.025	.0070	2	CMH120-2-0125					H12021
3/16	3/16	.128	.148	2.00	.040	.0350	2	CMH60-2-0187	H06022				
		.089	.112	2.00	.040	.0230	2	CMH82-2-0187		H08222			
		.074	.104	2.00	.040	.0200	2	CMH90-2-0187			H09022		
		.062	.096	2.00	.040	.0170	2	CMH100-2-0187				H10022	
		.043	.085	2.00	.040	.0120	2	CMH120-2-0187					H12022
1/4	1/4	.165	.190	2.50	.060	.0520	3	CMH60-3-0250	H06033				
		.165	.190	2.50	.060	.0520	5	CMH60-5-0250	H06053				
		.109	.145	2.50	.060	.0350	3	CMH82-3-0250		H08233			
		.109	.145	2.50	.060	.0350	5	CMH82-5-0250		H08253			
		.095	.134	2.50	.060	.0300	3	CMH90-3-0250			H09033		
		.095	.134	2.50	.060	.0300	5	CMH90-5-0250			H09053		
		.080	.124	2.50	.060	.0250	3	CMH100-3-0250				H10033	
		.080	.124	2.50	.060	.0250	5	CMH100-5-0250				H10053	
		.055	.110	2.50	.060	.0170	3	CMH120-3-0250					H12033
3/8	3/8	.264	.305	2.50	.070	.0610	3	CMH60-3-0375	H06034				
		.264	.305	2.50	.070	.0610	5	CMH60-5-0375	H06054				
		.175	.232	2.50	.070	.0400	3	CMH82-3-0375		H08234			
		.175	.232	2.50	.070	.0400	5	CMH82-5-0375		H08254			
		.153	.215	2.50	.070	.0350	3	CMH90-3-0375			H09034		
		.153	.215	2.50	.070	.0350	5	CMH90-5-0375			H09054		
		.128	.199	2.50	.070	.0290	3	CMH100-3-0375				H10034	
		.128	.199	2.50	.070	.0290	5	CMH100-5-0375				H10054	
		.088	.176	2.50	.070	.0200	3	CMH120-3-0375					H12034
		.088	.176	2.50	.070	.0200	5	CMH120-5-0375					H12054
1/2	1/2	.364	.420	3.00	.080	.0690	3	CMH60-3-0500	H06035				
		.364	.420	3.00	.080	.0690	5	CMH60-5-0500	H06055				
		.242	.320	3.00	.080	.0460	3	CMH82-3-0500		H08235			
		.242	.320	3.00	.080	.0460	5	CMH82-5-0500		H08255			
		.210	.297	3.00	.080	.0400	3	CMH90-3-0500			H09035		
		.210	.297	3.00	.080	.0400	5	CMH90-5-0500			H09055		
		.176	.274	3.00	.080	.0340	3	CMH100-3-0500				H10035	
		.176	.274	3.00	.080	.0340	5	CMH100-5-0500				H10055	
		.121	.243	3.00	.080	.0230	3	CMH120-3-0500					H12035
		.121	.243	3.00	.080	.0230	5	CMH120-5-0500					H12055

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

Table continues on the following page...

2, 3 or 5 Flute HP Helically Fluted Chamfer Mills with P-Max Coating

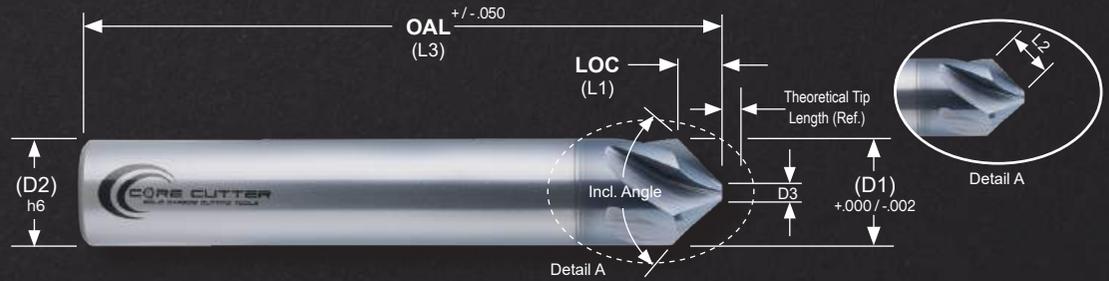
Custom made configurations of the CMH style are available upon request

Cutting Parameters
pp. 66 - 67



Permittable ISO Material Categories

N P M K S H



Tool Geometry

EDP #'s by Incl. Chamfer Angle

Cut Dia. (D1)	Shank Dia. (D2)	Cutting Edge Length (L2)	LOC (L1)	OAL (L3)	Tip Diameter (D3)	Theoretical Tip Length (Ref.)	Flute Count	Tool Description	Incl. Chamfer Angle				
									60°	82°	90°	100°	120°
5/8	5/8	.463	.535	3.00	.090	.0780	3	CMH60-3-0625	H06036				
		.463	.535	3.00	.090	.0780	5	CMH60-5-0625	H06056				
		.308	.408	3.00	.090	.0520	3	CMH82-3-0625		H08236			
		.308	.408	3.00	.090	.0520	5	CMH82-5-0625		H08256			
		.268	.378	3.00	.090	.0450	3	CMH90-3-0625			H09036		
		.268	.378	3.00	.090	.0450	5	CMH90-5-0625			H09056		
		.225	.349	3.00	.090	.0380	3	CMH100-3-0625				H10036	
		.225	.349	3.00	.090	.0380	5	CMH100-5-0625				H10056	
		.154	.309	3.00	.090	.0260	3	CMH120-3-0625					H12036
3/4	3/4	.154	.309	3.00	.090	.0260	5	CMH120-5-0625					H12056
		.562	.650	3.00	.100	.0870	3	CMH60-3-0750	H06037				
		.562	.650	3.00	.100	.0870	5	CMH60-5-0750	H06057				
		.325	.460	3.00	.100	.0500	3	CMH90-3-0750			H09037		
		.325	.460	3.00	.100	.0500	5	CMH90-5-0750			H09057		
		.188	.375	3.00	.100	.0290	3	CMH120-3-0750					H12037
.188	.375	3.00	.100	.0290	5	CMH120-5-0750					H12057		

EDP #'s indicated in orange are those that are declared to be factory stock; regarding the availability of the remaining component numbers, please contact us.

SPEEDS & FEEDS

Suggested Initial Cut Values for all Chamfer Series Tooling

ISO Material Categories		SFM	Chamfer Tooling Series Feed Table (f_z)													
			$D1_{eff} \leq 1/8$		$D1_{eff} \leq 3/16$		$D1_{eff} \leq 1/4$		$D1_{eff} \leq 3/8$		$D1_{eff} \leq 1/2$		$D1_{eff} \leq 5/8$		$D1_{eff} \leq 3/4$	
			CMS	CMH	CMS	CMH	CMS	CMH	CMS	CMH	CMS	CMH	CMS	CMH	CMS	CMH
N	Wrought Aluminum Alloys 1100, 2024, 6061, 7075	1200 -to- 2000	.00188	.00281	.0028	.0042	.0038	.0056	.0056	.0084	.0075	.0113	.0094	.0141	.0113	.0169
	Cast Aluminum Alloys A356, A360, A380, A390	550 - 800	.00155	.00233	.0023	.0035	.0031	.0047	.0047	.0071	.0062	.0093	.0078	.0116	.0093	.0140
	Brass, Bronze, Copper 101, 110, 260, 360, 932	435 - 750	.00135	.00203	.0020	.0030	.0027	.0041	.0041	.0062	.0054	.0081	.0068	.0101	.0081	.0122
P	Free Machining Steels 1018, 1215, 12L14	300 - 500	.00098	.00146	.0015	.0022	.0020	.0029	.0029	.0044	.0039	.0059	.0049	.0073	.0059	.0088
	Alloys Steels 4130 (Chrome Moly), 4140, 4340, 8620	250 - 350	.00088	.00131	.0013	.0020	.0018	.0026	.0026	.0039	.0035	.0053	.0044	.0066	.0053	.0079
	Tool & Die Steels A2, D2, H13, P20, S7	110 - 225	.00080	.00120	.0012	.0018	.0016	.0024	.0024	.0036	.0032	.0048	.0040	.0060	.0048	.0072
M	Martensitic Stainless Steel 410, 416, 420, 440C, 440F	275 - 380	.00085	.00128	.0013	.0019	.0017	.0026	.0025	.0038	.0034	.0051	.0043	.0064	.0051	.0077
	Austenitic Stainless Steel 303, 304, 316, 321	250 - 340	.00078	.00116	.0012	.0017	.0016	.0023	.0023	.0035	.0031	.0047	.0039	.0058	.0047	.0070
	PH Stainless Steel 13-8, 15-5, 17-4	200 - 275	.00070	.00105	.0011	.0016	.0014	.0021	.0021	.0032	.0028	.0042	.0035	.0053	.0042	.0063
K	Gray Cast Iron GG10, GG20, GG30	325 - 450	.00073	.00109	.0011	.0016	.0015	.0022	.0022	.0033	.0029	.0044	.0036	.0054	.0044	.0065
	Ductile Cast Iron A536 Grade 60-40-18	275 - 375	.00065	.00098	.0010	.0015	.0013	.0020	.0020	.0030	.0026	.0039	.0033	.0049	.0039	.0059
	Malleable Cast Iron 310M8, 22010, M4504	250 - 325	.00060	.00090	.0009	.0014	.0012	.0018	.0018	.0027	.0024	.0036	.0030	.0045	.0036	.0054
S	Titanium Ti-3AL, Ti-4AL, Ti-5AL, Ti-6AL	175 - 280	.00075	.00113	.0011	.0017	.0015	.0023	.0023	.0035	.0030	.0045	.0038	.0056	.0045	.0068
	HRSA (Co) Rene 41, HS-188, X-40, AiResist 13, Stellite	110 - 165	.00068	.00101	.0010	.0015	.0014	.0020	.0020	.0030	.0027	.0041	.0034	.0051	.0041	.0061
	HRSA (Fe) A286, Incoloy, Udimet, Discaloy	100 - 150	.00060	.00090	.0009	.0014	.0012	.0018	.0018	.0027	.0024	.0036	.0030	.0045	.0036	.0054
	HRSA (Ni) Inconel, MAR-M-247, UdimeT-700, Haynes, Monel, Rene 150, Waspaloy	75 - 125	.00055	.00083	.0008	.0012	.0011	.0017	.0017	.0026	.0022	.0033	.0028	.0041	.0033	.0050
H	Hardened Steel (<55 HRC)	115 - 150	.00045	.00068	.0007	.0010	.0009	.0014	.0014	.0021	.0018	.0027	.0023	.0034	.0027	.0041
	Hardened Steel (>55 HRC)	70 - 100	.00038	.00056	.0006	.0008	.0008	.0011	.0011	.0017	.0015	.0023	.0019	.0028	.0023	.0034

Speeds and Feeds suggested within the table are only estimated starting parameters and may require increase/decrease adjustments based on your particular application and/or setup - Core Cutter LLC, assumes no liability.

KEY

Co	Cobalt (Chemical Element - see p. 79)	HP	Heavy Peripheral ($a_e = 30\%$ -to- 50% of Dia.)	SFM	Surface Feet per Minute
D1	Tool Cutting Diameter	HEM	High Efficiency Milling (see pp. 84-86)	S	Slotting ($a_e = 100\%$ of Dia.)
F	Finishing (see p. 93)	LP	Light Peripheral ($a_e = 18\%$ -to- 29% of Dia.)	HRC	Rockwell Hardness "C" Scale
F_z	Feed per Tooth	Ni	Nickel (Metallic Element - see pg. 79)		
F_e	Iron (Chemical Element - see p. 79)	ISO	International Organization for Standardization		

CHAMFERING GUIDELINES

Completing a component by adding the required finishing details.

Chamfer tools are essential for enhancing the overall quality of machined components by deburring sharp edges, constructing countersink angles for hole preparation and even beveling component features for print settlement. Primarily used in the field of machining and metalworking, this tool is utilized to produce a slanted edge, also referred to as a beveled edge or chamfer, on a workpiece.

In this catalog, we provide two series of tools: CMS (pp. 61–62) and CMH (pp. 63–65). The CMS series is designed for basic operations and includes a center-cutting end geometry. On the other hand, the CMH series is built for optimal efficiency and results with a very precise (+.000/-0.002) tip diameter, ensuring highly accurate machine tool probe touch-off for convenience. This is a non-center cutting tool but includes geometry like no other in the market.

Chamfering Guidelines

- Make sure the effective cutting diameter ($D1_{eff}$) of the tool serves as the basis for your speed and feed rates (Fig. 3).
- Proper Saddling (Fig. 1): It is advisable to choose a tool size that matches the chamfer width (cw) by using less than 80% of the cutting edge, as seen in Figure 1, and positioning the tool at the center. The (L2) dimension may be found within our product charts on pages 62, 64, and 65.
- To get a better surface finish, increase speed and reduce feed.
- Helical interpolation (Fig. 2) is preferable to straight plunging with any of our chamfering tools and when back chamfering as well (Fig. 3).
- Climb milling should always be programmed for the best possible surface quality.
- To achieve the optimal surface finish, we suggest using our CMH Series (pp. 63–65). The positive rake and helix of this tool enhance its ability to shear chips, resulting in exceptional performance and an excellent finish.

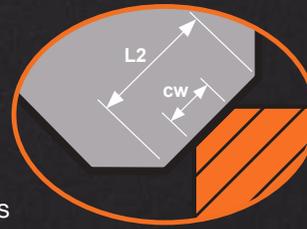


Fig. 1 - Chamfer Saddling

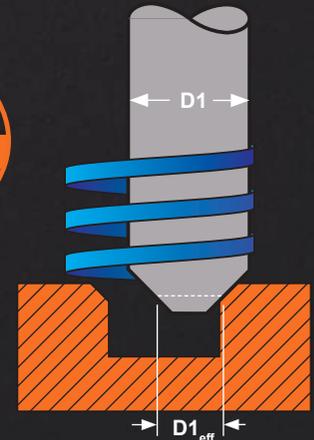


Fig. 2 - Helical Interpolation with our chamfering cutters

Depth of Cut (h)

The amount of material removed with a chamfer mill is usually negligible when producing light countersink features or mild edge deburring. As a result, integrating chip thinning calculations and programmed lateral movement along the cutting edge may increase tool life and prevent tool notching.

However, if you are more heavily beveling with a chamfer cutter, we suggest that you take it in multiple passes based upon your chamfer altitude (h) and the length of the hypotenuse (c), as shown in Fig. 4. Make sure your chamfer mill's length of cut (L1) will cover the length of the hypotenuse (c). Once the altitude is calculated, divide the total height by 10–15% of the tool diameter on 2 and 3 flute tools and 8–10% of the tool diameter on 4 and 5 flute tools to determine the number of passes you will need to employ. The formula for finding the height (h) of a right triangle, as shown in Fig. 4, is $h = a \times b \div c$.

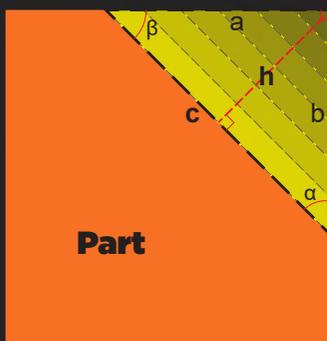


Fig. 4 - Heavy Beveling Strategy

Naturally, the material and its hardness will also need to be considered in this cutting strategy, as they will determine whether to raise or reduce the depth of cut.

The CMH Series has a non-center cutting tip diameter that impacts the length of the cutting edge. To effectively cover a longer edge length with this series, it may be necessary to consider using a bigger diameter tool in order to accommodate the extended bevel length (c).

In order to get optimal results while performing extensive beveling on both non-ferrous and ferrous materials, we suggest using our CMH 2 or 3 flute series (pp. 64–65) for initial roughing of the bevel, followed by the application of our CMH-5 (5 flute) series (found on pages 64–65) to achieve an exceptional finished output. The high performance chamfer mills are made to cut, so please make sure to properly adjust the feed rate accordingly and by leaving enough material for the tooth to get under the material and shear the chip properly. See page 93 for further information on finishing parts.

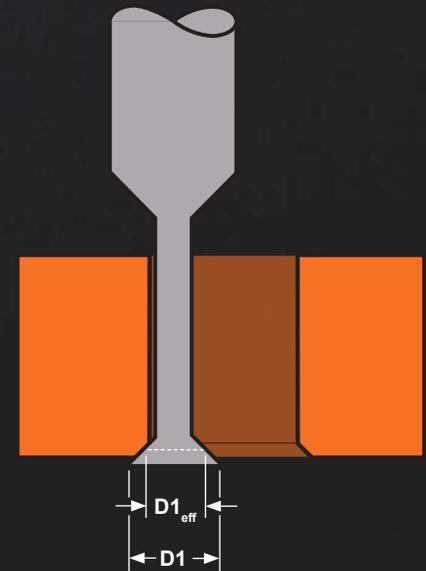


Fig. 3 - Helical Interpolation with a back chamfer tool.

TECHNICAL RESOURCES

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Need addition technical help?



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Please like and follow our social media platforms, which include a new technical series called **DYK** (Did You Know) for continuous technical information, machining tips & tricks, and product updates.



HIGH-PERFORMANCE TOOLING

Essential components of a high-performance cutting tool

While we at Core Cutter are experts in the design, manufacture, and operation of high-performance tooling, we also recognize that our clients depend on us to manufacture the tools so they can easily apply them. Nevertheless, in certain situations, this can be a little unclear, so we want to make sure that every one of our clients are familiar with our tooling journey.

Let's start by providing a concise summary of what we define as a high-performance tool and the features that each Core Cutter product offers.

Raw Material - We are dedicated to offering the highest quality carbide tools on the market. Our unwavering commitment to excellence ensures that we never compromise, even if it requires additional investment in the future. Our track record demonstrates our unwavering commitment to quality. Similar to the way a strong foundation ensures stability and longevity for your house, we exclusively utilize high-quality sub-micro grain substrate for our tools. This ensures that our tools have exceptional durability and a long lifespan, making them ideal for even the most demanding applications.

Edge Prep - When using a new tool, have you ever noticed that it created a loud scream or squeal noise for a few minutes until it settled in and then quieted down? Previously, a machinist would achieve this by rubbing a penny along the cutting edge. However, with the advancement of technology and equipment, we can now apply edge prep and scientific engineering to our tooling, resulting in an improvement in both tool life and performance. Through this technique, the engineered wear land for shortened break-in durations is established. But it also creates the conditions for uniform and steady wear land propagation throughout the life of the tool.

Tool Coating - Surface treatments have made huge strides in the last two decades, enabling a cutting tool to prepare and resist high cutting zone temperatures, avoidance of a built-up edge (BUE), and enjoy a lower coefficient of friction (resulting in better chip evacuation). At Core Cutter, we partner with the leading surface treatment providers, allowing us to keep up with the rapidly changing technology and always striving to bring the best coatings to our customers. Our market-leading coating selections are showing customers extended tool life, tougher edge strength, and durability, along with elevated speeds and feeds.

Geometry - In our field, creating high-performance tool geometry is an art that calls for application knowledge, tool geometry comprehension, and a great deal of 5-axis grinding skill. Good HP tool construction includes appropriate flute design, core strengthening, superior surface treatments, and proper "free cutting" end work that permits proper chip evacuation.

Some notable high-performance tooling attributes

- **Lip Dubbing** - (aka dubbing the lip) This process eliminates the cutting tooth's "hook" and merges it in the direction of the corner radius, resulting in a far stronger cutting edge advantage, as shown in figures 1 and 2.
- **Corner Radius Blending** - The external diameter of the tool must seamlessly integrate with the radius of each tool corner. It is an ability that we can apply with proficiency.

TIP To accurately verify the diameter-to-corner radius blend on a tool equipped with a helix, you must roll the tool to reveal the blend on a comparator.

- **Core Strength** - We employ various methods to strengthen and reinforce the foundation of our tools. Whether it's a heavily designated core diameter or tapered to increase strength as it heads up through the length of cut, we have the expertise to handle it all.
- **Edge Strength**
 - **Ferrous Tooling** - The eccentric OD relief, located posterior to the cutting edge, presents a prominent convex-shaped surface that maximizes the strength of the cutting edge. At Core Cutter, we use it, yet it proves to be the most challenging to manufacture.
 - **Non-Ferrous Tooling** - Our non-ferrous tools feature a cylindrical margin, which contributes to increased stability, reduced chatter, enhanced precision, improved heat dissipation, and the prevention of edge fracture. Following the cylindrical margin will be the O.D. relief, which endows our non-ferrous tooling line with exceptional free-cutting properties.

Thinking of using GP tooling?

It may be cheaper, but it will have a damaging effect on your throughput, which in turn reduces your efficiency and, ultimately, your profitability.

Low-cost general-purpose (GP) tooling has a function, but be ready to deal with any or all of the following:

- Lower MRR
- Shorter Tool Life
- Low Operator Confidence
- Lower Part finish
- Higher Scrap rate
- Random Tool Survivability
- Lower Regrind ROI
- Inconsistent Performance

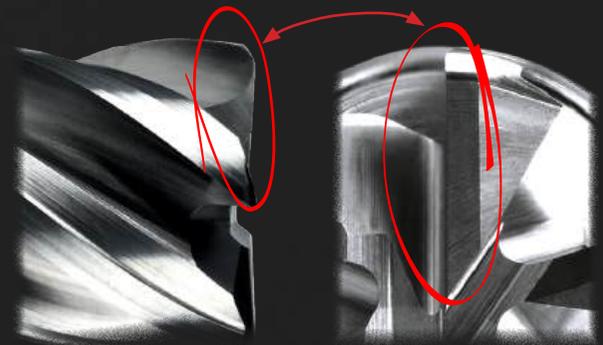
This type of tooling category (aka GP) are commonly manufactured with:

- Always Driven by Low Costing
- Low Cost Raw Material
- Standard 30° Helix
- Non-center cutting
- Limited radii choices
- Pri/Sec "flat" OD grind
- Uncoated or Basic Tool Coatings
- Low or No Corner Strength

It is essential to recognize that, on average, tool expenses constitute just 5–8% of the overall component cost; enhancing throughput will provide a far greater return on investment, while optimizing machine usage relative to tool costs.

Fig. 1 - Dub to Corner

Fig. 2 - Result = less hook and stronger cutting edge



TOOL CALCULATION VAULT

Here are some useful milling formulas that you can apply

The Outcome	Abbr.	Imperial		Metric	
		Units	Formula	Units	Formula
Spindle Speed	n	rev./min.	$(V_c \times 3.82) \div D1$	rev./min.	$(V_c \times 318.3) \div D1_m$
Cutting Speed	V_c	ft./min.	$.262 \times D1 \times n$	m/min.	$.00314 \times D1_m \times n$
Table Feed	V_f	In./min.	$f_z \times Z \times n$	mm/min.	$f_z \times Z \times n$
Feed per Tooth	f_z	Inch	$V_f \div (n \times Z)$	mm	$V_f \div (n \times Z)$
Feed per Revolution	f_n	In./rev.	$V_f \div n$	mm/rev.	$V_f \div n$
Metal Removal Rate <i>(Refer to page 87 for further details.)</i>	MRR	In. ³ /Min.	$a_e \times a_p \times V_f$	cm ³ /Min.	$a_e \times a_p \times V_f$
Radial Chip Thinning <i>(Refer to page 88 for further details.)</i>	f_z (adj)	Inch	$\frac{f_z \times (D1/2)}{\sqrt{(D1 \times a_e) - a_e^2}}$	mm	$\frac{f_z \times (D1_m/2)}{\sqrt{(D1_m \times a_{e(mm)}) - a_{e(mm)}^2}}$
Circular Feed Rate Adjustment <i>(Refer to pages 89-90 for more details.)</i>	V_f (adj)	Inch	$V_f \times (\text{Hole } \emptyset - \text{Tool } \emptyset) \div \text{Hole } \emptyset$	mm	$V_f \times (\text{Hole } \emptyset - \text{Tool } \emptyset) \div \text{Hole } \emptyset$
Ball Nose Effective Dia. <i>(Refer to page 92 for further details.)</i>	D_{eff}	Inch	$D1_{\text{eff}} = 2 \times \sqrt{R^2 - (R - a_p)^2}$	mm	$D1_{\text{eff}} = 2 \times \sqrt{R^2 - (R - a_{p(mm)})^2}$
Floor Finishing <i>(Refer to page 93 for further details.)</i>	a_e	Inch	$a_e = (D1 - (2 \times \text{Tool Corner Radius})) \times .75$	mm	$a_e = (D1 - (2 \times \text{Tool Corner Radius})) \times .75$
Power Requirements <i>(Refer to page 75 for further details.)</i>	HP_m	Hp(l)	$\frac{(MRR/K)}{E}$	Hp(M)	$\frac{(MRR/K)}{E}$

KEY

a _e	Radial Depth of Cut (Inch)	E	Machine Efficiency Factor	n	Revolutions per Minute
a _{e(mm)}	Radial Depth of Cut (Metric)	F _n	Feed per Revolution (in./rev or mm/rev)	R	Tool Cutting Diameter Radius (D/2)
a _p	Axial Depth of Cut	F _z	Feed per Tooth (in. or mm)	V _c	Cutting Speed (SFM for Inch, SMPM for metric)
D1	Tool Cutting Diameter (Inch)	F _{z(adj)}	Feed per Tooth (in. or mm) adjusted for chip thinning	Z	Number of Flutes
D1 _m	Tool Cutting Diameter (Metric)	HP _m	Spindle Est. Horsepower	Ø	Diameter
D _{eff}	Effective Cutting Tool Diameter	K	Workpiece Material Constant		

IT'S NOT JUST THE TOOL

Performance of a tool depends on numerous mechanical interactions

As a consumer, your primary objective should be to procure high-performance tools that exhibit the maximum achievable metal removal rates (MRR) given the unique characteristics of your intended application. Generally, an increased MRR corresponds to greater machine utilization, which subsequently results in increased throughput and, consequently, increased profitability.

Over the past ten years, machine tools have improved in speed, intelligence, robustness, and accuracy, which has allowed for increased performance. However, there are numerous other (non-cutting tool) attributes that affect your ability to maximize MRR when applying cutting tools, which can also limit your material removal achievements.

Everything from the CNC program through the machine and out to the cutting tool is made up of a "symphony of attributes" that must be optimally synchronized to determine its success or not, and you are the conductor!

Here, you'll find well-structured lists of key factors that can have a significant impact on the performance of your tools, even if they aren't directly tied to cutting tools. For more information on these topics, please refer to the technical section of this catalog as it provides comprehensive coverage for better understanding. We acknowledge that you may not have direct control over these factors, but it's crucial to keep in mind that they all contribute to the tool's effectiveness.

Programming Related (Pages 72-73)

- Hierarchy: Program-to-tool
- HEM Options
- G-Code Familiarization
- Centerline Programming



Machine Tool Related (Pages 74-75)

- Spindle Connection
- HP/Torque Curve
- Drive Type
- Guide ways
- Machine History



Tool Holding Related (Pages 76-77)

- Major Aspects of Choosing
- Common Types
- Pull Studs
- Draw-bar Tension

Workpiece Related (Pages 78-83)

- Material Condition
- Material Hardness
- Workpiece Rigidity
- Work - Hardening Ability



IMPORTANCE OF PROGRAMMING

In a milling application, the program is of utmost importance since it is

CNC machining is a traditional subtractive manufacturing technology that shapes metal using a variety of cutting tools. Parts produced by the machining process are often utilized in crucial situations and must be exceedingly exact and precise; yet, in order for the machine tool to conduct any action, it is completely directed by the use of a CNC program.

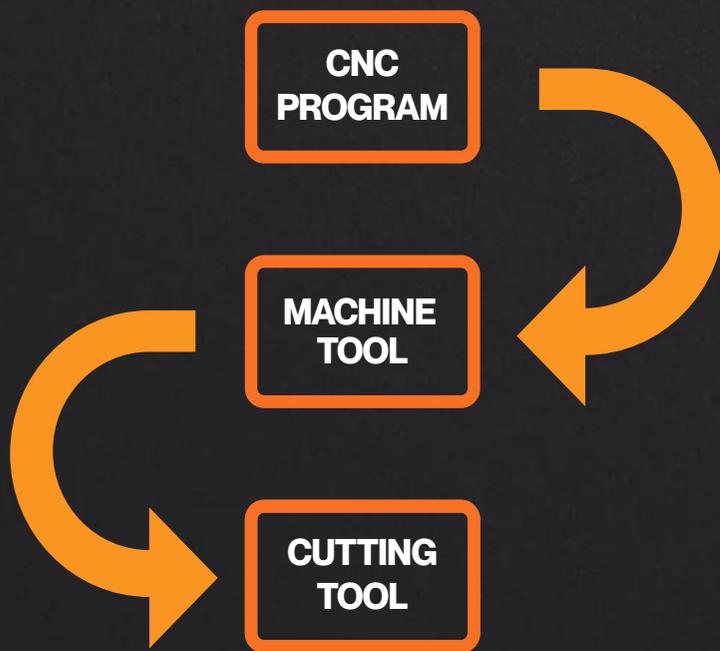


Fig. 1 - Program-to-Tool Hierarchy

Now that we've established the program-to-tool hierarchy (Fig. 1), let's look more closely at what a good set of instructions looks for and understands in general, even if we're not all programmers.

Knowing whether your CAM software permits dynamic control of feeds and rates under all conditions to ensure a consistent chip load during the cut is critical information for programming, efficiency, and maintaining our productivity focus (as measured by MRR). Should this be the situation, it will be imperative that we acquaint ourselves with and implement the optimized tool path (HEM) during our roughing operation (Fig. 2) if appropriate. The objective is to expedite the removal of material while minimizing the cycle time producing the component.

Following are some of the most popular questions about rough milling with this HEM method. For more information on this subject, please see pages 84–86.

- Does my CAM system include an HEM solution?
- Can this kind of strategy be handled by my CNC machine?
- Does this kind of HEM approach work with the design of my part?
- Will I need to purchase brand-new tool holders?
- Does it require the priciest tools to use this strategy?
- Would I keep using the large diameter tooling I use now?

CNC Program Instructs

Writing a set of instructions, known as CNC programming or G-code, describes the operations that a CNC machine will perform. In other words, the CNC program informs the machine tool what to do, where to go, and how quickly to go.

Machine Tool Follows Instruction

Today's production demands require extremely accurate CNC machine tools, yet without some kind of programmed instruction to tell them what to perform, the machines are useless on their own.

Cutting Tools Are Merely a Passenger

The sizes, shapes, materials, and construction of high-quality cutting tools for CNC operations are virtually limitless; nonetheless, the programming ultimately dictates the tool's location, speed, and timing of operation.

F AUTODESK
Fusion 360

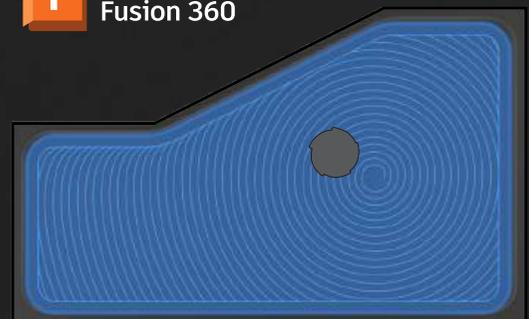


Fig. 2 - HEM Tool Path Example (Shown, is the adaptive clearing tool path generated by Autodesk® Fusion 360™)

IMPORTANCE OF PROGRAMMING (Cont.)

responsible for transmitting all the instructions to the machine tool.

Here's a very simple example of a 1/4" endmill and its related programming code (Fig. 4). You'll undoubtedly hear the phrase "speeds-n-feeds" as you work your way through different CNC tasks, and it turns out that this is one of the most crucial elements (for the tool) to get correctly.

Understanding the motions and instructions for the cutting tool is critical when the program is operating (simulated or real). On the opposite page, we discussed the program-to-tool hierarchy and said that the tool is obligated to perform what the program or machine instructs it to do. However, the controllables here are speed, feed, and suitable cut depths, which can all be programmed by you (or the programming department) - remember, you are the **conductor!**

Throughout this catalog, we provide beginning speed, feed, and radial depth of cut recommendations; each is located at the conclusion of each tool section. For your convenience, we have included a fast reference below.

- Roughing see pp. 23-24
- Miniature Tooling see pp. 29-30
- Non-Ferrous Tooling see pp. 42-43
- Ferrous Tooling see pp. 58-59
- Chamfer Milling see pp. 66-67

Programming Type - The tool is typically programmed along its centerline (Fig. 3); this practice is acceptable, but it is important to be mindful of it.

This is not inherently a negative thing, but be advised that it could lead to the tool being operated at an incorrect feed rate where it matters most—on its peripheral edge.

This becomes particularly important when the tool is cornering, as the heightened engagement angle leads to greater surface contact at an inappropriate feed rate.

Subsequently, you can read and learn more about this specific topic on pages 88-90 of this catalog.

Run 1/4" endmill at 9,200 rpms. In G Code, usually preceded with an "S"

Table feed of 18 IPM noted, usually preceded with a "F"

Cutter Comp with table feed adjustment to 36 IPM

An Example of a Basic Program

%	Start of Program
00001 (PROJECT1)	Program Number, Program Name, Programmer Name, Date, and Machine Tool
(T1 0.25 END MILL)	Tool description
N1 G17 G20 G40 G49 G80 G90	Safety block to ensure machine is in safe mode.G17 plane selection, imperial/metric, G40 Cutter compensation cancel, cancel tool length offset,G80 Canned cycle cancel, G90 absolute positioning mode
N2 T1 M6	Load Tool #1.
N3 S9200 M3	Spindle Speed 9200 RPM, On CW.
N4 G54	Use Fixture Offset #1.
N5 M8	Coolant On.
N6 G00 X-0.025 Y-0.275	Rapid above part.
N7 G43 Z1. H1	Rapid to safe plane, use Tool Length Offset #1.
N8 Z0.1	Rapid to feed plane.
N9 G01 Z-0.1 F18.	Line move to cutting depth at 18 FPM.
N10 G41 Y0.1 D1 F36.	CDC Left, Lead in line, Dia. Offset #1, 36 IPM.
N11 Y2.025	Line move.
N12 X2.025	Line move.
N13 Y-0.025	Line move.
N14 X-0.025	Line move.
N15 G40 X-0.4	Turn CDC off with lead-out move.
N16 G00 Z1	Rapid to safe plane.
N17 M5	Spindle Off.
N18 M9	Coolant Off.

Fig. 3 - Tool Programming Options



Fig. 4 - A simple program Courtesy of AUTODESK®

MACHINE TOOL RELEVANCE

In addition to increasing your chances of success, mastery of your

We have seen the whole range of machine tools in action as one of the leading providers of cutting tools for subtractive machining today. Naturally, it keeps us attentive, but it has also assisted us in understanding the differences and critical information to investigate so that, if an application has to be troubleshooted, we can do it.

The CNC machine tool sector is diverse in terms of size, form, and capacity, which explains why we encounter so many questions while engaging with and/or troubleshooting an application with our customers. We had to learn and adapt to a wide range of equipment, as well as their condition.

As previously stated on page 72, the machine tool runs in line with the program's instructions. These complicated devices, propelled by a sophisticated internal computer system, are designed to work at optimum efficiency, precision, and consistency. Given the importance of this to the success of our cutting tools and the ultimate objective of maximizing your MRR, we feel obligated to share our knowledge and understanding of CNC machine tools with our users—even if just to raise awareness.

To begin, let us examine—or at least appreciate—the following critical elements of your CNC machine tool that may have a direct impact on the cutting tool's success:



Spindle Connection(s) - When preparing to use carbide tooling, it is a good idea to take into account the spindle sizes and connections you are utilizing. Even though the spindle connection on an operational machine is predetermined, it's an important feature to understand.



Generally speaking, the market is divided into two main types of connections: the traditional **Steep Taper** (7:24 Taper Ratio) connection and the more recent **HSK** (1:10 Taper Ratio) connection.

We will start with the widely used Steep Taper, also known as V-Flange, which can come in both single contact and dual contact designs. The main purpose of this connection is to provide a tapered surface area of contact between the tool holder and spindle, as shown by the green line in Figure 1. The tool holder must fulfill two crucial tasks simultaneously: firstly, it must precisely determine

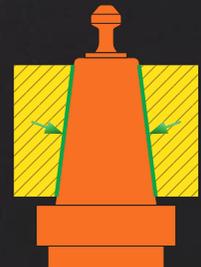


Fig. 1 - Steep Taper

the position of the tool holder in relation to the spindle, and secondly, it must establish a strong and exclusive contact between the spindle and the tool holder to securely keep the tool holder in place. Reason why it is so important to keep the internal and external tapers both clean and free of damage, pitting, and debris.

The green line in figures 1 and 2 represent locations of contact. Figure 1 clearly shows a solitary 360° taper contact, whereas the flange face lacks any contact. Figure 2 illustrates two separate contact regions: the 360° taper contact in addition to the 360° flange face contact. The contact regions significantly improves the rigidity and stiffness of this dual-contact system. Dual contact holders are easily accessible and strongly endorsed by us, our distributor partners can help you with the proper tool holder you may need.

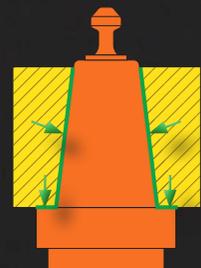


Fig. 2 - Steep Taper w/ Dual Contact

Tool Diameter Guidelines for Steep Taper Connections

Taper Size	30	40	50
Tool Dia. Suggestions	≤ .500 Tool Diameter	≤ .750 Tool Diameter	No Diameter Restrictions

MACHINE TOOL RELEVANCE (Cont.)

machine tool grants you unlimited access to additional superpowers!

HSK Taper (ISO 12164/DIN 69893/ASME B5.62): Translation: "hollow shank-taper" Hohl Sahft Kegel is a German design that was created in response to the need for tool holders that could match the productivity of modern machine tools, provide superior rigidity and repeatability at aggressive cutting parameters, and secure tools with more force and consistency (resulting in improved MRR).

The increased contact area (vs. V-flanged) and dual contact of the HSK provide a much stiffer and a more rigid design can result in better tool life, part accuracy, and often an improved surface finish.

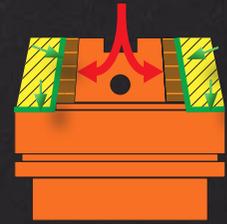


Fig. 3 - HSK Taper

Taper Call out	HSK-25	HSK-32	HSK-40	HSK-50	HSK-63	HSK-80	HSK-100	HSK-125	HSK-160
Taper Size (D)	25mm	32mm	40mm	50mm	63mm	80mm	100mm	125mm	160mm

TIP For optimal contact & performance, the tapers on either connection styles covered in this section must be free of chatter marks, pitting, dirt, and oil. There are inexpensive taper cleaning tools for less than \$100 that can give you a good piece of mind!

Spindle Condition: The state of the CNC machine tool spindle is important for the overall efficiency and accuracy of machining operations. The spindle is a pivotal element responsible for securely gripping and rotating the cutting tool, exerting direct influence on crucial parameters such as speed, precision, and surface quality. Ensuring the spindle's condition is monitored and maintained is crucial for achieving efficient and dependable machining.

The HP and torque curves: Your machine may not have 25 horsepower across the whole RPM envelope, even though its pasted with a big **25HP** on the front panel. There is a specific area in the RPM range where the stated maximum torque is reached. It is wise to know where your peak torque regions (Fig. 4) are, allowing you to use the tool at its optimal speed and preventing the machine from possibly stalling during heavy traditional milling operations. These curve charts are usually found and provided within your machine manual.

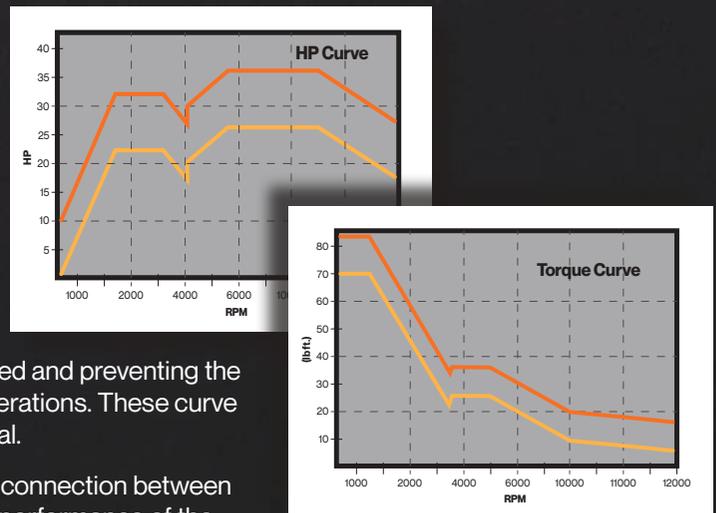


Fig. 4 - Machine Tool HP & Torque Curves

Direct Drive, Gear Driven, or Belt Driven: The connection between the motor and spindle is a crucial factor that directly impacts the performance of the machining process. Direct drive systems stand out for having fewer components, which results in lower power losses, less backlash, and more positioning control. Gear-driven spindles are considered high-efficiency because they excel at transferring power efficiently, adjusting speed, and operating over a wide range of speeds. Conventional machines used belt drives, which might provide some help with dampening, yet they produced decreased efficiency (power loss) owing to friction and a limited capacity to handle higher torque situations.

Linear or Box Ways: The design of the guide way on your machine tool is very important because they serve as the structural support and guidance system for the movement of the workpiece. The options are usually a box-way (Fig. 5) or a linear-guide (Fig. 6) machine (a mix of the two is employed occasionally), and each has advantages and disadvantages. Of the two, the box ways that are commonly mentioned have a higher load capacity, are heavier duty, and offer some significant damping benefits. Faster and more precise positioning, faster acceleration and deceleration rates, and extremely tight positional precision are all made possible by linear guides and excellent for HEM machining (Further details on pages 84-86).

Machine Tool History: Insight into any past or present issues with your shop's machine tools, especially the chosen CNC machine, should not be disregarded. At times, these issues may evade detection and disrupt the implementation of suitable cutting tool troubleshooting methodologies. Kindly inform us if the machine tool has had any recent challenges; this will facilitate more efficient troubleshooting.



Fig. 5 - Box Way

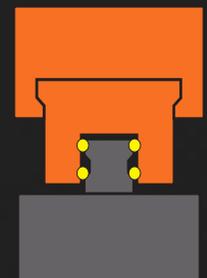


Fig. 6 - Linear Guides

SIGNIFICANCE OF TOOL HOLDING

Tool holding is indeed a crucial aspect of machining setups that can signifi-

As a top cutting tool provider, we must know, understand, and help our customers choose the right tool holding solution since it is a big piece of the puzzle. CNC tool holders must firmly secure cutting tools accurately with little run out—it counts folks!

As the final point of mechanical contact between our tool and the machine, the right tool holder is vital to tool performance and life. We utilize tool holders most of our clients have on hand, but broken, incorrect, or antiquated units might be an issue. While we agree the expense of replacement can be substantial, we have to ask, "What is the opportunity loss or cost" of not utilizing a superior one?

Regular inspection, qualification, and/or replacement of worn-out tool holders and tool holder components (such as collets, collet nuts, etc.) is recommended. Although the tool holder may endure a great deal of usage (with the right maintenance), it does have a finite lifespan and will progressively lose precision, strength, and reliability as time goes on



What features should a good tool holder have, if you ask us?

- **Full-Shank Clamping Force:** We prefer full concentric shank contact with high gripping force when we can get it.
- **Low Run-out:** An extremely crucial factor in this situation is that the holder must be as accurate and generate as little runout as possible roughly 10% of tool life is lost for every .0001 in the indicated runout.
- **Rigidity:** The tool desperately requires rigidity in order to enhance its efficacy and achieve its ultimate goal of maximizing MRR.
- **Versatility:** There are some great rigid-and-accurate tool holders that are "sleevable" to accommodate many different shank diameters while still giving you full shank contact.



Side-Lock: holders are used in heavy machining operations, providing a more secure grip for cutting tools compared to collets. However, it is necessary to utilize tools that have a pre-ground Weldon flat. The position, exactness, and correctness of the flat surface on the tool determine the amount of deviation and alignment of the tool-to-holder. We can provide the factory ground flat on any of our tooling in order to ensure optimal performance. Additional weldon flat details can be found on page 5.



Collet Systems: Collet systems are extensively accessible and highly favored in workshop settings, mostly because of their cost-effectiveness and adaptability to various shank diameters. Although they exhibit considerable adaptability and little runout, their partial shank contact restricts gripping power, while correct torquing and cleaning remain problematic in this category. Recent advancements, such as bearing nuts and reduced clamping angles, have significantly contributed to improvements.



Hydraulic: Hydraulic holders, unlike conventional tool holding systems such as collet chucks and end mill holds, use pressurized hydraulic fluid to encase a bladder around the tool shank. Upon engagement of the adjustment screw, the fluid activates, sealing the tool holder's bore and securely retaining the tool. This category often exhibits a pronounced response to axial cutting pressure as opposed to excessive radial cutting pressures. Additionally, the hydraulic fluid that supports the cutting tool acts as a vibration dampener, therefore reducing chatter and vibration throughout the machining process.



Milling Chuck: Their high tool shank retention force, low runout, and low maintenance make them an excellent choice for heavy machining, despite the fact that their nose diameters can be a bit of a constrictor in confined spaces. Typically, these employ a tapered bearing concept, where tightening the nut triggers the needle bearing cage to move axially along a tapered cone, generating a very powerful clamping force. You can sleeve these down from the main bore diameter to accommodate a wide range of tool sizes, thereby increasing their versatility.



Shrink Fit: There is no clamping system that can match the grip, concentricity, and performance of a shrink-fit interface. Shrink-fit tool holders have a bore that is actually too small for the shank to fit, but when heated to several hundred degrees, the bore expands and allows the cutting tool shank to fit in the bore. After the cutting tool is inserted, the tool holder cools around the shank, and the two components virtually become one piece. Additionally, nose diameters can be extremely thin, allowing you to machine difficult-to-reach areas.

We are a fully licensed Haimer Safe-Lock® Shank provider, and we can help you with this solution!

SIGNIFICANCE OF TOOL HOLDING (Cont.)

cantly impact the performance, accuracy and proper execution of the tool.

Retention Knobs (aka Pull Stud): The least noticeable (but extremely critical) component of the tool holder is the retention knob, also referred to as a pull stud (Fig. 1). It connects the tool holder to the machine (via a draw bar) and is strong, even under heavy pulling loads and frequent use, but if it wears out or is the wrong style for your machine tool, problems will occur. It is good practice to make sure you are using the right retention knob for your machine and to regularly check for any signs of fatigue it may be exhibiting.

While regularly inspecting and evaluating your retention knobs, please look for?

- The correct style matched for your machine spindle.
- Inspect for thread fatigue, cracking, or stretching.
- Straightness or concentricity of the neck.
- Deformation of crown radii and/or angles.
- Fretting, denting, and/or any flattening evidence

TIP | Depending on the frequency of use, retention knobs should be replaced every 1-2 years at a minimum and inspected for damage regularly.



Fig. 1 - Retention Knob

Draw bar Tension (force): The draw bar on a machine tool spindle provides the sufficient force that holds the tool and tool holder assembly in place (through the use of a Belleville washer stack) when the spindle rotates, preventing centrifugal forces from opening it up. The draw bar force varies by spindle manufacturer, but below is a chart to help you understand the forces your draw bar experiences regularly.

Steep Taper Draw bars	
BT30	1,200 ft. lbs.
CV40/BT40	2,300 ft. lbs.
CV50/BT50	5,000 ft. lbs.
CV60	13,000 ft. lbs.

HSK-ISO 12164-1 Draw bars	
HSK32 A/C	1,120 ft. lbs.
HSK40 A/C	1,530 ft. lbs.
HSK50 A/C	2,470 ft. lbs.
HSK63 A/C	4,050 ft. lbs.
HSK80 A/C	6,290 ft. lbs.
HSK100 A/C	10,120 ft. lbs.
HSK125 A/C	15,740 ft. lbs.

It is important to detect (early) a reduced clamping force and to replace a worn stack of Belleville washers before spindle damage occurs. Draw bar dynamometers are affordable, easy to use, and can quickly detect serious problems before damage occurs.

TIP | Draw bar force should be checked and recorded every few months or so.

The key for the features numbered on figures 2 & 3 are listed below:

- 1. Belleville Washer Stack:** Lubricate, inspect, and check force periodically with a draw bar dynamometer.
- 2. Gripper or Retention Balls:** Imagine how many cycles these have to open and close day after day. Give the pull stud a bit of grease to help reduce the drag and extend the life of these features.
- 3. Tool Holder:** Check the taper regularly for cleanliness, fretting, and damage, if any.
- 4. Machine Tool Taper:** clean (spindle wiping tools are very inexpensive) and inspect regularly; if needed and the spindle is in good shape, on site spindle taper regrinding can be done.

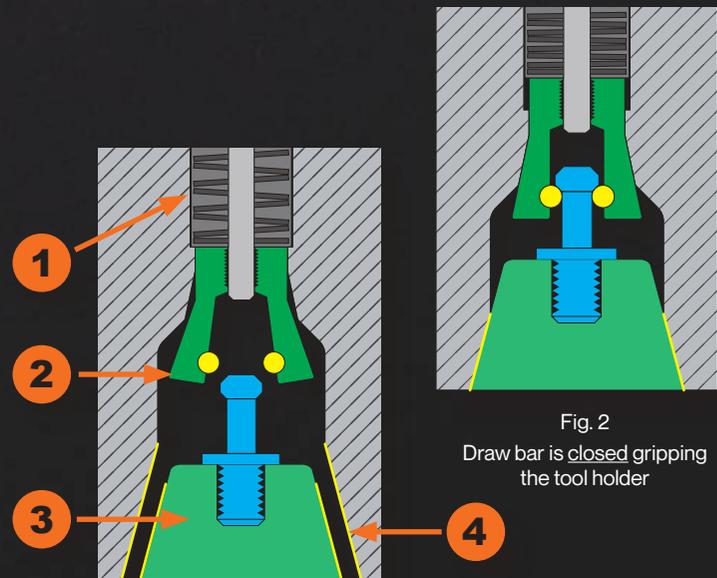


Fig. 3
Draw bar is open and releasing tool holder

Fig. 2
Draw bar is closed gripping the tool holder

MATERIAL KNOWLEDGE

Being familiar with your media enables you to approach it with assurance!

A thorough understanding of the properties of the material you are machining will enable you to better tailor your program strategy, tooling, speeds, and feeds to address its demands. While many industries use steel, cast iron, and aluminum, those in the aerospace, defense, or medical sectors likely deal with difficult metals on a regular basis: titanium, heat-resistant nickel alloys, stainless steel, and other resilient and high-tensile strength materials that are well-known for their difficulty to machine. If the material is developed to withstand high temperatures, deformation, and/or corrosion, it is probably tough to machine.

Here are some important material factors that you need to know before you start making your part!

Material Composition: Materials can have their composition altered, and specific uses can be achieved by adding different alloys. For example, alloy steel is a steel type that has been strengthened and hardened through the addition of elements like molybdenum (Mo), manganese (Mn), nickel (Ni), chromium (Cr), vanadium (V), silicon (Si), and boron (B). Stainless steel, on the other hand, starts off as a low or medium alloy steel and is further enhanced with corrosion-resistant elements like chromium (Cr) and nickel (Ni), which make it extremely abrasive for tooling but confer superior corrosion resistance to stainless steel.

Material Hardness: It is best to confirm and check the material yourself rather than taking the part print call-out for granted. Researching and understanding your material condition, makeup, and hardness is critical to proceeding and dialing in your cutting tools. The hardness of the part is typically reflected on the part print, but we have experience where the material comes in a different hardness than the print actually calls out.

The most common material-hardness abbreviations we come across in our business are:

- **HRA** = Rockwell "A" Hardness
- **HRC** = Rockwell "C" Hardness
- **HRB** = Rockwell "B" Hardness
- **HB** = Brinell Hardness

TIP A material hardness & tensile strength chart can be found on page 100 of this catalog.

Material Condition: We have come across a variety of states that can affect cutting strategies, some of which are as follows: Annealed, Quenched and Tempered, Hot Rolled, Cold Rolled, Casting, and Forging (the last having a quality that makes the material much denser and can be more taxing on a cutting tool). Each different condition has its own set of challenges that may necessitate different approaches to machining, as well as different feeds and speeds for cutting.

TIP It is suggested to "conventionally mill" the raw material to remove surface scale and then return to climbing milling. Instead of hammering down on the crust as with climb milling, it will let the cutting teeth work their way up through it.

Work-Hardenability: If the material you are working with contains elements such as silicon, manganese, nickel, chromium, and molybdenum, problems could arise the longer you stay in the cut! The degree of hardening depends on the amount of heat generated during the cutting action as well as the properties of the material, such as its carbon content and other alloying elements! So what to do? Ensure your tools are sharp, do not dwell in place, use coolant-fed tooling when possible, and keep feed rates optimal to get in and out of cut quickly.

Machinability Factor: Generally speaking, machinability is influenced by a wide range of factors, such as the hardness of the material, feeds, speeds, cutting fluids, rigidity of the tool holding device, micro structure, grain size, heat treatment condition, chemical composition, fabrication methods, hardness, yield, and tensile strength of the work piece. These relative ratings, also known as "machinability ratings" found on page 82, indicate a general ranking based on a scale of difficulty.

Thermal Conductivity: The temperature of the cutting edges rises and falls periodically when the teeth of a milling cutter enter and exit the workpiece material. The heat generated by metal cutting is absorbed by the components of the machining system; generally, 10 percent of the heat infuses the workpiece, 80 percent of the heat goes into the cut chips, and 10 percent of the heat goes into the tool. It is ideal for the chips to absorb the majority of the heat, as high temperatures can damage the tool and shorten its useful life.



PERIODIC TABLE OF ELEMENTS

Knowing the correct composition of your materials can help you achieve success.

atomic number → 26 ← oxidation states (most common)
 chemical symbol → Fe ← radioactive elements
 name → Iron
 atomic mass → 55.845

actinoids
 lanthanoids

 nonmetals
 alkali earth metals
 metalloids
 halogens
 lanthanoids
 alkali metals
 transition metals
 post-transition metals
 noble gases
 actinoids

Carbon is one of the most important & common elements to take into consideration while analyzing our materials and their capacity for heating and shaping. Individually, it possesses little strength and is easily malleable. However, when combined with steel, it enhances the steel's hardness, tensile strength, and ability to withstand deterioration. The carbon content is the defining characteristic that classifies carbon steel as low, medium, or high carbon.

Low carbon steel has a maximum carbon content of 0.25%, medium carbon steel is between 0.25-0.5%, and high carbon steel is between 0.5 and 1.25%. Carbon steel has a maximum carbon concentration of 2%, above that refers to a carbon-iron alloy called cast iron.

It is important to consider this carbon amount in your material while you are planning and assembling your application strategy, as it can verify your material's suitability for heat treatment and determine if you are dealing with a case-hardened or fully hardened situation. Your material's carbon content has a direct impact on its hardening ability.

Case Harden Ability <.3% (C) Full Hardenability >.3% (C)

Additionally, the two most notable alloys that we find having the most significant influence on tool life are:

(Cr) Chromium: In terms of hardness, this fourth transition metal on the periodic table ranks third, just after carbon (diamond) and boron. Used to increase the corrosion resistance, tensile strength, and high temperature strength of steels, particularly stainless steel. Cutting tool life is reduced, and cutting edge degradation is increased, despite the fact that it aids steel. So, to address its properties, it is necessary to use a submicrograin carbide substrate, a high-quality tool coating, edge prep, and cutting parameters that are respectful of its characteristics (i.e., speed can kill in this highly abrasive alloy).

(N) Nickel: Ranked as the fifth most abundant element on earth, its primary use is in the process of alloying, especially in combination with chromium and other metals, to create stainless and heat-resistant steels. The element greatly resists corrosion even at its highest temperatures, not to mention its ability to increase strength as well as resistance to heat and oxidation. A very key element that also wrecks havoc on cutting tools if not applied correctly. The material hardens as you machine it, so the key is to get in and out as quickly (within reason) as possible. The addition of nickel to any material as an alloy that seriously decreases its machinability factor, as seen within the machinability factor chart on p. 82.

STEEL GROUP INFORMATION

Let's look into the common steel designations, compositions and grades.

A universal numbering system classifies machined materials. Combining AISI and SAE languages (SAE J1086: Numbering Metals and Alloys) in 1995 created a standardized alloy numbering system. Since the standards were unified, call outs like AISI 4340, SAE 4340, and 4340 are often used and equivalent generally speaking (more important is the component print call out specifying the exact ASTM material specification).

AISI/SAE Steel Grades - Below is a table of AISI material grades that explains the type of steel that each four-digit number represents and the requirements that go along with it.

- **1xxx** - Carbon Steel
- **2xxx** - Nickel Steel
- **3xxx** - Nickel Chromium Steel
- **4xxx** - Molybdenum Steel
- **5xxx** - Chromium Steel
- **6xxx** - Chromium Vanadium Steel
- **7xxx** - Tungsten Steel
- **8xxx** - Nickel Chromium Vanadium Steel
- **9xxx** - Silicon Manganese Steel

1018
Series Identifier Amount (%) of Carbon Present (# × .01)

AISI Steel	Code	Specification
Carbon Steel	10XX	Plain carbon steel, Mn 1.00% max
	11XX	Resulfurized free cutting
	12XX	Resulfurized - Rephosphorized free cutting
	15XX	Resulfurized - Plain carbon steel, Mn 1.00-1.65%
Manganese Steel	13XX	Mn 1.75%
Nickel Steel	23XX	Ni 3.50%
	25XX	Ni 5.00%
Nickel Chromium Steel	31XX	Ni 1.25%, Cr 0.65-0.80%
	32XX	Ni 1.75%, Cr 1.07%
	33XX	Ni 3.50%, Cr 1.50-1.57%
	34XX	Ni 3.00%, Cr 0.77%
Molybdenum Steel	40XX	Mo 0.20-0.25%
	41XX	Mo 0.40-0.52%
Chromium Molybdenum Steel	41XX	Cr 0.50-0.95%, Mo 0.12-0.30%
	43XX	Ni 1.82%, Cr 0.50-0.80%, Mo 0.25%
Nickel Chromium Molybdenum Steel	47XX	Ni 1.05%, Cr 0.45%, Mo 0.20-0.35%
Nickel Molybdenum Steel	46XX	Ni 0.85-1.82%, Mo 0.20-0.25%
	48XX	Ni 3.50%, Mo 0.25%
Nickel Chromium Molybdenum Steel	93XX	Ni 3.25%, Cr 1.20%, Mo 0.12%
	94XX	Ni 0.45%, Cr 0.40%, Mo 0.12%
	97XX	Ni 0.55%, Cr 0.20%, Mo 0.20%
	98XX	Ni 1.00%, Cr 0.80%, Mo 0.25%

AISI Steel	Code	Specification
Chromium Steel	50XX	Cr 0.27-0.65%
	51XX	Cr 0.80-1.05%
	50XXX	Cr 0.50%, C 1.00% min
	51XXX	Cr 1.02%, C 1.00% min
	52XXX	Cr 1.45%, C 1.00% min
Chromium Vanadium	61XX	Cr 0.60-0.95%, V 0.10-0.15%
Tungsten Chromium Steel	72XX	W 1.75%, Cr 0.75%
Nickel Chromium Molybdenum Steel	81XX	Ni 0.30%, Cr 0.40%, Mo 0.12%
	86XX	Ni 0.55%, Cr 0.50%, Mo 0.20%
	87XX	Ni 0.55%, Cr 0.50%, Mo 0.25%
	88XX	Ni 0.55% Cr 0.50% Mo 0.35%
Silicon Manganese Steel	92XX	Si 1.40-2.00%, Mn 0.65-0.85% Cr 0.65%
Nickel Chromium Molybdenum Steel	93XX	Ni 3.25%, Cr 1.20%, Mo 0.12%
	94XX	Ni 0.45%, Cr 0.40%, Mo 0.12%
	97XX	Ni 0.55%, Cr 0.20%, Mo 0.20%
	98XX	Ni 1.00%, Cr 0.80%, Mo 0.25%
Nickel Chromium Molybdenum Steel	93XX	Ni 3.25%, Cr 1.20%, Mo 0.12%
	94XX	Ni 0.45%, Cr 0.40%, Mo 0.12%
	97XX	Ni 0.55%, Cr 0.20%, Mo 0.20%
	98XX	Ni 1.00%, Cr 0.80%, Mo 0.25%

TIP The "L" in carbon and alloy steel designations typically stands for the addition of .15-.35% lead for machining, however, in stainless steel such as 304L, indicates that carbon content is limited to 0.03 percent. Remember, while higher carbon content generally improves hardness and wear resistance, it may also make the material more challenging to machine.

AISI Stainless Steel Material Grades

Stainless steel is available in five distinct classifications: austenitic, ferritic, martensitic, duplex, and precipitation hardening. The names are derived from the crystal structure of the steels, which provides insights into their behavior throughout metalworking processes.

- **Austenitic (303, 304, 316, 347):** Chromium-Nickel alloys, with 304 being one of the most popular, holding 18% chromium and 8% nickel make-up and one of the more prevalent being used. However, the group also includes 316, which has 16% to 18% chromium, making it great for places where corrosion is a problem but much harder to machine. They are not fully hardened (with such a low carbon content) by heat treatment and are nonmagnetic.
- **Ferritic (405, 430, 444, 447):** The amount of chromium in ferritic chromium metals ranges from 10.5% to 30%, with 447 having the most chromium. Like martensitic stainless steel, they do not have any nickel alloys, making them very resistant to corrosion but less easy to weld and harden in cold temperatures. They are not fully hardenable (with such a low carbon content) by heat treatment, but they are magnetic due to their large iron content (Fe).
- **Martensitic (410, 416, 420, 440C):** They were mainly made to meet the needs for hardness, high strength, resistance to wear, and resistance to corrosion. Also, they are ferromagnetic, which means they can keep being magnetic even when the magnetic field is taken away. In contrast to ferritic and austenitic stainless steels, these can be hardened by case hardening; however, the 440 series can be fully hardened because it contains between 60 and 1.20% carbon. The letter designation in the 440 series determines the following: 440A =.60-.75% carbon, 440B =.75-.95% carbon, and 440C =.95-1.20% carbon.
- **Duplex (S31803, S32205):** The duplex (Austenitic-Ferritic) micro structure contributes to this family's high strength and high resistance to stress, corrosion cracking mechanically due to their high chromium levels (18-28%) and sufficient levels of nickel (1-25%) and contain a very low amount (<.04%) of carbon. This group can be more difficult to machine due to its higher hardness and corrosion resistance.
- **Precipitation Hardened (15-5 ph, 13-8 ph, 17-4 ph):** When modified, martensitic precipitation-hardening stainless steels have an austenitic structure, but when they cool to room temperature, they change to a martensitic structure. Grades 17-4 (17% chromium, 4% nickel), 13-8 (13% chromium, 8% nickel), and 15-5 (15% nickel, 17% chromium), with carbon contents ranging between .03 and .12%. The H900, H1025, and H1150 designations are common aging-hardening conditions that represent the temperature at which they age for a certain time period.

TIP Here are some common SS heat treat conditions: **H900(44HRC), H925(42HRC), H1025(38HRC), H1075(HRC36), H1100(HRC35), H1150(33HRC)**

Maraging Steel (Grade 200, 250, 300, 350)

These are double vacuum melted alloys that are very low in carbon and high in nickel and are known for having a micro structure that is both flexible and strong by containing iron, 18% nickel, cobalt, molybdenum, titanium, and other elements. The name comes from **MAR**tensitic and **AGE**ing (a precipitation hardening process) that makes this category very tough, relatively soft and readily machined.

304L
Series Identifier Letter "L" signifies a limited carbon content

13-8
13% Chromium Content 8% Nickel Content

H900
Target Temperature

Stands for Hardening

SUPER-ALLOY INFORMATION

Super-alloys, are some of the toughest materials we see in our market.

The cutting of nickel-based super-alloys is challenging due to their remarkable resilience to high temperatures, hardness, and propensity to increase in hardness throughout the cutting process. Having knowledge of notable alloys is the initial step (as shown below in the charts), and as you can see, it is common to observe higher levels of nickel, chromium, and cobalt. These elements can negatively impact the lifespan of tooling and need to be taken into serious consideration when applying a tool, programming strategy, and cutting parameters.

As previously stated, these materials undergo significant work hardening during machining. Therefore, it is crucial to maintain appropriate feed rates and depths of cut; additionally, it is advisable to aim for minimizing your time spent in-cut. It is necessary to adjust the surface feet per minute and, if possible, make use of high-pressure coolant, as re-cutting super-alloy chips (that are not forgiving at all) have the ability to bind, chip, or even fracture the tool.



Let's look at the four main super-alloy grouped families, along with their notable alloys (sorted by dominant alloy amount).

Nickel Based

Udimet 188	(Ni) 24%, (Cr) 24%, (W) 16%
Inconel 617	(Ni) 44.5%, (Cr) 24%, (Co) 15%, (Mo) 10%
Incoloy 925	(Ni) 46%, (Cr) 22.5%
Incoloy 825	(Ni) 46%, (Cr) 23.5%, (Fe) 22%
Waspaloy AMS 5708	(Ni) 50.6%, (Cr) 21%, (Co) 15%
Waspaloy AMS 5706	(Ni) 51.6%, (Cr) 21%, (Co) 15%
Hastelloy C22	(Ni) 53%, (Cr) 22%, (Mo) 14.5%
Nimonic 263	(Ni) 54%, (Cr) 21%, (Co) 21%
Inconel 718	(Ni) 55%, (Cr) 21%
Hastelloy C276	(Ni) 57%, (Cr) 15.5%, (Mo) 16%
Udimet X-720	(Ni) 57%, (Cr) 16.5%, (Co) 15.5%
Haynes 230	(Ni) 57%, (Cr) 22%, (W) 14%
C276	(Ni) 58%, (Cr) 16%, (Mo) 16.5%
Inconel 625	(Ni) 58%, (Cr) 23%, (Mo) 10%
Rene 77	(Ni) 58.4%, (Cr) 14.6%, (Co) 15%
Mar-M-247	(Ni) 60%, (Co) 10%, (Cr) 8%
Nimonic 80A	(Ni) 67%, (Cr) 21%, (Ti) 2.7%

Iron Based

RA330	(Fe) 40%, (Ni) 34%-37%, (Cr) 18%-20%
Kovar 29	(Fe) 53%, (Ni) 29%, (Co) 17%
Incoloy 800	(Fe) 53%, (Ni) 30%-35%, (Cr) 19%-23%
Invar 36	(Fe) 64%, (Ni) 36%
Fecralloy	(Fe) 73%, (Cr) 20%-22%
A286	(Fe) 73%, (Ni) 24%-27% (Cr) 13.5%-16%

Cobalt Based

Haynes 188	(Co) 39%, (Cr) 22%, (Ni) 22%, (W) 14%
Tribaloy T-800	(Co) 44.5%, (Cr) 18.5%, (Mo) 30%
Stellite 6B	(Co) 50%, (Cr) 32%, (W) 5.5%, (Ni) 3%
Haynes 25	(Co) 51%, (Cr) 20%, (Ni) 10%
Alloy L-605	(Co) 53%, (Cr) 20%, (W) 15%, (Ni) 11%
Stellite 31	(Co) 56%, (Cr) 25%, (Ni) 10%, (W) 7%
T-400	(Co) 60%, (Mo) 28%, (Cr) 8%
Stellite 25	(Co) 62%, (Cr) 21%, (Ni) 11%
Stellite 21	(Co) 65%, (Cr) 27.5%, (Mo) 5.5%

Titanium

Also classified as a super-alloy, titanium alloys are engineered to combine the desirable characteristics of titanium with the strengths of other metals. Common alloying elements include aluminum and vanadium, which contribute to increased strength and heat resistance. For example, Ti-6Al-4V is a popular titanium alloy that consists of 6% aluminum and 4% vanadium.

In spite of titanium's potential usefulness in highly demanding parts, its spring back effect causes problems during subtractive machining processes. Despite titanium's well-known resistance to heat and failure, its abrasive qualities and work-hardening tendencies can pose challenges during machining and undoubtedly lead to swift tool degradation.

Our research has led us to believe that the machining of titanium may be improved with the use of skilled cutting techniques (HEM pp. 84-86), the right tool geometries (Chip Breakers pp. 9-24), adequate chip removal, and optimal cutting parameters.

We are well-versed in titanium alloy tooling and can advise you on the best cutting tool options for your specific needs. In our experience, the perfect combination of high-quality carbide, precisely ground edges, protective tool coatings, and acceptable cutting settings has proven to be the most effective formula for overcoming titanium applications. To overcome these material problems, which generally prevail, we often employ multi-fluted tooling in conjunction with an effective tool path strategy.



MACHINABILITY CHART

This chart helps estimate the machining difficulty for various materials.

The machinability of a material is contingent upon its physical properties and the conditions of the operation. Forecasting machinability is difficult because of the many unexpected variables inherent in milling, as noted in this catalog.

When evaluating the machinability of a workpiece material, two factors must be considered: the material's condition and its physical properties, as well as its microstructure. Alloyed materials, especially superalloys, exhibit complexity. It is essential to thoroughly understand the heat treatment, tensile strength, work hardening properties, and primary alloying elements of your material that influence tooling.

Machinability refers to the ease of machining a material. The physical properties and cutting conditions of the material determine machinability, typically expressed as a percentage or normalized value. The American Iron and Steel Institute (AISI) has determined AISI No. 1212 carbon steel (shown below in yellow) a machinability rating of 100%, and the baseline factor of the chart.

AISI/SAE Designation	Machinability Rating	Carbon Content	Notable Alloy(s)	AISI/SAE Designation	Machinability Rating	Carbon Content	Notable Alloy(s)
Carbon Steel				Martensitic Stainless Steel			
1010	.66	(C) .08-.13	(Mn) .30-.60	410	.55	(C) <0.15	(Cr) 11.50-13.50, (Ni) ≤.75
1018	.78	(C) .14-.20	(Mn) .30-.60	416	.85	(C) <0.15	(Cr) 12.00-14.00, (Ni) ≤.60, (Mn) ≤1.25
1020	.80	(C) .17-.23	(Mn) .30-.60	420	.45	(C) <0.15	(Cr) 15.00-16.00, (Ni) .15-.25
1040	.64	(C) .37-.44	(Mn) .60-.09	440C	.40	(C) <0.15	(Cr) 12.00-14.00, (Si) ≤1.00
1050	.54	(C) .48-.55	(Mn) .60-.09	Custom 455	.28	(C) <0.05	(Cr) 11.00-12.50, (Ni) 7.50-9.50, (Cu) 1.50-2.50, (Ti) .80-1.40
1137	.72	(C) .32-.39	(Mn) 1.35-1.65	Precipitation Hardened Steels			
1141 (ANNEALED)	.70	(C) .37-.45	(Mn) 1.35-1.65	13-8PH	.36	(C) <0.05	(Cr) 12.25-13.25, (Ni) 7.50-8.50, (Mo) 2.00-2.50, (Al) .90-1.35
1144	.76	(C) .40-.48	(Mn) 1.35-1.65	15-5PH	.45	(C) <0.05	(Cr) 14.00-15.50, (Ni) 3.50-5.50, (Cu) 2.50-4.50
1144 (STRESS-PROOF)	.83	(C) .40-.48	(Mn) 1.35-1.65, (P) .040	17-4PH	.48	(C) <0.07	(Cr) 15.00-17.50, (Ni) 3.50-5.00, (Cu) 3.00-5.00
1212	.100	(C) ≤0.13	(Mn) .70-1.0, (P) .07-.12	Super-Alloys			
12L14	1.70	(C) .15	(Mn) .85-1.15, (P) .04-.09, (Pb) .15-.35	Inconel 625	.12	(C) <0.01	(Ni) 58.00, (Cr) 20.00-23.00, (Mb) 8.0-10.0
Alloy Steel				Inconel 718	.12	(C) <0.08	(Ni) 50.00-55.00, (Cr) 17.00-21.00
4130	.69	(C) .28-.33	(Mn) .40-.60, (Cr) .80-1.10	Inconel X-750	.12	(C) <0.08	(Ni) 36.00, (Cr) 14.00-17.00, (Ti) 2.25-2.75
4140	.61	(C) .38-.43	(Mn) .75-1.00, (Cr) .80-1.10	Invar 36	.55	(C) <0.10	(Ni) 35.00-38.00
4340	.57	(C) .37-.43	(Cr) .80-1.10, (Ni) 1.65-2.00	Alloy C (C-276)	.18	(C) <0.10	(Ni) 50.00-52.00, (Cr) 14.50-16.50, (Mb) 15.0-17.0
5130	.68	(C) .28-.33	(Cr) .80-1.10, (Si) .15-.30	Kovar	.22	(C) <0.02	(Ni) 29.00, (Co) 17.00, (Mb) 15.0-17.0
52100	.40	(C) .98-1.10	(Cr) 1.30-1.60	Carpenter 20 (Incoloy 20)	.40	(C) <0.06	(Ni) 32.50-35.00, (Cr) 14.80, (Ti) 2.13, (Mo) 1.30, (Mn) 1.00
8620	.66	(C) .18-.23	(Cr) .40-.60, (Si) .15-.35, (Ni) .40-.70	A286	.54	(C) <0.04	(Ni) 25.50, (Cr) 19.00-21.00, (Cu) 3.00-4.00, (Mo) 2.00-3.00
9310	.51	(C) .07-.13	(Cr) 1.00-1.40, (Ni) 3.00-3.50	Maraging 300	.60	(C) <0.03	(Ni) 18.50, (Co) 9.00, (Mo) 4.80
Tool & Mold Steel				Grey Cast Iron			
A2	.42	(C) .95-1.05	(Cr) 4.75-5.50	Class 20	.73	(C) 3.25-3.50	(Si) 1.80-2.30
D2	.27	(C) 1.40-1.60	(Cr) 11.00-13.00	Class 25	.55	(C) 3.25-3.50	(Si) 1.80-2.30, (Ni) .05-.20
H13	.55	(C) .32-.45	(Cr) 4.75-5.50, (Mo) 1.10-1.75	Class 30	.48	(C) 3.25-3.50	(Si) 1.80-2.30, (Ni) .05-.20, (Cr) .05-.45
S7	.75	(C) .45-.55	(Cr) 3.00-3.50, (Mo) 1.30-1.80	Class 45	.36	(C) 3.25-3.50	(Si) 2.10-2.30
P20	.65	(C) .28-.40	(Mn) .60-1.00, (Cr) 1.40-2.00	Nodular (Ductile) Iron			
Maraging C300	.57	(C) .30	(Ni) 18.50, (Mo) 4.8, (Co) 9.00	60-40-18	.61	(C) 3.40-3.80	(Si) 2.00-2.50, (Mg) .025-.055, (Cr) ≤.08
Austenitic Stainless Steel				65-45-12	.61	(C) 3.40-3.80	(Si) 2.35-2.75, (Mg) .025-.055, (Cr) ≤.08
303	.78	(C) <0.10	(Cr) 17.00-19.00, (Ni) 8.00-10.00	80-55-06	.39	(C) 3.40-3.80	(Si) 2.35-2.75, (Mg) .025-.055, (Cr) ≤.08
304	.45	(C) <0.08	(Cr) 18.00-20.00, (Ni) 8.00-10.50	Aluminum/Magnesium Alloys			
316	.45	(C) <0.08	(Cr) 16.00-18.00, (Ni) 10.00-14.00	Aluminum (Wrought)	3.6	n/a	Depends on individual grade
321	.36	(C) <0.08	(Cr) 17.00-19.00, (Ni) 9.00-12.00	Aluminum (Cast)	4.5	n/a	Depends on individual grade
347	.36	(C) <0.08	(Cr) 17.00-19.00, (Ni) 9.00-12.00, (Nb) ≤1.00	Aluminum (Die Cast)	.76	n/a	Depends on individual grade
Ferritic Stainless Steel				Magnesium (Cold Drawn)	4.8	n/a	Depends on individual grade
405	.60	(C) <0.08	(Cr) 11.50-14.50	Magnesium (Cast)	4.8	n/a	Depends on individual grade
430	.54	(C) <0.08	(Cr) 16.00-18.00, (Ni) ≤.50				
444	.45	(C) <0.02	(Cr) 18.20-18.50, (Ni) ≤.50				
447	.37	(C) <0.12	(Cr) 28.00-30.00, (Mo) 3.50-4.50				

COMPONENT DESIGN & WORK HOLDING

Rigidity criteria apply to both your part & your work holding.

CNC work holding refers to the methods and devices used to secure and position workpieces on CNC machines during subtractive machining operations. The effectiveness of work holding solutions is crucial in achieving precision, repeatability, and efficiency in CNC machining and adds crucial rigidity for carbide tooling.

Here are some common CNC work holding methods and devices:

- Vice Systems
- Clamping Systems
- Zero-Point Clamping
- Fixture Plates and Tombstones
- Magnetic Work holding
- Pallet Changers
- Collet Systems
- Vacuum Work holding
- Chucking Jaw Systems

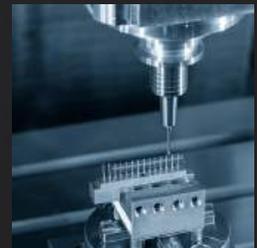
While each of the aforementioned methods has their advantages and disadvantages, what matters most is that your fixturing is well-positioned, secure, and has a respectable clamping force. In a notably challenging application, we invested much effort diagnosing tool failure, despite changes to the tool, tool holder, speed, feeds, and software. We identified the issue as a little, hardly perceptible movement in the clamping mechanism. Following the reconfiguration and optimization of the fixturing configuration, the tool began to operate seamlessly.



Our approach involves considering work holding and component rigidity as interconnected factors. This entails doing a comprehensive analysis of various aspects, such as the close relationship between work holding, the positioning of the workpiece in relation to the spindle, and the design of the workpiece itself. Additionally, we examine any elements that may contribute to issues such as vibration, chatter, and inadequate rigidity.

Questions to ask yourself regarding component design (i.e. your part).

- **Does the part have thin walls?** To maintain rigidity, thin walls necessitate the use of new sharp (lightly edge-prepped) tooling and may benefit from employing a step-milling roughing method. To get further information, please refer to page 95.
- **Are the floors thin?** If the thin floor span is excessive, it might cause warping, allowing the tool's endwork to grip as the floor distorts. Witness markings or corner breakage may be observed. Reconfiguring speeds, feeds, depth of cut, and retract height may be necessary.
- **Does it favor chip collection or evacuation?** When using VMCs (typically excluding HMCs), your workpiece may generate a phenomenon known as a "bowl" effect. This phenomenon causes chips to accumulate instead of properly evacuating, potentially leading to re-cutting, which is detrimental to any tool.
- **Are there any (unsupported) features?** If your item has an overhanging feature (inside or outside), which might cause vibration and chatter, it is a beneficial idea to give additional support or dampening to keep the cutting conditions suitable.



Questions to ask yourself regarding work holding.

- **Is the part at the top, middle, or bottom of Tombstone?** Depending on their overall construction, table mounting, and part-to-tombstone mounting procedures, tombstones increase the amplification of harmonics and some rigidity from their most rigid bottom to their least rigid upper surface.
- **Is the part hanging over the vice?** Inevitably, this will result in a "diving board" effect, causing vibration, chatter, and tool degradation. To get the best outcome, either relocate the component or provide more reinforcement to the projecting portion.
- **Is the part "bridged" in the Vice?** What we are referring to is whether the part clamped in the vice is supported underneath by something or simply suspended in the air. The thickness (or lack thereof) of the raw material can generate harmonics, potentially causing the surface to flex and become convex or concave as the vice tightens. Securing a piece of wood underneath will help support and dampen.
- **Is your part a casting?** Each casting is unique, and we have observed numerous challenges with the secure clamping of these components. Often, customers will machine one or two surfaces for clamping, which is crucial to prevent any movement of the item.
- **Is a trunnion or rotary table being used?** Our findings show that adapting trunnions (or portable rotary tables) produces different results than putting a part on a more stable surface. Although they are a less expensive solution for a 4th (and 5th in some circumstances) axis in machining, this does not mean they are ineffective. However, changes in machining methods, rates, feeds, and cut depths may be required.



HIGH EFFICIENCY MILLING

High efficiency milling (HEM), is a method with which we have considerable fami-

High-efficiency milling (HEM) is a machining technique designed to optimize the rate of material removal (MRR), especially in roughing operations. This strategy prioritizes efficiency by minimizing cycle time, ensuring process stability and extending the lifespan of tooling. Setting aside time for review is beneficial, even if it may not be appropriate for every application, machine, or component shape.

Various CAM products, such as Mastercam® Dynamic Motion™, Autodesk Fusion® Adaptive Clearing™, and Esprit ProfitMilling™, now provide this programming enhancement. Additionally, there are standalone solutions, such as volumill.com, that provide a very reliable High Efficiency Machining (HEM) solution. Undoubtedly, this advancement in programming has made substantial strides in the last decade, leading to a more effective rough milling tool path than ever before.

Outlined below are many fundamental elements and tactics linked to high-efficiency milling:

Elevated Speeds and Feeds

- **Higher Spindle Speeds** - As a result of the production of a thinner chip, it is not unusual for us to use greater spindle speeds (within reasonable limits) compared to conventional milling techniques. Hence, it is advantageous to use machine tools equipped with high-speed spindles in materials that are compatible with such technology.
- **Increased Feed Rates** - The use of higher feed rates is justified by the chip thinning advantage (refer to page 88) provided by the HEM method, resulting in a significantly increased material removal rate (MRR) per unit of time.

Depths of Cut

- **Shallow Depth of Cut (a_p)** - HEM often utilizes a more shallow depth of cut (a_p) in comparison to conventional milling. This decreases the radial contact of the tool, hence decreasing the stresses exerted on it and enabling larger feed rates due to the chip thinning effect (see page 88). This is a great parameter to adjust when looking to reduce your program size, HEM programs can get large and reducing your step over shortens up the program, however, it also thins the chip requiring chip thinning adjustments.
- **High Axial Engagement (a_p)** - Although the shallow depth of cut (a_p) may lead some to believe that we are sacrificing efficiency, we compensate for this by increasing the axial engagement (a_p), which also enables us to utilize more of the length of cut (L1). If your part does not allow for a large axial depth of cut you may want to re-evaluate your MRR calculations vs traditional and see if the MRR is going to make the most sense for your part?

Constant Engagement

- **Constant Tool Engagement Angle** - An objective of HEM is to provide a continuous and stable interaction between the tool and the workpiece. This facilitates a uniform allocation of cutting forces, effective thermal contact management, minimizes tool wear, and greatly reduces the risk of breakage. These tool paths let us to use smaller tools, create corners by sweeping, and employ low engagement angles (see to pages 88-90) for milling the component with significant success.

Heat in the Chip

- **Heat-transporting chips** - Chip formation, irregular thermal zone visitation, and tooling temperature degradation are some of the effects of conventional machining. It is necessary to control the heat, eliminate the source, and adjust the heat variable. The goal at this point is to incorporate the heat produced by the cutting force into the chip and remove it from the tool using the proper evacuation methods. The quick chip creation is one problem that HEM causes, but it also manages the thermal variable and maintains the heat in the chip extensively. It might be difficult at times, but you have to be prepared to swiftly clean, manage, and remove a large amount of chips from the cutting area, as HEM can produce chips swiftly.

Trochoidal Milling

- **Trochoidal tool paths:** This phrase appears to be used a lot in our industry. It is defined as the curve formed by a point on a circle's radius, or the radius expanded as the circle rolls on a fixed straight line. To put it simply, it facilitates your tool-path efficiency and is often integrated into HEM in one form or another. If you don't have a complete HEM solution choice, it may be helpful to use a trochoidal option, especially in a slot where the slot width is at least 1.5 times the tool diameter and the depth of the slot is more than 2x the tool diameter.

Coolant has Multiple Purposes

- **A Multi-Purpose Factor:** Metal cutting produces heat and friction, much like other subtractive manufacturing techniques, which leads to the creation of chips. One of HEM's main advantages is its capacity to reduce cutting forces by bringing the temperature down and then clearing it away from the tool via chip evacuation. Therefore, we see that using coolant really serves two purposes while utilizing HEM strategies: first, it lubricates the cutting surface, thus reducing friction; and second, it facilitates the proper removal of rapid chip development.

Tool Selection and Coatings

- **High-Performance Tooling:** Optimizing your material removal rate (MRR) while using a high-efficiency machining (HEM) strategy necessitates the careful choice of high-performance cutting tools equipped with sophisticated coatings. High-performance tooling has the necessary structure and durability to successfully handle a job of this kind, but general-purpose tools often lack these capabilities. To gain a deeper understanding of the distinctive characteristics of high-performance tooling, refer to page 69, and to choose the right tool, check out our selection guide on page 86 of this catalog.

Machine Tool Readiness

- **Machine readiness:** With a wide variety of CNC machines and high-efficiency milling processes, we have had great success helping clients improve the performance of their applications. We don't place any limitations on the machine tool that is being used, nor do we provide any brand preference. The device must, nevertheless, be in top shape, be kept up-to-date, possess healthy look-ahead skills, enough memory, wholesome speed and feed competence, and have precise positioning abilities. Without a doubt, high-efficiency milling (HEM) offers significant advantages in the appropriate scenario. However, when evaluating the machine tool, it must possess qualities that can withstand the entire race, just as an Indy car must successfully complete all 500 laps!

HIGH EFFICIENCY MILLING (Cont.)

arity with and is considered a strategy whose primary goals are to maintain or

It is essential to recognize that HEM strategies may not be appropriate for all shops, applications, or components. Generally, rough milling requires the most time, effort, and tooling when conducting a subtractive machining process. Consequently, it is a CAM tool path strategy designed primarily for removing a great deal of material in the minimum amount of time; if your part is near-net or does not require a great deal of initial material removal, this strategy may not be suitable for you.

In order for you to make informed decisions, let's examine some of the arguments for and against this tool path strategy.

Advantages	Disadvantages
Increased Throughput (MRR)	Increased Machine Memory
Reduced Cycle Times	High Precision Tool Holders
Extended Tool Life	Excellent Spindle Condition
Improved Surface Finish	Fixturing Challenges
Enhanced Predictability	Shop Adaptability/Culture
Decreased Spindle Load	Part Configuration/Shape
Increased Tool Survivability Rate	Reprogramming Clearance
Tool Reconditionability	Machine Tool Accuracy Limitations
Higher Machine Utilization	Effective Chip Evacuation

At Core Cutter, we possess extensive HEM (high-efficiency machining) expertise and are eager to assist you in evaluating the potential opportunities. We have also made a concentrated effort to comprehend, adopt, and, in some instances, collaborate with organizations that provide these types of solutions!

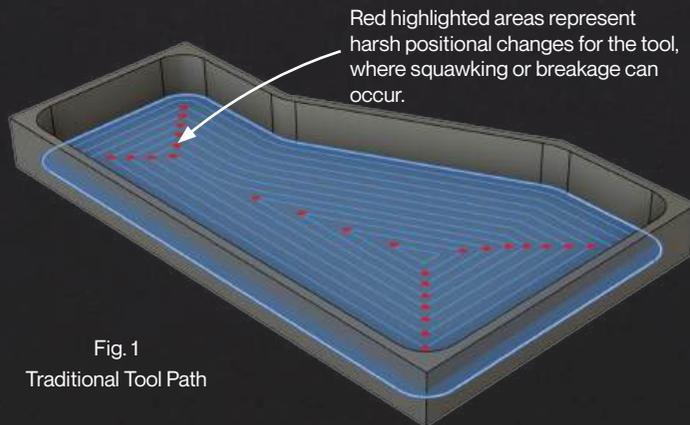


Fig. 1
Traditional Tool Path

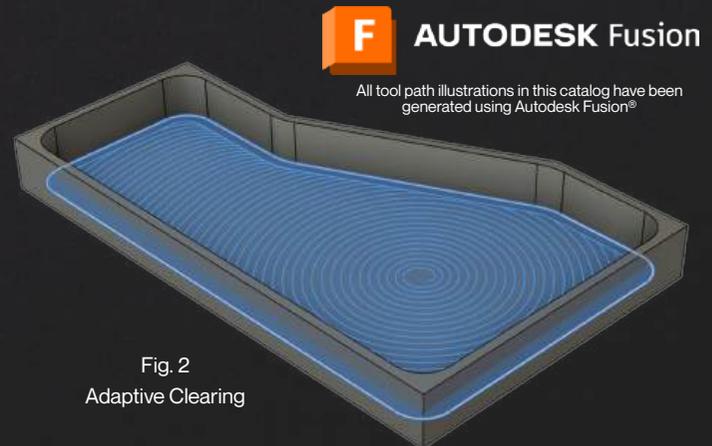


Fig. 2
Adaptive Clearing

Parallel Offset Tool Path

This tool path is used a lot, but it's like driving an old, slow car when you have a fast muscle car waiting in the garage!

- **Areas of concern:** In the given section, denoted as (Fig. 1), there are a total of 27 troubled regions that raise concerns or indicate issues, shown by red dots.
- **90-degree turns:** Programs often exhibit a common pattern of following the outline of a component and suddenly altering their course at each change of direction (shown by the red dots). This presents significant difficulties for any cutting tool.
- **Cornering:** The component's corners often coincide with the tool's radius, increasing the tool engagement angle (TEA). This raises the tool load and often causes it to remove more material than its maximum rate (MRR), producing poor results. See pages 88-90 for further details.
- **Comfort Zone:** More than anything, this tool route is usually a product of a knowledge comfort zone. It's not wrong, but as you witness the red dots (i.e., trouble) in Fig. 1, you now see the issues it creates for the tool.

HEM Tool Path

This is the equivalent of pulling out the Maserati from the garage; buckle up for some real speed, feed, and fun.

- **Mitigated Trouble:** Observe that we have avoided the 90° corner motions (Fig. 2), which eliminates trouble and allows for optimization.
- **Constant Engagement:** The tool is now continuously engaged, maintaining a well-regulated load on the tool and ensuring a smooth cutting action across the entire part.
- **Dynamic Parameters:** Depending on the program, the tool dynamically manages the MRR when it reaches various completion milestones. This means that certain applications will automatically adapt MRR elements (up or down) to maintain efficacy and tool safety.
- **Chip thinning:** Now that it's safe to do so, you may use this aspect dynamically to maximize your MRR across the component (see p. 88).
- **Relax:** Now sit back and relax; you're in excellent hands with all types of safety features built into programs like this. They truly eliminate all the danger spots, enabling you to optimize your MRR!

HIGH EFFICIENCY MILLING (Cont.)

increase tool life (mainly roughing) while maximizing material removal rates (MRR).

Having discussed the benefits and drawbacks of HEM programming as well as the overall approach, it is now necessary to concentrate on our general suggestions for using Core Cutter tooling in conjunction with HEM tool path techniques.

When choosing a Core Cutter tooling option, take into account these crucial tool characteristics.

- 1. Flute Count:** Using multi-fluted tooling is imperative as it enables you to maximize your metal removal rate (MRR).
 - **For aluminum** - Our primary selection for HEM in non-ferrous materials is our three flute tools (pp. 37-41); however, we can also provide quotes and manufacture tools with additional flutes for aluminum, utilizing an HEM strategy.
 - **Ferrous materials (including titanium)** - Although we don't set a fixed number of flutes in HEM, a higher flute count (5 minimum) results in improved metal removal rates, less tool deflection, and increased tool life.
- 2. Length of Cut (LOC)** - Since length of cut (A_p) is a component that helps us preserve our MRR, try to use as much of it as you can.
- 3. Corner Radii** - Strengthening the tool's corner with a radius at these elevated speeds and feeds is crucial and will increase tool life.
- 4. Tool Coatings** - Employing the proper tool coating is a necessity at these elevated speeds and feeds in ferrous materials and/or superalloys, such as Inconel or Titanium.

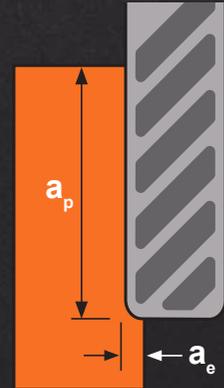


Fig. 1 - Illustration of a HEM light Radial DOC (a_p) and Heavy Axial DOC (a_e)

High Efficiency Milling (HEM) DOC Guidelines

	Flute Count	Tool Series	Axial Depth of Cut (A_p)	Radial Depth of Cut (A_e)
N	3f	AL3	Up to 3.5 x Tool Diameter	10%-to-25% of the Diameter
		AL3-CB	Up to 3.5 x Tool Diameter	12%-to-30% of the Diameter
		AL3-RN	Up to full length of cut (L1)	10%-to-25% of the Diameter
P	5f	VST5	Up to 3.5 x Tool Diameter	8%-to-20% of the Diameter
		VST5-CB	Up to 3.5 x Tool Diameter	8%-to-15% of the Diameter
		VST5-RN	Up to full length of cut (L1)	8%-to-10% of the Diameter
		VXR5-CB	Up to 3.5 x Tool Diameter	8%-to-15% of the Diameter
M	6f	VST6	Up to 3.75 x Tool Diameter	8%-to-20% of the Diameter
		VST6-CB	Up to 3.75 x Tool Diameter	10%-to-30% of the Diameter
		VST6-RN	Up to full length of cut (L1)	8%-to-10% of the Diameter
K	7f	VMF7	Up to 4.0 x Tool Diameter	7%-to-10% of the Diameter
		VMF7-CB	Up to 4.0 x Tool Diameter	9%-to-13% of the Diameter
S	9f	VMF9	Up to 4.0 x Tool Diameter	5%-to-8% of the Diameter
		VMF9-CB	Up to 4.0 x Tool Diameter	6%-to-9% of the Diameter
H	11f	VMF11	Up to 4.0 x Tool Diameter	3%-to-6% of the Diameter
		VMF11-CB	Up to 4.0 x Tool Diameter	5%-to-8% of the Diameter



Are you encountering inadequate computer memory space while trying to upload your HEM Tool Path? A viable approach we have identified is to decrease the RDOC (A_e) value, which will lead to a reduction in the overall length of the program (i.e., less memory needed). It is crucial to acknowledge that a drop in RDOC (A_e) leads to a decrease in chip thickness, potentially requiring an increase in IPM (refer to page 88).

METAL REMOVAL RATE (MRR)

A productivity measurement, usually expressed as (in³/min.) or (mm³/Min.).

An essential parameter in milling that must be understood, controlled, and improved is the metal removal rate (MRR). Throughput is a statistical measure that measures the rate at which your cutting parameters generate results. Increasing this factor leads to an increase in your productivity (throughput), while decreasing it results in a drop in your throughput.

The computation is dependent on three known variables: IPM (V_f), RDOC (a_e), and ADOC (a_p). Note that if any of these three variables experience dynamic changes by the software during component machining, then the resultant MRR will be more indicative of an average value than a precise measurement.

$$\text{MRR (In}^3 \text{ min.)} = \text{RDOC (} a_e \text{)} \times \text{ADOC (} a_p \text{)} \times \text{IPM (} V_f \text{)}$$

Any of these three variables will have an impact on your MRR, and there is no set upper limit for MRR per tool since it is determined by a number of factors including tool design, flute count, chip management, material being cut, and other considerations. However, you may alter any or all of these components separately to attain and maintain the tool's optimal load, making it a controllable variable. The golden ticket is finding the optimum MRR for your specific tool & application!

Even if MRR is now a part of your "symphony", you are still the conductor. When trying HEM methods, it is particularly important to remember that even little modifications of the (3) MRR attributes may have a large impact on your outcome.

Therefore, when we place it into perspective, we realize that adjustments can either improve or diminish our results, and that minor adjustments can frequently have a significant impact (especially in HEM). An example of this is making a 10% radial depth of cut (a_e) adjustment during a HEM application utilizing a 1/2" tool with a 7% (.035) radial depth of cut (a_e); this would only be a (.0035) adjustment and could significantly impact program length and/or tool performance. It is prudent to recognize that even minor adjustments can yield significant outcomes, good or bad.



Let's look at a real-time example:

Conventional Machining Technique

Material: 4140 H1150 (33 HRC)
Tool Path: Parallel Offset
Operation: 7" x 5" Cavity Milling 1.0" deep
The Tool: 1/2" (D1) 4 flute Variable Pitch
Cut Parameters: 250 SFM, .0035, 50% (a_e), 2 x D (a_p)
MRR: .25 x .50 x 27 ipm = 3.38 In³ min.

Improved Machining Technique

Material: 4140 H1150 (33 HRC)
Tool Path: HEM
Operation: 7" x 5" Cavity Milling 1.0" deep
The Tool: 1/2" (D1) 5-flute Chip Breaker Tool
Cut Parameters: 650 SFM, .0043, 10% (a_e), 4 x D (a_p)
MRR: .050 x 1.00 x 106 ipm = 5.30 In³ min.

The Results!

- ✓ The result is a 57% increase in throughput
- ✓ Tool life doubled
- ✓ Spindle load dropped by 37%.
- ✓ Part scrap decrease by 5%
- ✓ Machine utilization increased

Impressive Improvement

- ✓ Our client was able to produce a component at a significantly more competitive price.
- ✓ Chip management has vastly improved with the chip breaker tool, allowing the operator to worry less about proper chip removal and focus more on the operation.
- ✓ Even with an increase in tool cost, the shop throughput savings heavily outweighed the tool cost.

CHIP THINNING & TOOL ENGAGEMENT

If understood, these situations may help you solve difficult challenges.

Heat and vibration are two of the most prevalent tool killers. Because friction generates heat and the cutting motion is the tool's intended use, it is impossible to completely remove it, but it is possible to regulate it. Same with vibration; it's hard to completely eliminate it, but you can work hard to control and minimize it. For instance, managing your TEA and SFM can regulate your friction and variable pitch constructed tooling can help to minimize vibration usually caused by a feature, or even a natural harmonic signature created by the application itself.

The following three factors that are under our control (Remember, you still the conductor) and might potentially mitigate (or at least lessen) the negative effects of heat and vibration will be discussed in further detail.

- Chip Thinning ($f_{z(adj)}$)
- Tool Engagement Angle (TEA)
- Cornering & Acceleration

Chip Thinning

As a general rule, a thinner effective chip will result from cutting with a width that is less than half of the tool's diameter (Fig. 2). The tool's reduced tool engagement angle with the material leads to a reduction in chip thickness and the subsequent need for feed correction, resulting in sometimes dramatic productivity gains. However, if chip thinning is not done and a short radial depth of cut (a_e) is used ($<10\% \times D1$), the tool may be rubbing instead of cutting and shearing the chip away from the material, leading to a low effective chip thickness (at the tooth). The speed and feed charts within this catalog (at the end of each main product section) do include HEM-adjusted chip loads, which are based on a 10% step over (a_e).

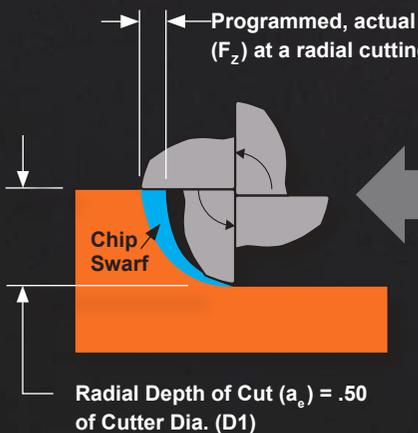


Fig. 1 - Step Over (a_e) $\geq .50 \times D1$

Chip Thinning Calculation

$$f_{z(adj)} = \frac{f_z \times (D1/2)}{\sqrt{(D1 \times a_e) - a_e^2}}$$

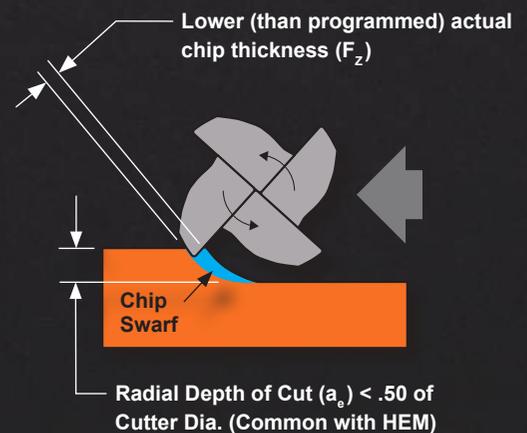


Fig. 2 - Step Over (a_e) $< .50 \times D$

Tool Engagement Angle (TEA)

The phrase "tool engagement angle" often denotes the angle at which a cutting tool, such as an endmill, interacts with the workpiece during machining or metal cutting processes. Optimizing the angles at which tools interact with the material is essential for accomplishing effective removal of material, reducing wear on the tools (due to heat and vibration), and producing the appropriate surface finishes. The suitable angles are fully contingent upon the radial depth of cut (A_e) as a percentage of your tool diameter and the directional path the tool is heading.

Below is a representation of the contact (TEA) angles a 1/2" diameter tool will experience during a straight line cut, but at different radial depth (a_e) amounts.

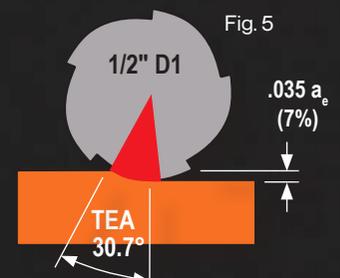
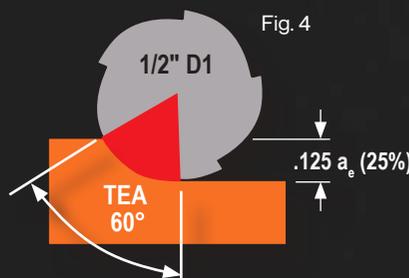
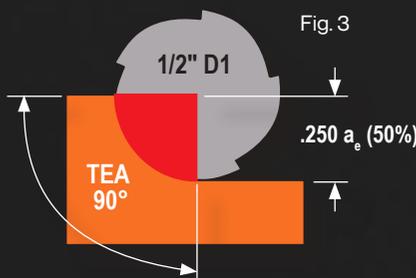
Knowing your TEA

$$a_e = r \times (1 - \cos(\text{TEA}))$$

Knowing your width of cut

$$\text{TEA} = \cos^{-1} \left(1 - \frac{a_e}{r} \right)$$

Here's some helpful Straight Line Cut "TEA" calculations (i.e. r = Tool Radius)



CORNERING & ACCELERATION RISKS

A milling cutter is no different than a car trying to corner and accelerate properly, if you

Let's take a look a little closer at a couple of corner situations, one good and one bad, that will build your awareness of this critical process every endmill faces one way or another. Most available HEM programs intuitively reach for a corner solution, allowing for lower heat and vibration generation, smaller tool diameters, and a much greater rate of success.

Extreme TEA Angle (>90°)

- Increased heat generation
- High Vibration Exposure
- Increased HP requirement
- Tool breakage area
- Reduced feed & speeds
- Squawking is normal

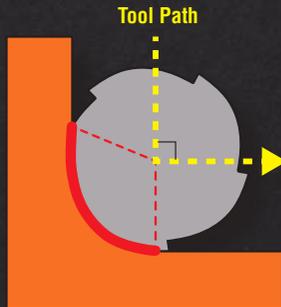


Fig. 6 - TEA > 90°

Managed TEA Angle (≤90°)

- Less heat generation
- Lower Vibration Exposure
- Decreased HP requirement
- Tool damage negated
- Increased Feeds
- Accommodates Smaller Tool Diameters

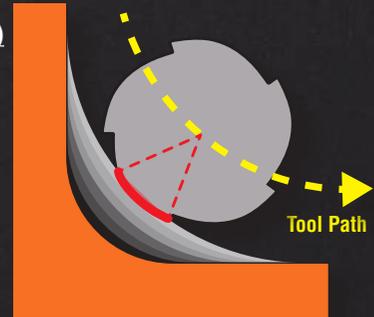
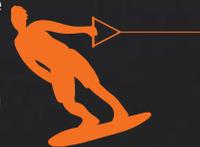


Fig. 7 - TEA ≤ 90°

Cornering & Acceleration

When sending a tool into an inner corner and/or using helical interpolation to open up a hole with an endmill, it is important to know that the peripheral acceleration of the tool at the outside diameter will be higher than the programmed feed based on the centerline of the tool (hence, resulting in a higher IPM). For this reason, if the tool is following a curved path, like a hole (Fig. 9) or inside corner (Fig. 8), the tangential (a_{tan}) and centripetal (a_c) accelerations will elevate on the peripheral cutting edges of the tool. The specific values will depend on factors like the angular velocity, the rate of change of the angular velocity, and the radius of the circular path it is traversing.

A good analogy of this that comes to mind is a water skier getting pulled behind a boat. As the boat is going straight, the skier and the boat are both moving at the same velocity (speed); however, as the boat makes a turn, the skier will undergo an increase in acceleration. As the boat turns more tightly, the skier's acceleration increases at a quicker rate.



As a result, if you can picture the tool's centerline **1** as "the boat" and its periphery surface **2** as "the skier", you probably have a much better picture on

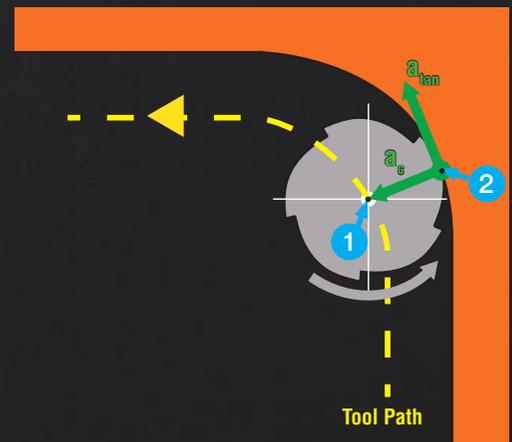


Fig. 8 - Acceleration on Inside Corner

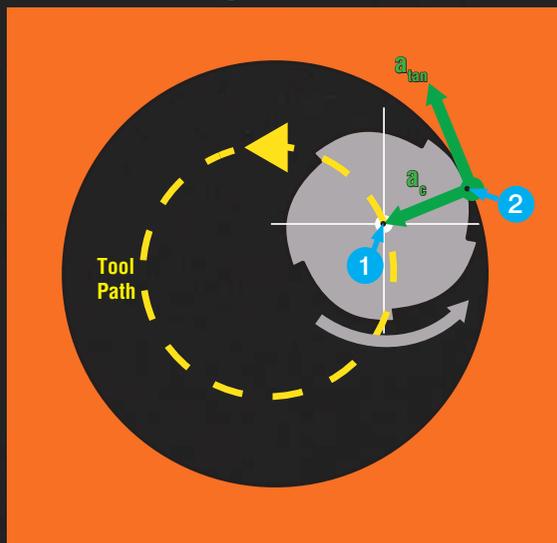


Fig. 9 - Acceleration on Inside Interpolation

how, when making an interior corner, the tool's outside diameter acceleration naturally increases, which in turn causes your feed rate to increase as well, resulting in a significantly higher feed rate at the tooth.

So we know our feed rate is now above recommendations; therefore, we will need to reduce the feed rate during these high TEA interior arc situations and, in some cases, even lessen the radial step over (AE) to accommodate. Evidence of this is usually squawking or breakage in these high-TEA areas.

In addition to using a smaller diameter tool, CAM systems with a HEM tool path solution typically adapt and modify MRR to decrease these trouble spots. Here's a helpful tip if you're trying to manually resolve this issue.

TEA ≤ 90°	TEA ≤ 105°	TEA ≤ 120°	TEA ≤ 135°	TEA ≤ 150°	TEA ≤ 180°
Reduce Feed by 10%	Reduce Feed by 15%	Reduce Feed by 20%	Reduce Feed by 25%	Reduce Feed by 30%	Reduce Feed by 50%

CORNERING & ACCELERATION RISKS (Cont.)

have the right suspension (setup), tires (tool) and good surface (part) then your good!

Now that we have covered the centripetal and tangential velocities that are associated with tooling, especially while cornering, let's go further into these topics and examine the links between the challenges that you have just learned about. Illustrated in Figure 10 is an instance where a client employs a 1/2" diameter endmill to open up a hole to a targeted larger diameter. The endmill is inserted into a .625 pre-drilled hole, then expanded radially to achieve a diameter of 1.50. You can see that we have depicted the process as stages 1, 2, and 3 (Fig. 10).

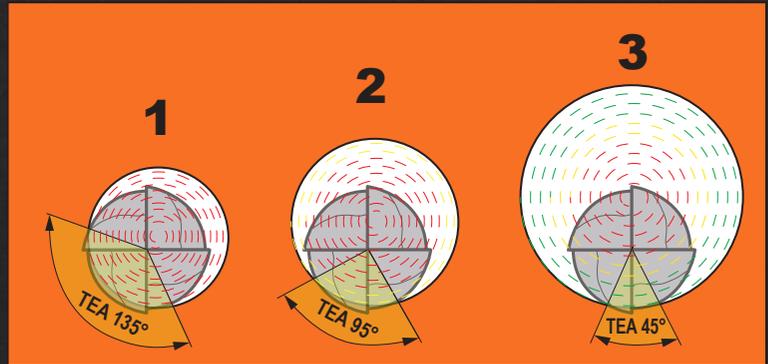


Fig. 10 - Acceleration on Inside Hole Interpolation

The area depicted by red dashed lines, delineates where the tool experiences the greatest increases in tangential and centripetal velocities as well as the greatest angles of engagement.

Furthermore, the yellow dashed lines suggest a warning zone where velocity differences still exists, while the green line represents a region where velocity amplification decreases in parallel with the angle of contact.

So basically, you have the choice of reducing the speed and feed on the 1/2" tool in steps 1 and 2, or you could attack it with a smaller tool that will lessen the velocity and TEA challenges, but going with a smaller diameter may induce deflection. Therefore, we could offset this deflection by adding a few more flutes (a larger core) and possibly reducing the radial depth of cut (a_p) accordingly. What you're probably noticing is that even though we were just "opening up a hole," this is actually more of a complex assignment for the cutting tool.

Expecting a Miracle, that's all

We refer to milling as a continuous interrupted cut because the movement of tools into and out of a cut is constantly dictated by the part's design and the quantity of work that must be accomplished. It is vital to recognize that tools face substantial demands, need excellent reliability, and must withstand a variety of tough situations in order to not only survive but also satisfy tool life requirements. Fortunately, with enhanced equipment, intelligent tool paths, excellent tooling, and increased machining knowledge, we can overcome the bulk of the difficult scenarios that our clients experience.

The illustration below merely represents a route that an endmill may travel through a component. Many other elements may be at play, but this is what the tool may be navigating during its path.

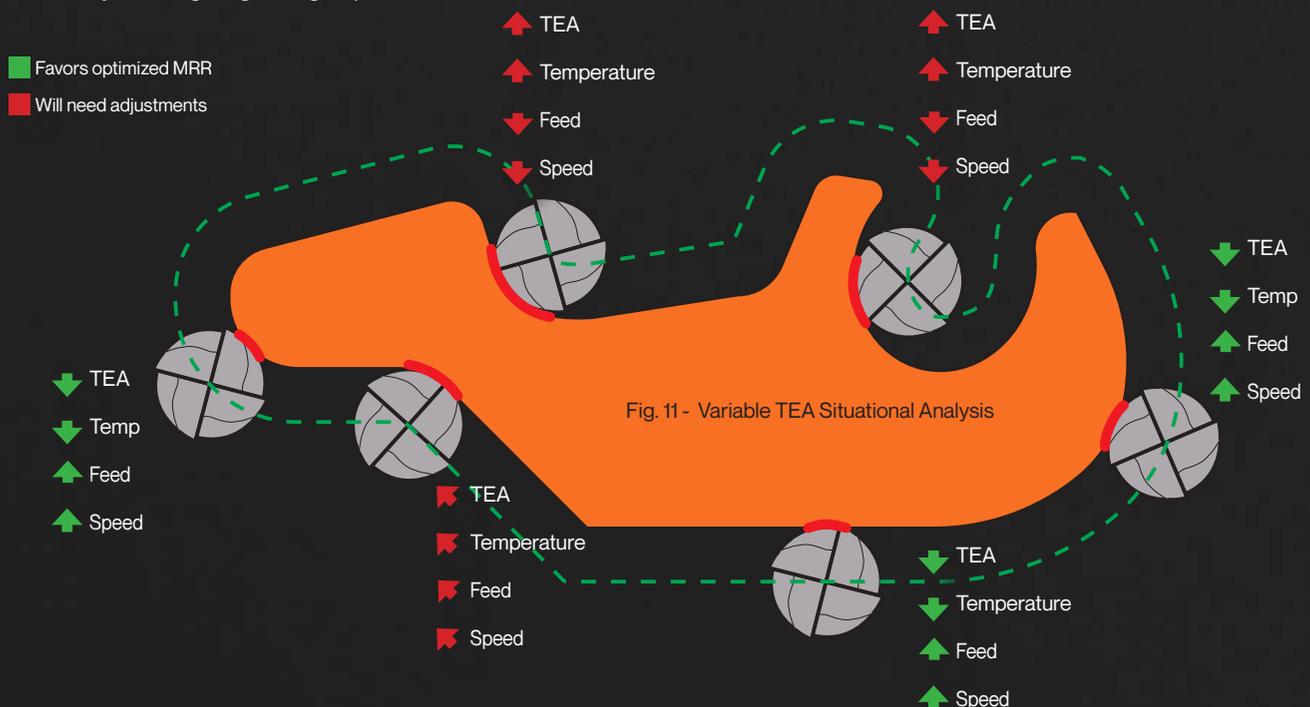


Fig. 11 - Variable TEA Situational Analysis

TYPES OF TOOL ENTRY

Welcome to the first cut determining the destiny of your tool life!

The selection of endmill type and entry technique you choose will have a substantial influence on the efficiency, quality, and precision of the process, as well as the lifespan of the tool. It's true, many people actually destroy their tool upon entry then any other time in the application. Ever wondered why a diver enters the waters backward? The presence of the tank on your back alleviates the resistance of the water, facilitating a smoother dive. In essence, it functions as a tool to aid in initiating the diving process. - basically just like were saying about helping the cutting tool get started in the material.

Below are some of the main entry strategies we witness;

Straight Descent - This term pertains to a tool (usually a drill) that moves either vertically (on a vertical machining center) or horizontally (on a horizontal machining center) towards the material along its axis, generally two approaches available to do this.

- **Plunge Milling** - is a machining method that involves inserting the milling cutter straight into the workpiece, rather than using the workpiece or cutter to follow a typical cutting path. Although some endmills are center-cutting, their design does not allow them to effectively plunge straight or properly manage chip evacuation. It remains one of the most destructive methods for an endmill to penetrate material.
- **Pilot hole** - A conventional and highly valued machining method used to ease the positioning of an end mill, and established with a drill. It facilitates the effortless insertion of the end mill, ensuring an initial smooth side milling start and extending the tool's lifetime by minimizing early damage upon entry into the material. Additional information can be found on the importance of drilled hole diameter-to-endmill diameter inefficiencies on pp. 89-90.

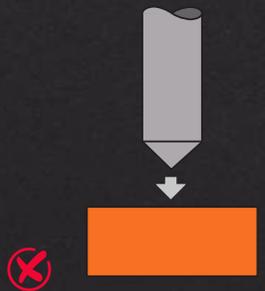


Fig. 1 - Straight Decent

Ramping - A machining technique in which an end mill travels along the workpiece, gradually diving into the material along a ramped path. Overall, ramp milling is a useful machining process that offers several benefits, particularly in terms of tool life and overall machining efficiency. However, and due to the handling of various forces applied to tool and cutting edge (axial, radial, tangential, torque etc.), some vigilance is required.

We have found that ramping at a low angles ($<3^\circ$) with re-adjusted feed per tooth (due to chip thinning see p. 88) can help in high tensile strength materials.

- **Straight Ramping** - A well-established approach that should be considered, however it does subject the tool's edge to various stresses. Additionally, it is important to ensure that the tool selection incorporates effective chip evacuation as the ramp angle and material depth grow on both sides of the tool. Efficient elimination of chips and prevention of their re-cutting is crucial in these sorts of processes.
- **Zig Zag Ramping** - Seen quite often and embraced as a good tool movement entry technique, it involves a lot of the same characteristics of straight ramping (i.e., ensuring effective chip evacuation as the ramp angle and material depth grow on both sides of the tool and prevention of re-cutting them), but when transitioning from one level to another, you can (and should) incorporate a downward helical transition level-to-level, which the tool will like.



Fig. 2 - Ramping

Helical Interpolation - An acceptable machining method in which a cutting tool moves along a helical trajectory along an downward axial path (blue ribbon - Fig. 3) while removing material. Usually using a G02 code that permits the tool to rotate in a clockwise direction while moving in a downward spiral trajectory. Similar to what we learned in the cornering section (pp.89 - 90), the smaller the tool's programmed helical radius trajectory, the larger your tangential and centripetal velocity will be and may need feed readjusting. In steels, sometimes a lighter angle ($<3^\circ$) with increased feed works well.

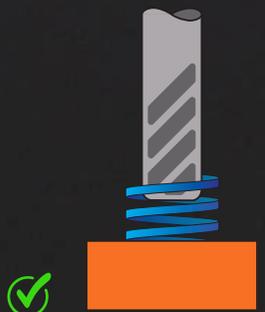


Fig. 3 - Helical Interpolation

Side Entry - If the decision is between choosing a sweeping or straight (perpendicular) entry with an endmill, the sweeping entry is the clear winner! No doubt that we prefer the sweeping entry with a cutting feed reduction when machining tough materials and until the tool can get fully engaged.

- **Sweep in** - Notated with green check mark, is one of our favorite methods of tool entrance because it enables the tool to approach, engage, and settle into the material gently and with the greatest results. It is common to employ up to a 50% decrease in feed to ensure the cutting edges settle in before the full machining party begins.
- **Perpendicular Entry** - Simple to program, yet one of the most difficult entries for a tool to withstand. If you think about it, the tool entering a component (with material on both sides of the tool) is no different from a complete slotting situation. As a result, it should be addressed as such, with feed lowered correspondingly based on slotting guidelines throughout this catalog.

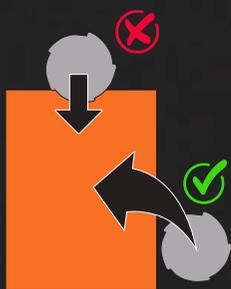


Fig. 4 - Side Entry

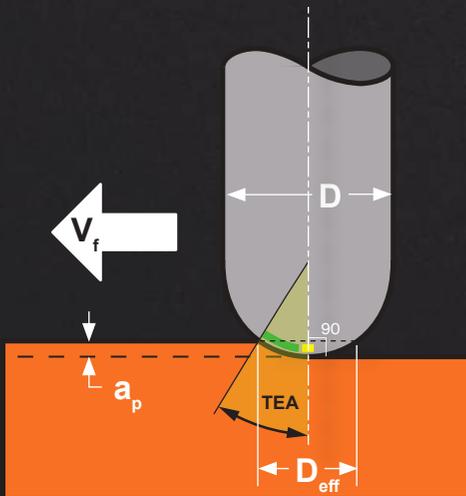
BALL NOSE MILLING

The sculpting of a complex part and its features are its main purpose!

Ball-nose milling is another very complicated operation that requires close attention to the tool's orientation, depths of cut, and geometry. It is a flexible machining process used to create complex and curved surfaces. It is sometimes one of the most frequently used and least understood tools in the toolbox, whether it is being used for generating intricate curved contours on a 5-axis machine or picking out corners on a 3-axis CNC machine. Let us analyze the fundamental principles of ball nose milling.

Effective Cutting Diameter

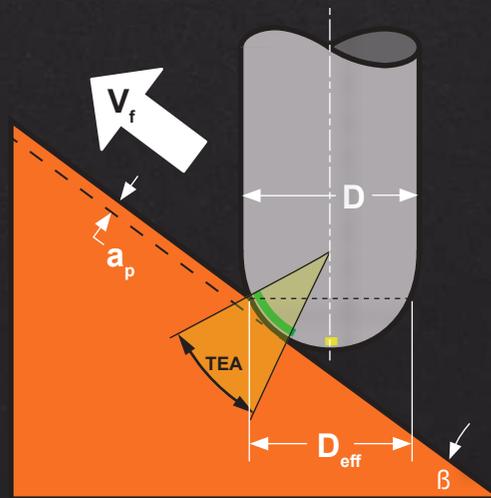
If employing less than the full diameter of the tool, make sure to use the effective cutting diameter (D_{eff}). The effective cutting diameter takes into account the step over or engagement of the tool in the material. If your a_p is less than your ball nose radius, it's important to base your tool's cutting parameters on the effective cutting diameter (D_{eff}) rather than the tool's full diameter.



Finding Effective Cutting Diameter

$$D_{eff} = 2 \times \sqrt{r^2 - (r - a_p)^2}$$

Fig. 1 - Ball Nose Milling @ 90° Orientation
(R = Tool Radius)



Finding Effective Cutter Diameter

$$D_{eff} = D1 \times \sin \left(\beta + \arccos \left(1 - \frac{2 \times a_p}{D} \right) \right)$$

Fig. 2 - Ball Nose Milling @ ≠90° Orientation

TIP | To determine the chip loads (f_z) and appropriate surface foot (SFM) for your ball nose tool, please consult the cutting parameter tables included at the end of each tool section you plan to use. Also, imperative to calculate the chip thinning result (p. 88) and utilize your adjusted chip load ($f_{z(ad)}$) if at all possible.

Tangency of the ball, to the material - The most efficient cutting action in a ball-nosed endmill occurs when it is positioned distant from the center of the tool, where it is in contact with the material. The central part of the ball nose endmill, as shown by the "yellow highlight" in figures 3 and 4, does not play a role in the cutting process. Consequently, it might lead to a smearing effect as it forcefully pushes through the material without any assistance from the surface feet per minute (SFM) in terms of shearing.

Although it may be challenging to entirely eliminate perpendicular ball nose milling, it is essential to recognize that the middle tangential region is notably impacted when dealing with resilient materials.

If it is possible to position the tool and/or the fixture in a manner that results in a contact situation that is not at a 90-degree angle (for example, by using a sine plate), it is advisable to do so. This approach is likely to provide much improved surface finishes.

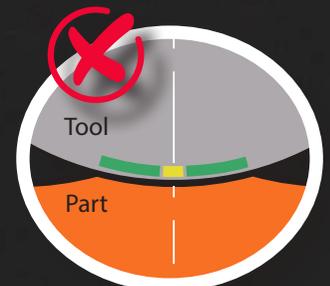


Fig. 3

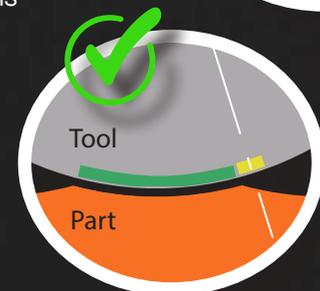


Fig. 4

UNDERSTANDING SURFACE FINISH

Here's a brief overview on surface finishing, symbols, calculations and helpful hints.

Surface finishing refers to the process of modifying the surface of a material to achieve a desired appearance or functional characteristic. The objective of the surface finishing procedure is to minimize or remove the height of irregularities (cusp height) in order to get a more even and polished surface.

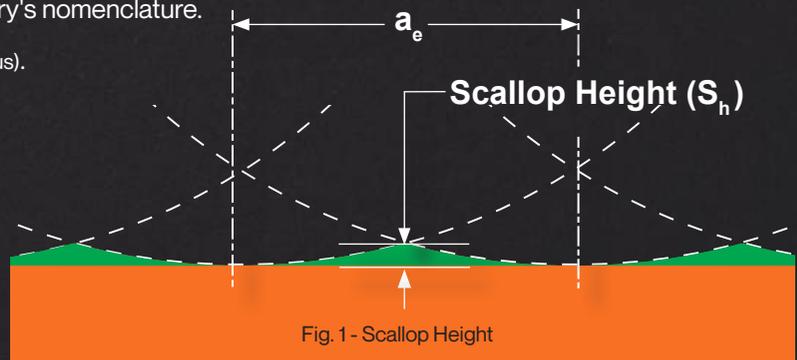
Although there is a connection, the precise term for the point where two adjacent strips meet is a cusp (represented by green in Fig. 1), and the specific measurement of the height of each of these cusps is referred to as a scallop height (Fig. 1). Both "cusp" and "scallop height" have similar meanings within our industry's nomenclature.

This is the formula for figuring the scallop height (r = Tool Radius).

$$S_h = r - \sqrt{r^2 - (a_e/2)^2}$$



TIP The step-over (a_e) distance determines the height of the scallop on curved surfaces, which can vary. An algorithm in most modern CAM systems dynamically adjusts the stepover to maintain the maximum allowed scallop height at all times.



Surface Finish - Surface finish, a numerical assessment of a surface's entire texture, includes three fundamental elements: lay, waviness, and roughness, all closely linked to the previously stated scallop height. Ra is the predominant domestic surface measuring metric, although Rz enjoys widespread worldwide use.

The Surface Symbol:

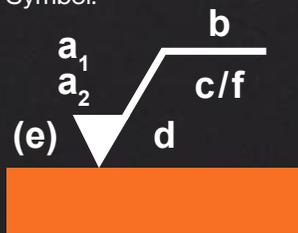
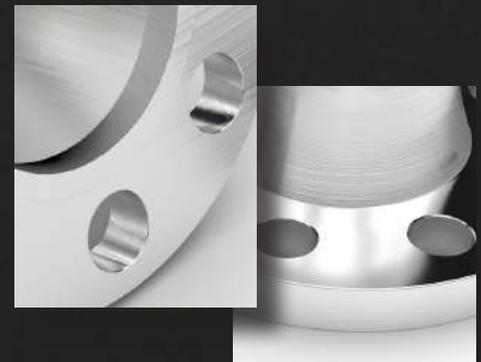


Fig. 2 - Finish Symbol

- a) Roughness value in Ra [micrometer]
(if only one value is shown, then it equals the high limit)
a₁: Ra - High Limit
a₂: Ra - Low Limit
- b) Machining method
- c) Reference length
- d) Grain or groove direction
- e) Machining addition
- f) Secondary roughness in Rz or Ry



Gaining a better finish - Several factors, such as tool runout, tool holder accuracy, cut material condition, and work holding rigidity, influence your results when striving for a high-quality finish. Here are some tips from us that can help enhance the quality of your surface finish.

- **Climb Milling** - Using a climb milling technique instead of a conventional one allows for a shearing chip effect, resulting in better finishes.
- **Corner Radii** - Make use of tools that have a corner radius; a greater radius allows for a better finish as it can act like a wiper.
- **Check Runout** - Ensure that the tool runout, as measured at the tool's tip upon installation in the machine, is less than .0005 TIR.
- **Variable Pitch** - Make use of variable pitch geometry; it reduces application harmonics (chatter), and it becomes more relevant as your axial depth of cut (A_p) rises.
- **Proper Step Over** - should ideally be between 3% and 5% of the tool's diameter; if it's less, you could be rubbing rather than cutting. Increasing your stepover (a_e) should improve surface quality, as the tooth can get behind the chip and shear it properly.
- **Speed & Feed** - Surface finish will benefit from an increase in RPM and a reduction in FPT.
- **Reduced Neck Tooling** - For the completion of high, thin walls, we recommend using reduced neck tooling. This provides a stronger depth-to-diameter ratio, reducing deflection; to eliminate any witness marks, you may need to overlap your axial depth of cut (a_p) by 25%.

To calculate step over (a_e) for bull nose facing



$$a_e = (D1 - (2 \times \text{Tool Corner Radius})) \times .75$$

Fig. 3 - Floor Finish Step Over Calculation

CAVITY & DEEP POCKET MILLING

We're going deep, so runout, chip removal, and tool strength can be a challenge!

Deep cavity milling demands careful consideration of the reach-to-diameter ratio, deflection reduction, and often reduced cutting parameters when selecting the proper tools and tool holders. Fabricating components with deep features and hard-to-reach areas often necessitates a lengthy total tool overhang. Excessive overhang ratios induce deflection and invite chatter.

When presented with an application like this, what should you ask yourself first?

- What is my maximum cutting depth?
- What is the narrowest portion of clearing area?
- What are the smallest wall-to-wall radius transitions?
- What style of programming do you have access too?
- Do you have strong coolant flow, or coolant through the spindle capabilities?

The Tool Holder

Choosing the right tool holder relies on cutting depth and feature clearance. Clients usually prefer a smaller nose diameter for such machining operations, and tool holding technology has addressed this requirement well recently.

The gage line serves as the measurement point for tool holders. Here, we demonstrate that standard steep taper tool holders (Fig. 2), dual contact, and HSK gage lines originate from the top of the flange face, as illustrated in Fig. 1. Therefore, we strongly recommend minimizing the total tool overhang length.

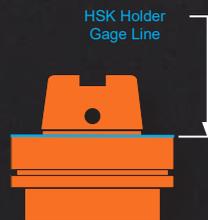


Fig. 1

We prefer a one piece holder (Fig. 2, detail C) or reduced neck tooling (Fig. 2, detail B), and discourage the use of extensions (Fig. 2, detail A), as this can lead to the stacking of tolerances and runout. Therefore, to avoid tolerance stacking, consider either a fully integrated tool holder with the appropriate reach for a regular or small length tool, or a reduced neck length tool (Fig. 2, detail B) to ensure optimal performance.

We need to work our way down

Descending into your basement without steps may be challenging, not to mention hazardous or nearly impossible! Hence, we ascend the staircase by traversing each individual step, known as the "tread riser distance," aka axial depth of cut (a_p). Similarly, while examining your deep pocket or cavity, we approach it by considering one "depth of cut" at a time, with the objective of reaching the very bottom to the total depth of cut.

Overlapping each axial depth will allow for you to remove previous level witness lines and produce a good smooth finish.

How deep can we dive?

If you are HEM roughing, then your depth allowance is greater as you work with a limited radial depth of cut (a_e) and a necked-down tool that hosts a shorter length of cut. But all too often we see someone trying to rough and finish with the same tool (i.e., 3" cavity depth, using a 1/2" 3" loc tool). You can accomplish this, but you must control your speed and feed during the roughing process to such an extent that the "savings" from combining the use of a rougher and a finisher may not outweigh the potential losses.

With HEM roughing, we can safely use a length of cut (LOC) up to four times the diameter ($4 \times D$). The same tool works for roughing and finishing without any issues. However, if a dynamically driven tool path (High Efficiency Machining, aka HEM) is not available, we recommend using a reduced neck tool (RN) in conjunction with the most precise tool holder, as shown in figure 3. Cut to an axial depth of 1.5 times the tool diameter ($1.5 \times D$) while maintaining a considerable radial depth of cut (a_e). This will guarantee maximum efficiency by controlling the metal removal rate (MRR) and simultaneously maximizing your productivity.

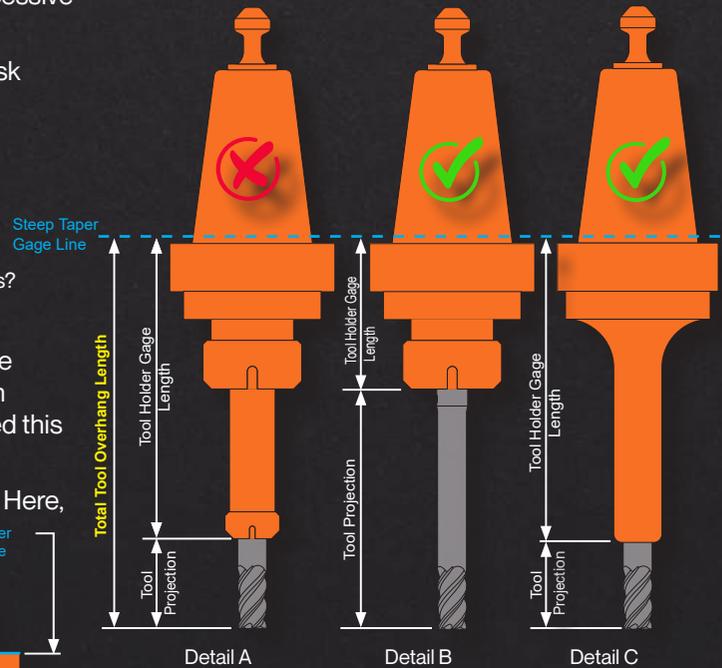


Fig. 2

Please note: shown are single contact steep taper holders, dual contact steep taper holders and HSK style gage lines are taken from the top of flange (shaded here in blue).

[Additional tool holder information can be found on pp. 76-77]

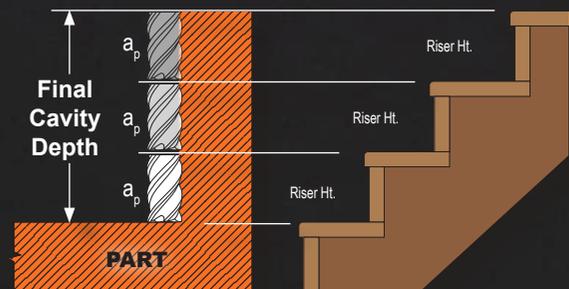


Fig. 3 - An example of reduced neck (RN) step down milling

THIN WALL MILLING

Bracing and stability is key when machining tall thin walls, here's some tricks.

A different building technique is required to develop high walls compared to conventional height walls in building construction. Machining is no exception; larger and thinner walls require additional measures to prevent detrimental forces, such as deflection, vibration, and distortion/warpage, from impeding our progress. Maintaining a broad cross-section behind the wall for stability is crucial, and we will delve into some of the fundamentals in this section, while acknowledging that each unique setup may present unique challenges.

We generally focus on these three important aspects first.

- **Laying the Groundwork for Your Tool Path Cutting Method**
- **Choosing the right tools for the job**
- **Setting the optimal cutting parameters**

Building the Wall(s)

Please review the provided situational analysis, as the illustrations (Figures 4 and 6) depict typical situations with tall, slender walls. We have simplified the analysis to two scenarios: a depth-to-diameter ratio $\leq 15:1$ or $>15:1$. Building the wall requires maintaining bracing as we go up levels.

- **Axially** - Apply a step-down methodology that aligns with the wall height ratio. Both of our approaches illustrate a method for descending the wall while maximizing rigidity and strength until reaching the final depth.

For walls $15:1$ or less, we suggest removing the "blocks" alphabetically (Fig. 4), starting with a stub or regular length tool, then using a reduced neck tool to remove the final "blocks/levels" that the first tool couldn't reach. Yes, two tools are required, but the main focus should be on maintaining the appropriate metal removal rate by regulating vibration, deflection, and raising the metal removal rate (MRR) to enhance roughing efficiency.

For walls $>15:1$, we suggest more of an alternating (i.e., overlapping) strategy, keeping some material behind the wall at all times (Fig. 6). Once again, we recommend starting with a stub or regular length tool and then using a reduced neck tool to remove the final "blocks or levels" that the first tool couldn't reach. As you machine each level leaping over the wall, make sure there is always some material bracing the next cut.

- **Radially** - Figure 5 shows the variable radial depth-of-cut method, which is essential when there is nothing on the other side of the wall. As we approach the wall, the cutting pressure decreases proportionally to the decreasing radial depth of the cut (a_e). Our objective is to reduce the pressure as we approach the wall, but we can compensate by increasing the feed rate due to chip thinning (refer to page 88 for further details). There will undoubtedly be a balance here, but at least you now have some additional knowledge.

Deep Reach Tooling (aka Reduced Neck "RN" Tooling)

We maintain and stock an extensive selection of reduced neck tooling to assist in any of the aforementioned circumstances. It is essential to keep in mind that the diameter of the neck is slightly smaller than the cutting diameter of the tool; thus, these types of tools allow for deeper penetration without causing wall rubbing. Furthermore, we smoothly integrate the length of cut (L1) transition into the neck, minimizing the presence of witness lines during wall machining.

TIP | The "LBS" measurement (as shown in Fig. 6), which stands for "length below shank", is the maximum depth that the necked tool may be sent with-out making contact with the wall. This LBS measurement (L2) can be found throughout this catalog. **LBS = Maximum Tool Reach**

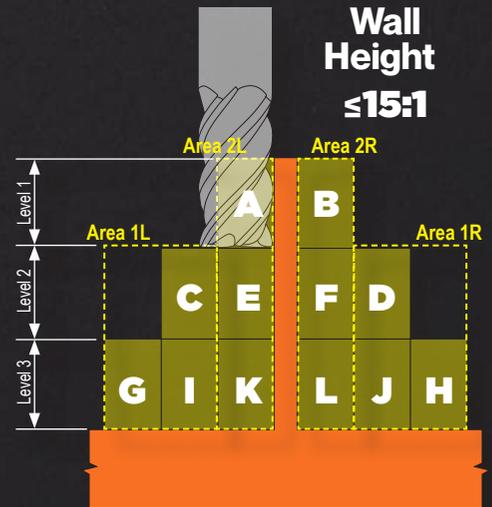


Fig. 4 - Material Removal Strategy $\leq 15:1$

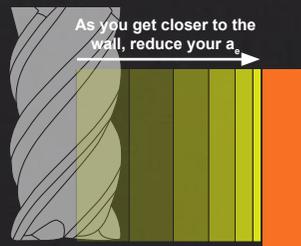


Fig. 5 - Radial DOC (a_e) Strategy

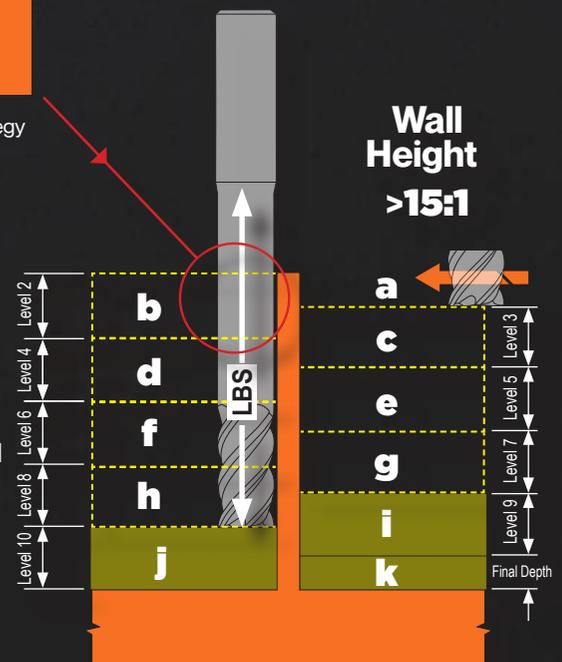


Fig. 6 - Material Removal Strategy $>15:1$

DRILLING 101

The process of drilling, renowned for its exceptional metal removal rates and

At Core Cutter, we manufacture many custom drill and step drill solutions for our customers. Give us a call, and we can help you with hole-making. We have successfully manufactured coolant-fed and non-coolant fed drills, as well as complex form drills for combining multiple operations.

Remember, the drill's primary function is to rough-in (aka prep) the hole, while the reamer primarily fulfills the final print criteria. Recent years, however, have seen significant improvements in high-performance drills, which often eliminate the need for a reaming operation entirely, depending on your hole tolerance requirements.

Drill Back Taper - Only at the transition from the point angle to the outside diameter does a drill bit meet its designed diameter. After that, a back-taper (Fig. 1) falls off the OD, primarily to prevent rubbing and friction as it penetrates deeper into the material.

Knowing this important fact about a drill makes you aware of the following: you can only measure the cutting diameter of the drill from corner to corner. If there is no back-taper after the corner, your drill will experience increased friction and heat buildup, leading to a high likelihood of failure.

Point Angles - Drills come with a wide variety of point angles; as this feature completes all of the cutting, it's critical to choose the appropriate one for the material and task. To put it simply, softer materials need a greater (steeper) angle, and to hold up while drilling harder, tougher materials, a lower (flatter) angle will be required.

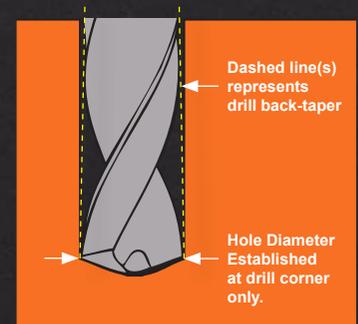
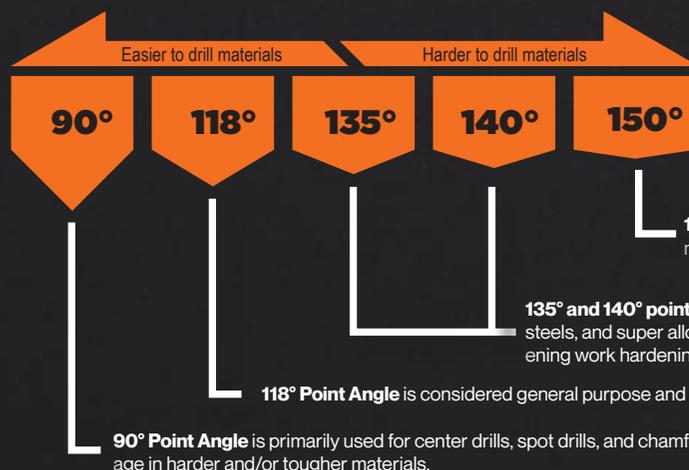


Fig. 1 - Drill Back-taper runs along entire flute length minimizing friction



Flat Bottom Drills

You can use flat-bottom drills for a wide range of drilling activities, including those on irregular surfaces, due to their adaptability. For example, you can use them to rectify mismatched holes, eliminate endmill dish debris and prior drill points, create spot face and counter bore characteristics, and even drill semi-circular holes (material on only one side of the tool) around the outside of a component. We often produce them as a custom-make for our customers.

150° point angles produce smaller chips and can be used for harder and stronger materials

135° and 140° point angles are designed and intended to drill your tougher steels, cast iron, stainless steels, and super alloys. This design assures maximum lip involvement in the earliest possible time, lessening work hardening and higher accuracy.

118° Point Angle is considered general purpose and commonly used to drill into materials like wood, plastics, and soft metals.

90° Point Angle is primarily used for center drills, spot drills, and chamfering. Its cutting edges are the longest and thus more susceptible to damage in harder and/or tougher materials.

Work Hardening - An inevitable consequence of drilling many alloyed materials, and we go into this topic further in depth in our materials section (pp. 78-82). If you drill too quickly without using adequate feed, you risk creating a dwelling effect, which may actually harden your material. If you're working with materials that have work-hardening properties, like stainless steel and super-alloys, it's better to keep your dwelling to a minimum since the harder you work with them, the more they harden!

Incorrect Hole Results - Important to remember, a drill is considered a roughing tool for the most part, so pulling in a tight and straight result may include running a reamer or boring tool into the hole to reach final print requirements.

Hole Oversizing - First and foremost, check the tool diameter at the point (this may sound funny, but the incorrect size could have been used). If the diameter is confirmed to be correct, consider the following as potential suspects:

- Excessive setup runout
- Unmatched spotting drill angle
- Uneven lip (i.e. point angle off-center)
- Poorly resharpened tool
- Suspect tool holder (pp. 76-77)
- Tool not on centerline (lathe)
- Improper speed & feed
- Chip evacuation issues
- Too long of a flute length (shorten flute)
- Workpiece Rigidity (p. 83)
- Ensure proper coolant flow or flush

Hole Undersizing - First and foremost, check the tool diameter at the point (this may sound funny, but the incorrect size could have been used). If the diameter is confirmed to be correct, consider the following as potential suspects:

- Ensure proper coolant flow or flush
- Beware, as this is a common occurrence when machining shape memory alloys (SMA). Copper-aluminum-nickel and nickel-titanium (NiTi) are the two most common shape memory alloys, but you can also create SMAs by alloying zinc, copper, gold, and iron. Titanium is a common culprit, but we also receive calls from people who are drilling soft polymers, which tend to compress after drilling.

favorable axial pressure, may become more challenging as it delves deeper!

Hole Straightness - Managing this can be challenging, particularly when using smaller drills that go deep. If you're experiencing problems, consider these.

- Excessive setup runout
- Unmatched spotting drill angle
- No pre-hole drilled with shorter tool
- Point not self-centering
- Too long of a flute length
- Low drill core strength
- Depth-to-diameter ratio excessive
- Drill wander cause by work hardening
- Re-cutting chips - better chip evacuation
- Suspect tool holder (see pp. 76-77)
- Tool not on centerline (lathe)
- Non-uniform starting position

Some Important Measurements - Since we produce a large number of step drills for our clients, we felt it would be prudent to address several crucial issues related to our tools and drilling in general. Let's start by discussing the metrics and how they vary from end mill measurements (Fig. 3).

• **Flute Length** - In drill terminology, flute length is different from actual cutting length. Mainly, this term denotes the area where the flute of the drill will "sweep out" the outer diameter of the tool. Since drills often have slower helixes, the sweep-out may be much more pronounced compared to end mills, where the washout is shorter. A drill's flute length ceases to cut once it reaches the functional cut depth.

• **Cutting Depth** - The length of the cut and the functional cut depth are usually considered equal. All of our prints, as shown in Fig. 3, properly mark the area the tool is cutting (yellow in this example, bold on our prints). Please specify the exact dimensions, angles, and edges you intend to cut on any unique tool quote requests you make.

• **Step length** - We measure this critical feature, as depicted in Detail A, starting from the tool's point (Opt. 1) or shoulder (Opt. 2) and continuing until the transition (radius or chamfer) that initiates the step angle. If you prefer another method of dimensioning for your tool, please let us know and we'll accommodate as best we can.

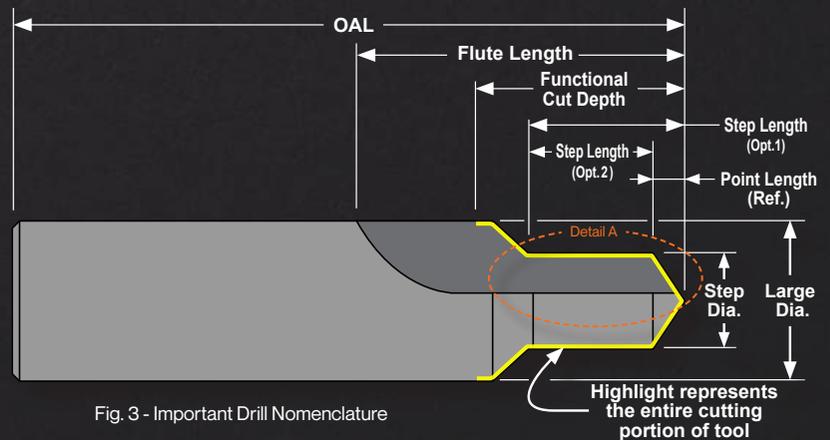


Fig. 3 - Important Drill Nomenclature

TIP Drilling Hints and Techniques

• **Free up the Point** - Employ drills with a center cutting point geometry, such as a split point or radius gash, to enhance accuracy and provide smoother cutting.

• **Spotting** - Use a spot drill for spotting that incorporates an angle greater than or equal to the point angle you are using. If your drill has a 140° point angle, then you should use either a 140° or 145° spot drill.

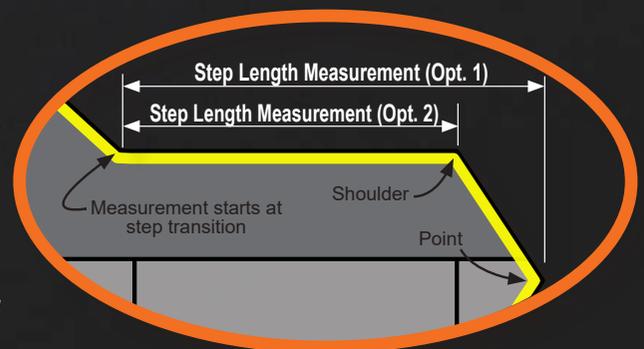
• **Speed & Feed Rule of Thumb** - Generally, the initial feed rate (V_f) for most solid carbide drills is set at .0012 per 1/16" of diameter. This might vary depending on the kind of material, but it's typically a decent place to start.

• **Step Tool (S&F basis)** - When assigning speeds and feeds to your step drill, base the feed (V_f) on the smallest diameter and the speed (RPM) on the largest diameter.

• **Call in the Pilot Drill** - To ensure the straightness and precision of your drilling when dealing with deep holes, it is highly recommended to first create a pilot hole that matches the diameter of the long drill and is 1-3 x diameter deep. This should stabilize the long drill inside the pilot hole, maintaining accuracy and straightness.

• **Deep Hole Suggestion** - For holes larger than 8xD, consider using parabolic flutes or coolant-fed drills, as they offer superior chip evacuation.

• **Tap Drill Sizes (Minor Dia. of Thread)** - Drill tap charts typically refer to a high-speed steel (HSS) drill that has a general-purpose point angle of 118° and is designed to drill a certain percentage oversize. However, many people are now using high-performance carbide drills, which significantly enhance hole quality and precision. The selection of the HP carbide drill diameter should be based on the tapped hole's "class of fit" (2B, 3B) and the desired H limit tolerance band. This will guide you to the appropriate carbide drill diameter that will achieve a drilling accuracy of +/- .0005 or higher and determine the minimum diameter of your thread.



Detail A - Closeup of Step Length Measurement

TOOL TROUBLESHOOTING

For your convenience, troubleshooting tips for our tools are included below.

Concern	Probable Cause	Possible Remedy
Breakage	Recheck your program	Often, we face a programming activity that positions the tool in a difficult or atypical scenario, usually culminating in failure. The tool functions only as a passenger, directed by the software and machine about its destination, method of travel, and speed. See page 72 for further information.
	Used and/or inadequately reground tool	Replace with a new or newly acquired and properly reground tool. See page 6 for more information about our reconditioning program.
	Excessive MRR	Either modify your tool path or alter your MRR (IPM, a_p , a_e) in order to effectively manage your MRR across the entire part, with particular attention to the confined machining areas. See page 87 for further information.
	Inadequate part entry	Change your part-entry approach. See page 91 for further solutions on this.
	Excessive tool overhang	Check your tool stick out, lessen your tool's length of cut, or move to a reduced neck tool for longer reach (see page 94 for long tool holder and reduced neck tips).
	Poor chip evacuation	The tool is re-cutting chips, and you need to manage the chip evacuation. Either change to a coolant through-tool (if you can) or reconfigure the coolant flush direction.
	Hand ground shank flat	Replace the tool with a factory ground shank flat, see page 7 for further information on shank configurations.
	Excessive Tool Runout	Recheck the T.I.R. shoot for a maximum of .0005 on the tool tip while in the holder, in the spindle.
	Excessive Length of Cut	Always utilize the shortest length of cut (L1) to reinforce and robusten the tool.
	Fixture and/or workpiece rigidity	A fixture setup and/or unsupported part feature can be a cause. See page 83 for further information.
	Tool holder security	Fully inspect the tool holder and tool holder components, clean and inspect the taper, and check to ensure a proper and undamaged pull stud. For example, one common suspect is a split or cracked collet nut (possibly look at changing to a bearing style nut). See pages 76–77 for further information.
Built-up Edge (BUE)	Feed rate is too low	Increase your feed rate (f_z), look at possible chip thinning techniques for leverage (see page 88).
	Insufficient coolant flush	There's a delicate balance to be struck here; too much and you risk creating a "vortex" around the tool, making it think you're giving it a lot of coverage when you're actually giving it very little, or just placing the coolant jet in the right place (with the chip thrown toward it rather than against it) to greatly increase its effectiveness.
	Low speed	Increase your RPM's to allow for more rotational force when throwing the chips further away from the tool. Of course, you have to be careful here due to the cornering and acceleration risks as noted on pages 89–90.
	Low coolant concentration	Increasing the lubricity of the water-soluble coolant (its concentration level) may aid in lowering the coefficient of friction on the tool and making chips glide more easily. Normal is 8-10%; maybe increase to 12-13% and see if this reduces your built-up edge (BUE).
	Type of milling	The forces of climb milling helps to clean the cutting edges as it's shearing the material upon each entry.
	No (or improper) tool coating	Low coefficient of friction tool coatings prevent materials from sticking to the surface. Check your tool's coating and make sure it is recommended for your component material. See page 3 for coating information.
Chatter & Vibration	Tool length or overhang too long	Consider a shorter tool and/or a shorter total tool overhang length, see page 94 for further information.
	Incorrect tool geometry for material	Make sure the proper tool is being used with a suitable material. We have a ton of choices for you to use, if you need our help selecting the proper tool just call us, we like helping!
	Excessive tool runout	Recheck the T.I.R. maximum of .0005 on the tool tip while in the holder, in the spindle.
	Excessive Speed	Lower your cutting speed (RPM) refer to our S&F charts throughout this catalog. If still an issue, then reduce your rpm's by 20% but maintain or increase chip load by a 10% increment.
	Excessive TEA	Downsize the tool diameter to alleviate any wall-to-wall radius match, increase the number of flutes to gain additional core strength.
	Part Feature Flexing	Reduce cutting parameters in these particular areas, refer to page 83 for further information.
	Fixturing rigidity	This may occur as a result of unobserved fixture movement (part bridging in vice, etc.); See page 83 for further information.
	Dull Tool	Replace with a new or newly acquired and properly reground tool. See page 6 for further information about our reconditioning program.
	Used and/or inadequately reground tool	Replace with a new or newly acquired and properly reground tool. See page 6 for further information about our reconditioning program.
	Tool holder issues	Fully inspect the tool holder and tool holder components, clean and inspect the taper, and check to ensure a proper and undamaged pull stud. For example, one common suspect is a split or cracked collet nut (possibly look at changing to a bearing style nut). See pages 76–77 for further tool holder information.
	Hand ground shank flat	Replace the tool with a factory ground shank flat, see page 7 for further information on shank configurations.
	Symmetrical tooling	Consider using our variable pitch design, which effectively disrupts harmonics. These can be found in our catalog and are typically represented with a "V" within their respective series nomenclature.
Tool "in-cut" un-stabilization	Occasionally, the tool will "bounce" because it is not sufficiently engaged in the cut. We advise raising your feed per tooth (f_z) and/or radial DOC (a_e) as needed. Once you get the tool settled in and stop the bouncing it should begin to quiet down and begin proper shearing of the material.	

TOOL TROUBLESHOOTING (Cont.)



207.588.7519



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Concern	Probable Cause	Possible Remedy
Corner Wear & Breakage	A used and/or inadequately reground tool	Replace with a new or newly acquired and properly reground tool. Many regrind solutions don't properly blend a corner radius with the tool O.D. and/or dub the cutting edge out to the radius building edge strength. See page 6 for more information on our excellent reconditioning program.
	Excessive Feed and/or Depth of Cut	A potential decrease in your feed rate and/or radial depth of cut to alleviate strain on the corner.
	Uncertainty in material hardness and condition	It is imperative to know your exact material condition and hardness. If you have cutting parameters for softer or easier material, then your corners will suffer when you machine harder or tougher materials. Knowing your material and hardness will help, find further information on this subject on pages 78–82.
	Excessive tool runout	Recheck the T.I.R. maximum of .0005 on the tool tip while in the holder, in the spindle.
	Fixture and/or workpiece rigidity	A fixture setup and/or unsupported part feature can be a cause, see page 83 for additional info.
	No corner protection	Square corner tools are the most susceptible to corner degradation. If possible, we recommend using tooling with a corner radius, which adds durability, strength, and tool life, as this geometry combined with a dub on the cutting edge (out to the corner) will give maximum tool strength.
	Too small of a corner radius	Making the tool's corner radius larger may be beneficial. For example, from a .030 to a .060 have helped many customers during roughing operations.
	Poor Tool Entry	The corners endure significant wear and tear, and the manner in which you introduced the tool to the material may have determined the fate of the corner from the beginning. See page 91 for preferred methods of entry.
Insufficient Finish	Edge build up	Inspect your radius closely, it may not have enough relief or been poorly blended with the O.D. proper radii manufacturer is key to optimum performance. Also, the tool may just need a bit more feed to clean that BUE off of it as its cutting.
	A used and/or inadequately reground tool	Replace with a new or newly acquired and properly reground tool. See page 6 for more information on our excellent reconditioning program.
	Too shallow of a radial depth cut (a_r)	We have found that if your radial depth of cut is too light the tool is rubbing more than shearing a chip. Increasing your radial depth of cut could help to increase your finish. More information on this can be found on this subject on page 93.
	Poor chip management	The tool is re-cutting chips, and you need to manage the chip evacuation. Either change to a coolant through-tool (if you can), add coolant grooves to the shank or reconfigure the coolant flush direction.
	Incorrect speed & feed	Lower feed rate (f_r) and increase speed (RPM)
	Possible incorrect flute count & helix angle	While not always applicable, there are instances when it is advantageous to reassess the quantity of flutes being used. Increasing the number of flutes, together with a greater helix, might result in a superior surface quality in some materials.
	Excessive Tool Runout	Recheck the T.I.R. maximum of .0005 on the tool tip while in the holder, in the spindle.
	Type of milling	Climb milling will traditionally give you a much better surface finish than conventional milling. Make sure you are climbing into the cut, which ensures a proper shearing of the chip.
Runout (Tool)	Fixture and/or workpiece rigidity	A fixture setup and/or unsupported part feature can be a cause, see page 83 for additional info.
	Rough Floor Finish	Re-evaluate the height of your scallop by maybe modifying the step-over amount (A_s); more can be found on this topic on page 93.
	Failing tool holder or tool holder components	Fully inspect the tool holder and tool holder components, clean and inspect the taper, and check to ensure a proper and undamaged pull stud. For example, one common suspect is a split or cracked collet nut (possibly look at changing to a bearing style nut). See pages 76–77 for further tool holder information.
	Machine tool spindle	Clean, inspect and possibly tru-up the machine spindle see pages 74–75 for more information.
	A used and/or inadequately reground tool	Replace with a new or newly acquired and properly reground tool. See page 6 for more information on our excellent reconditioning program.
Wall Taper	Hand ground shank flat	Replace the tool with a factory ground shank flat. See page 7 for more information on shank configurations.
	Tool shank not properly supported	We see this mainly when customers need more stick-out and decide to pull the shank forward, lowering the shank contact in the holder. Make sure you have at least 1.5 - 2.0 x Tool Diameter (typically) of full shank contact.
	Excessive tool overhang	Shorten up your tool OAL (L3) and/or LOC (L1) up to maximize rigidity
	Not having enough core strength	Adding to the flute count will strengthen the tool's core strength, helping to reduce tool deflection.
	Dual contact deflection	Contacting both the wall and the floor (and their connecting radius) includes multiple transitional forces and may result in deflection. We recommend milling the floor and wall separately and only touching the two when a blending operation is required, as well as lowering the MRR.
Runout (Tool)	Excessive tool runout	Recheck the T.I.R. maximum of .0005 on the tool tip while in the holder, in the spindle.
	Tool holder issues	Tool holder rigidity could be compromised Fully inspect the tool holder and tool holder components, clean and inspect the taper, and check to ensure a proper and undamaged pull stud. For example, one common suspect is a split or cracked collet nut. See pages 76–77 for further tool holder information.

HARDNESS CONVERSION CHART

A helpful guide following the relation between hardness and tensile strength.

Brinell Hardness	Rockwell Hardness			Tensile Strength	Brinell Hardness	Rockwell Hardness			Tensile Strength
	Tungsten Carbide Ball (3000 Kg)	A Scale 60 Kg	B Scale 100 Kg			C Scale 150 Hg	(Approx.) PSI	Tungsten Carbide Ball (3000 Kg)	
-	85.6	-	68.0	-	331	68.1	-	35.5	166,000
-	85.3	-	67.5	-	321	67.5	-	34.3	160,000
-	85.0	-	67.0	-	311	66.9	-	33.1	155,000
767	84.7	-	66.4	-	302	66.3	-	32.1	150,000
757	84.4	-	65.9	-	293	65.7	-	30.9	145,000
745	84.1	-	65.3	-	285	65.3	-	29.9	141,000
733	83.8	-	64.7	-	277	64.6	-	28.8	137,000
722	83.4	-	64.0	-	269	64.1	-	27.6	133,000
712	-	-	-	-	262	63.6	-	26.6	129,000
710	83.0	-	63.3	-	255	63.0	-	25.4	126,000
698	82.6	-	62.5	-	248	62.5	-	24.2	122,000
684	82.2	-	61.8	-	241	61.8	100.0	22.8	118,000
682	82.2	-	61.7	-	235	61.4	99.0	21.7	115,000
670	81.8	-	61.0	-	229	60.8	98.2	20.5	111,000
656	81.3	-	60.1	-	223	-	97.3	20.0	-
653	81.2	-	60.0	-	217	-	96.4	18.0	105,000
647	81.1	-	59.7	-	212	-	95.5	17.0	102,000
638	80.8	-	59.2	329,000	207	-	94.6	16.0	100,000
630	80.6	-	58.8	324,000	201	-	93.8	15.0	98,000
627	80.5	-	58.7	323,000	197	-	92.8	-	95,000
601	79.8	-	57.3	309,000	192	-	91.9	-	93,000
578	79.1	-	56.0	297,000	187	-	90.7	-	90,000
555	78.4	-	54.7	285,000	183	-	90.0	-	89,000
534	77.8	-	53.5	274,000	179	-	89.0	-	87,000
514	76.9	-	52.1	263,000	174	-	87.8	-	85,000
495	76.3	-	51.0	253,000	170	-	86.8	-	83,000
477	75.6	-	49.6	243,000	167	-	86.0	-	81,000
461	74.9	-	48.5	235,000	163	-	85.0	-	79,000
444	74.2	-	47.1	225,000	156	-	82.9	-	76,000
429	73.4	-	45.7	217,000	149	-	80.8	-	73,000
415	72.8	-	44.5	210,000	143	-	78.7	-	71,000
401	72.0	-	43.1	202,000	137	-	76.4	-	67,000
388	71.4	-	41.8	195,000	131	-	74.0	-	65,000
375	70.6	-	40.4	188,000	126	-	72.0	-	63,000
363	70.0	-	39.1	182,000	121	-	69.8	-	60,000
352	69.3	-	37.9	176,000	116	-	67.6	-	58,000
341	68.7	-	36.6	170,000	111	-	65.7	-	56,000

DECIMAL EQUIVALENT CHART

Interior decorating? We have these available in wall poster size 24" x 36".

	Imperial	Metric
1/64	.0156	0.397
.5 mm	.0197	0.500
1/32	.0313	0.794
1 mm	.0394	1.000
3/64	.0469	1.906
1/16	.0625	1.588
5/64	.0781	1.984
2 mm	.0787	2.000
3/32	.0938	2.381
7/64	.1094	2.778
3 mm	.1181	3.000
1/8	.1250	3.175
9/64	.1406	3.572
5/32	.1563	3.969
4 mm	.1575	4.000
11/64	.1719	4.366
3/16	.1875	4.763
5 mm	.1969	5.000
13/64	.2031	5.159
7/32	.2188	5.556
15/64	.2344	5.953
6 mm	.2362	6.000
1/4	.2500	6.350
17/64	.2656	6.747
7 mm	.2756	7.000
9/32	.2813	7.144
19/64	.2969	7.541
5/16	.3125	7.938
8 mm	.3150	8.000
21/64	.3281	8.334
11/32	.3438	8.731
9 mm	.3543	9.000
23/64	.3594	9.128
3/8	.3750	9.525
25/64	.3906	9.922
10 mm	.3937	10.000
13/32	.4063	10.319
27/64	.4219	10.716
11 mm	.4331	11.000
7/16	.4375	11.113
29/64	.4531	11.509
15/32	.4688	11.906
12 mm	.4724	12.000
31/64	.4844	12.303
1/2	.5000	12.700

	Imperial	Metric
13 mm	.5118	13.000
33/64	.5156	13.097
17/32	.5313	13.494
35/64	.5469	13.891
14 mm	.5512	14.000
9/16	.5625	14.288
37/64	.5781	14.684
15 mm	.5906	15.000
19/32	.5938	15.081
39/64	.6094	15.478
5/8	.6250	15.875
16 mm	.6299	16.000
41/64	.6406	16.272
21/32	.6563	16.669
17 mm	.6693	17.000
43/64	.6719	17.066
11/16	.6875	17.463
45/64	.7031	17.859
18 mm	.7087	18.000
23/32	.7188	18.256
47/64	.7344	18.653
19 mm	.7480	19.000
3/4	.7500	19.050
49/64	.7656	19.447
25/32	.7813	19.844
20 mm	.7874	20.000
51/64	.7969	20.241
13/16	.8125	20.638
21 mm	.8268	21.000
53/64	.8281	21.034
27/32	.8438	21.431
55/64	.8594	21.828
22 mm	.8661	22.000
7/8	.8750	22.225
57/64	.8906	22.622
23 mm	.9055	23.000
29/32	.9063	23.019
59/64	.9219	23.416
15/16	.9375	23.813
24 mm	.9449	24.000
61/64	.9531	24.209
31/32	.9688	24.606
25 mm	.9843	25.000
63/64	.9844	25.003
1	1.0000	25.400

TOOL TEST REPORT

We have a PDF of this available to use, call us!



207.588.7519



techsupport@corecutterusa.com

Core Cutter Sales Rep: _____ Date Tool Ordered: _____ Scheduled Test Date: _____

Order Type: Guaranteed Test Order (GTO): _____ Discounted Test Order: _____ Free of Charge: _____

PO #: _____ PO#: _____ Inv #: _____

Customer Information

Distributor: _____ End User: _____

Distributor Rep: _____ End User Contact: _____

Address: _____ City: _____ State: _____ Address: _____ City: _____ State: _____

Phone Number: () _____ Phone Number: () _____

Email: _____ Email: _____

Project Information

Material: _____ Condition: _____ Hardness: _____ Repeat or New Job? _____

Part Name: _____ Part Number: _____ Amount Mfg'd Annually: _____

Machine Tool Information

Machine Brand/Model: _____ HMC or VMC: _____ Max RPM's: _____

Spindle Type/Size: _____ Spindle Condition: _____

Tool Holder Information

Tool Holder Type: _____ Condition: _____ Balanced: _____ Proper Pull Stud: _____

Programming Information

Cam System Used: _____ Tool Path Type Used: _____ HEM or Traditional: _____

Testing Objective

Longer Tool Life: _____ Improved # Parts per Tool: _____ Better Part Finish: _____ Lower Cost per Part: _____ MADE in USA Brand: _____

Testing Information		Current Tool	Core Cutter	
Tool Info	Brand			
	EDP#			
	Lot #			
	New Tool or Reground Tool			
Tool Information	Cutting Diameter (D2)			
	Number of Flutes (z)			
	Length of Cut (L1)			
	Length Below Shank (L2)			
	Overall Length (L3)			
	Tool Coating			
	Tool Corner Condition (Sq, Radi, Chamfer)			
	Shank Config (Weldon/Flat/Safelock etc.)			
	Tool Projection (from gage line)			
Cutting Parameters	RPM's			
	IPT			
	IPM			
	Radial Depth of Cut (a _r)			
	Axial Depth of Cut (a _p)			
Test Results	Number of Parts per Tool			
	Cu. or Linear Inches per Tool			
	Minutes per Tool			
	Surface Finish Result			

EDP PAGE FINDER

Trying to find a needle in a haystack is like embarking on a medieval quest armed with nothing but determination and a

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118101	57	201010	33	201620N	35	202300	33	203211	34	203800	35
118111	57	201011	34	201621	36	202301	34	203220	33	203801	36
118112	20	201020	33	201621N	36	202310	33	203221	34	203810	35
118201	57	201021	34	201630	35	202311	34	203230	33	203811	36
118211	57	201030	33	201630N	35	202320	33	203231	34	203820	35
118212	20	201031	34	201631	36	202321	34	203240	33	203821	36
118301	57	201040	33	201631N	36	202340	33	203241	34	203830	35
118311	57	201041	34	201640	35	202341	34	203300	33	203831	36
118312	20	201100	33	201640N	35	202600N	35	203301	34	203840	35
200000	33	201101	34	201641	36	202601N	36	203310	33	203841	36
200001	34	201110	33	201641N	36	202610N	35	203311	34	203900	35
200010	33	201111	34	201700	35	202611N	36	203320	33	203901	36
200011	34	201120	33	201701	36	202620N	35	203321	34	203910	35
200040	33	201121	34	201710	35	202621N	35	203330	33	203911	36
200041	34	201130	33	201711	36	202640N	35	203331	34	203920	35
200100	33	201131	34	201720	35	202641N	36	203340	33	203921	36
200101	34	201140	33	201721	36	202800	35	203341	34	203930	35
200110	33	201141	34	201730	35	202801	36	203400	33	203931	36
200111	34	201200	33	201731	36	202810	35	203401	34	203940	35
200140	33	201201	34	201740	35	202811	36	203410	33	203941	36
200141	34	201210	33	201741	36	202820	35	203411	34	205000	33
200200	33	201211	34	201800	35	202821	36	203420	33	205001	34
200201	34	201220	33	201801	36	202840	35	203421	34	205010	33
200210	33	201221	34	201810	35	202841	36	203430	33	205011	34
200211	34	201230	33	201811	36	203000	33	203431	34	205020	33
200240	33	201231	34	201820	35	203001	34	203440	33	205021	34
200241	34	201240	33	201821	36	203010	33	203441	34	205030	33
200700	35	201241	34	201830	35	203011	34	203600N	35	205031	34
200701	36	201300	33	201831	36	203020	33	203601N	36	205040	33
200710	35	201301	34	201840	35	203021	34	203610N	35	205041	34
200711	36	201310	33	201841	36	203030	33	203611N	36	205050	33
200740	35	201311	34	202100	33	203031	34	203620N	35	205051	34
200741	36	201320	33	202101	34	203040	33	203621N	36	205100	33
200800	35	201321	34	202110	33	203041	34	203630N	35	205101	34
200801	36	201330	33	202111	34	203100	33	203631N	36	205110	33
200810	35	201331	34	202120	33	203101	34	203640N	35	205111	34
200811	36	201340	33	202121	34	203110	33	203641N	36	205120	33
200840	35	201341	34	202140	33	203111	34	203700	35	205121	34
200841	36	201600	35	202141	34	203120	33	203701	36	205130	33
200900	35	201600N	35	202200	33	203121	34	203710	35	205131	34
200901	36	201601	36	202201	34	203130	33	203711	36	205140	33
200910	35	201601N	36	202210	33	203131	34	203720	35	205141	34
200911	36	201610	35	202211	34	203140	33	203721	36	205150	33
200940	35	201610N	35	202220	33	203141	34	203730	35	205151	34
200941	36	201611	36	202221	34	203200	33	203731	36	205200	33
201000	33	201611N	36	202240	33	203201	34	203740	35	205201	34
201001	34	201620	35	202241	34	203210	33	203741	36	205210	33

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questionable sense of optimism. You stare at that haystack and think, 'Surely, the needle couldn't have rolled too far.' Little

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205211	34	205631	36	205800-BLK	35	206110	33	206720-BLK	35	207030	33
205220	33	205631N	36	205801	36	206111	34	206721	36	207031	34
205221	34	205640	35	205801-BLK	36	206120	33	206721-BLK	36	207040	33
205230	33	205640N	35	205810	35	206121	34	206730	35	207041	34
205231	34	205641	36	205810-BLK	35	206130	33	206730-BLK	35	207100	33
205240	33	205641N	36	205811	36	206131	34	206731	36	207101	34
205241	34	205650	35	205811-BLK	36	206140	33	206731-BLK	36	207110	33
205250	33	205650N	35	205820	35	206141	34	206740	35	207111	34
205251	34	205651	36	205820-BLK	35	206200	33	206740-BLK	35	207120	33
205300	33	205651N	36	205821	36	206201	34	206741	36	207121	34
205301	34	205700	35	205821-BLK	36	206210	33	206741-BLK	36	207130	33
205310	33	205700-BLK	35	205830	35	206211	34	206800	35	207131	34
205311	34	205700N	35	205830-BLK	35	206220	33	206800-BLK	35	207140	33
205320	33	205701	36	205831	36	206221	34	206801	36	207141	34
205321	34	205701-BLK	36	205831-BLK	36	206230	33	206801-BLK	36	207200	33
205330	33	205701N	36	205840	35	206231	34	206810	35	207201	34
205331	34	205710	35	205840-BLK	35	206240	33	206810-BLK	35	207210	33
205340	33	205710-BLK	35	205841	36	206241	34	206811	36	207211	34
205341	34	205710N	35	205841-BLK	36	206300	33	206811-BLK	36	207220	33
205350	33	205711	36	205850	35	206301	34	206820	35	207221	34
205351	34	205711-BLK	36	205850-BLK	35	206310	33	206820-BLK	35	207230	33
205400	33	205711N	36	205851	36	206311	34	206821	36	207231	34
205401	34	205720	35	205851-BLK	36	206320	33	206821-BLK	36	207240	33
205410	33	205720-BLK	35	205900	35	206321	34	206830	35	207241	34
205411	34	205720N	35	205901	36	206330	33	206830-BLK	35	207300	33
205420	33	205721	36	205910	35	206331	34	206831	36	207301	34
205421	34	205721-BLK	36	205911	36	206340	33	206831-BLK	36	207310	33
205430	33	205721N	36	205920	35	206341	34	206840	35	207311	34
205431	34	205730	35	205921	36	206400	33	206840-BLK	35	207320	33
205440	33	205730-BLK	35	205930	35	206401	34	206841	36	207321	34
205441	34	205730N	35	205931	36	206410	33	206841-BLK	36	207330	33
205450	33	205731	36	205940	35	206411	34	206900	35	207331	34
205451	34	205731-BLK	36	205941	36	206420	33	206901	36	207340	33
205600	35	205731N	36	205950	35	206421	34	206910	35	207341	34
205600N	35	205740	35	205951	36	206430	33	206911	36	207400	33
205601	36	205740-BLK	35	206000	33	206431	34	206920	35	207401	34
205601N	36	205740N	35	206001	34	206440	33	206921	36	207410	33
205610	35	205741	36	206010	33	206441	34	206930	35	207411	34
205610N	35	205741-BLK	36	206011	34	206700	35	206931	36	207420	33
205611	36	205741N	36	206020	33	206700-BLK	35	206940	35	207421	34
205611N	36	205750	35	206021	34	206701	36	206941	36	207430	33
205620	35	205750-BLK	35	206030	33	206701-BLK	36	207000	33	207431	34
205620N	35	205750N	35	206031	34	206710	35	207001	34	207440	33
205621	36	205751	36	206040	33	206710-BLK	35	207010	33	207441	34
205621N	36	205751-BLK	36	206041	34	206711	36	207011	34	207600N	35
205630	35	205751N	36	206100	33	206711-BLK	36	207020	33	207601N	36
205630N	35	205800	35	206101	34	206720	35	207021	34	207610N	35

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did you know, that haystack is the Bermuda Triangle for needles – they vanish into a realm of hay and mischief. You start the

EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.
20761N	36	207821	36	208331	34	208831	36	293201	34	300040	38
207620N	35	207821-BLK	36	208340	33	208831-BLK	36	293210	33	300041	39
207621N	36	207830	35	208341	34	208840	35	293211	34	300100	38
207630N	35	207830-BLK	35	208400	33	208840-BLK	35	293220	33	300101	39
207631N	36	207831	36	208401	34	208841	36	293221	34	300110	38
207640N	35	207831-BLK	36	208410	33	208841-BLK	36	293230	33	300110C	38
207641N	36	207840	35	208411	34	208900	35	293231	34	300111	39
207700	35	207840-BLK	35	208420	33	208901	36	293240	33	300111C	12
207700-BLK	35	207841	36	208421	34	208910	35	293241	34	300140	38
207700N	35	207841-BLK	36	208430	33	208911	36	295300	33	300141	39
207701	36	207900N	35	208431	34	208920	35	295301	34	300200	38
207701-BLK	36	207901N	36	208440	33	208921	36	295310	33	300201	39
207701N	36	207910N	35	208441	34	208930	35	295311	34	300210	38
207710	35	207911N	36	208700	35	208931	36	295320	33	300210C	38
207710-BLK	35	207920N	35	208700-BLK	35	208940	35	295321	34	300211	39
207710N	35	207921N	36	208701	36	208941	36	295330	33	300211C	12
207711	36	207930N	35	208701-BLK	36	210000	33	295331	34	300240	38
207711-BLK	36	207931N	36	208710	35	210001	34	295340	33	300241	39
207711N	36	207940N	35	208710-BLK	35	210010	33	295341	34	300700	40
207720	35	207941N	36	208711	36	210011	34	295350	33	300701	41
207720-BLK	35	208100	33	208711-BLK	36	210040	33	295351	34	300710	40
207720N	35	208101	34	208720	35	210041	34	296200	33	300711	41
207721	36	208110	33	208720-BLK	35	210100	33	296201	34	300740	40
207721-BLK	36	208111	34	208721	36	210101	34	296210	33	300741	41
207721N	36	208120	33	208721-BLK	36	210110	33	296211	34	300800	40
207730	35	208121	34	208730	35	210111	34	296220	33	300801	41
207730-BLK	35	208130	33	208730-BLK	35	210140	33	296221	34	300810	40
207730N	35	208131	34	208731	36	210141	34	296230	33	300811	41
207731	36	208140	33	208731-BLK	36	210200	33	296231	34	300840	40
207731-BLK	36	208141	34	208740	35	210201	34	296240	33	300841	41
207731N	36	208200	33	208740-BLK	35	210210	33	296241	34	300900	40
207740	35	208201	34	208741	36	210211	34	297100	33	300901	41
207740-BLK	35	208210	33	208741-BLK	36	210240	33	297101	34	300910	40
207740N	35	208211	34	208800	35	210241	34	297110	33	300911	41
207741	36	208220	33	208800-BLK	35	210700	35	297111	34	300940	40
207741-BLK	36	208221	34	208801	36	210701	36	297120	33	300941	41
207741N	36	208230	33	208801-BLK	36	210710	35	297121	34	301000	38
207800	35	208231	34	208810	35	210711	36	297130	33	301001	39
207800-BLK	35	208240	33	208810-BLK	35	210740	35	297131	34	301010	38
207801	36	208241	34	208811	36	210741	36	297140	33	301011	39
207801-BLK	36	208300	33	208811-BLK	36	210800	35	297141	34	301020	38
207810	35	208301	34	208820	35	210801	36	300000	38	301020C	38
207810-BLK	35	208310	33	208820-BLK	35	210810	35	300001	39	301021	39
207811	36	208311	34	208821	36	210811	36	300010	38	301021C	12
207811-BLK	36	208320	33	208821-BLK	36	210840	35	300010C	38	301030	38
207820	35	208321	34	208830	35	210841	36	300011	39	301031	39
207820-BLK	35	208330	33	208830-BLK	35	293200	33	300011C	12	301040	38

EDP PAGE FINDER (Cont.)

search with the confidence of a knight about to rescue a damsel in distress. Every straw becomes a potential needle, and

EDP#	Pg.										
301041	39	301621	41	302221C	12	303120	38	303431	39	303930	40
301100	38	301621N	41	302240	38	303120C	38	303435	38	303931	41
301101	39	301630	40	302241	39	303121	39	303436	39	303935	40
301110	38	301630N	40	302300	38	303121C	12	303440	38	303936	40
301111	39	301631	41	302301	39	303130	38	303441	39	303940	40
301120	38	301631N	41	302310	38	303131	39	303600N	40	303941	41
301120C	38	301640	40	302311	39	303135	38	303601N	41	305000	38
301121	39	301640N	40	302320	38	303136	39	303610N	40	305001	39
301121C	12	301641	41	302320C	38	303140	38	303611N	41	305010	38
301130	38	301641N	41	302321	39	303141	39	303620N	40	305011	39
301131	39	301700	40	302321C	12	303200	38	303621N	41	305020	38
301140	38	301701	41	302340	38	303201	39	303630N	40	305020C	38
301141	39	301710	40	302341	39	303210	38	303631N	41	305021	39
301200	38	301711	41	302600N	40	303211	39	303635N	40	305021C	12
301201	39	301720	40	302601N	41	303220	38	303636N	40	305030	38
301210	38	301721	41	302610N	40	303220C	38	303640N	40	305031	39
301211	39	301730	40	302611N	41	303221	39	303641N	41	305035	38
301220	38	301731	41	302620N	40	303221C	12	303700	40	305036	39
301220C	38	301740	40	302621N	40	303230	38	303701	41	305040	38
301221	39	301741	41	302640N	40	303231	39	303710	40	305041	39
301221C	12	301800	40	302641N	41	303235	38	303711	41	305050	38
301230	38	301801	41	302800	40	303236	39	303720	40	305051	39
301231	39	301810	40	302801	41	303240	38	303721	41	305100	38
301240	38	301811	41	302810	40	303241	39	303730	40	305101	39
301241	39	301820	40	302811	41	303300	38	303731	41	305110	38
301300	38	301821	41	302820	40	303301	39	303735	40	305111	39
301301	39	301830	40	302821	41	303310	38	303736	41	305120	38
301310	38	301831	41	302840	40	303311	39	303740	40	305120C	38
301311	39	301840	40	302841	41	303320	38	303741	41	305121	39
301320	38	301841	41	303000	38	303320C	38	303800	40	305121C	12
301320C	38	302100	38	303001	39	303321	39	303801	41	305130	38
301321	39	302101	39	303010	38	303321C	12	303810	40	305131	39
301321C	12	302110	38	303011	39	303330	38	303811	41	305135	38
301330	38	302111	39	303020	38	303331	39	303820	40	305136	39
301331	39	302120	38	303020C	38	303335	38	303821	41	305140	38
301340	38	302120C	38	303021	39	303336	39	303830	40	305141	39
301341	39	302121	39	303021C	12	303340	38	303831	41	305150	38
301600	40	302121C	12	303030	38	303341	39	303835	40	305151	39
301600N	40	302140	38	303031	39	303400	38	303836	40	305200	38
301601	41	302141	39	303035	38	303401	39	303840	40	305201	39
301601N	41	302200	38	303036	39	303410	38	303841	41	305210	38
301610	40	302201	39	303040	38	303411	39	303900	40	305211	39
301610N	40	302210	38	303041	39	303420	38	303901	41	305220	38
301611	41	302211	39	303100	38	303420C	38	303910	40	305220C	38
301611N	41	302220	38	303101	39	303421	39	303911	41	305221	39
301620	40	302220C	38	303110	38	303421C	12	303920	40	305221C	12
301620N	40	302221	39	303111	39	303430	38	303921	41	305230	38

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you find yourself negotiating with the hay as if it's a mythical creature guarding the precious metallic treasure. 'Come on,

EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.
305231	39	305620	40	305736	41	305920	40	306226	39	306726	41
305235	38	305620N	40	305736-BLK	41	305921	41	306230	38	306726-BLK	41
305236	39	305621	41	305736N	41	305930	40	306231	39	306730	40
305240	38	305621N	41	305740	40	305931	41	306240	38	306730-BLK	40
305241	39	305630	40	305740-BLK	40	305935	40	306241	39	306731	41
305250	38	305630N	40	305740N	40	305936	41	306300	38	306731-BLK	41
305251	39	305631	41	305741	41	305940	40	306301	39	306740	40
305300	38	305631N	41	305741-BLK	41	305941	41	306310	38	306740-BLK	40
305301	39	305635	40	305741N	41	305950	40	306310C	38	306741	41
305310	38	305635N	40	305750	40	305951	41	306311	39	306741-BLK	41
305311	39	305636	41	305750-BLK	40	306000	38	306311C	12	306800	40
305320	38	305636N	41	305750N	40	306001	39	306320	38	306800-BLK	40
305320C	38	305640	40	305751	41	306010	38	306321	39	306801	41
305321	39	305640N	40	305751-BLK	41	306010C	38	306325	38	306801-BLK	41
305321C	12	305641	41	305751N	41	306011	39	306326	39	306810	40
305330	38	305641N	41	305800	40	306011C	12	306330	38	306810-BLK	40
305331	39	305650	40	305800-BLK	40	306020	38	306331	39	306811	41
305335	38	305650N	40	305801	41	306021	39	306340	38	306811-BLK	41
305336	39	305651	41	305801-BLK	41	306025	38	306341	39	306820	40
305340	38	305651N	41	305810	40	306026	39	306400	38	306820-BLK	40
305341	39	305700	40	305810-BLK	40	306030	38	306401	39	306821	41
305350	38	305700-BLK	40	305811	41	306031	39	306410	38	306821-BLK	41
305351	39	305700N	40	305811-BLK	41	306040	38	306410C	38	306825	40
305400	38	305701	41	305820	40	306041	39	306411	39	306825-BLK	40
305401	39	305701-BLK	41	305820-BLK	40	306100	38	306411C	12	306826	41
305410	38	305701N	41	305821	41	306101	39	306420	38	306826-BLK	41
305411	39	305710	40	305821-BLK	41	306110	38	306421	39	306830	40
305420	38	305710-BLK	40	305830	40	306110C	38	306425	38	306830-BLK	40
305420C	38	305710N	40	305830-BLK	40	306111	39	306426	39	306831	41
305421	39	305711	41	305831	41	306111C	12	306430	38	306831-BLK	41
305421C	12	305711-BLK	41	305831-BLK	41	306120	38	306431	39	306840	40
305430	38	305711N	41	305835	40	306121	39	306440	38	306840-BLK	40
305431	39	305720	40	305835-BLK	40	306125	38	306441	39	306841	41
305435	38	305720-BLK	40	305836	41	306126	39	306700	40	306841-BLK	41
305436	39	305720N	40	305836-BLK	41	306130	38	306700-BLK	40	306900	40
305440	38	305721	41	305840	40	306131	39	306701	41	306901	41
305441	39	305721-BLK	41	305840-BLK	40	306140	38	306701-BLK	41	306910	40
305450	38	305721N	41	305841	41	306141	39	306710	40	306911	41
305451	39	305730	40	305841-BLK	41	306200	38	306710-BLK	40	306920	40
305600	40	305730-BLK	40	305850	40	306201	39	306711	41	306921	41
305600N	40	305730N	40	305850-BLK	40	306210	38	306711-BLK	41	306925	40
305601	41	305731	41	305851	41	306210C	38	306720	40	306926	41
305601N	41	305731-BLK	41	305851-BLK	41	306211	39	306720-BLK	40	306930	40
305610	40	305731N	41	305900	40	306211C	12	306721	41	306931	41
305610N	40	305735	40	305901	41	306220	38	306721-BLK	41	306940	40
305611	41	305735-BLK	40	305910	40	306221	39	306725	40	306941	41
305611N	41	305735N	40	305911	41	306225	38	306725-BLK	40	307000	38

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needle, show yourself. I promise I won't sew anything questionable with you". As time passes, your optimism transforms

EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.
307001	39	307320	38	307720-BLK	40	307900N	40	308321	39	308801	41
307010	38	307321	39	307720N	40	307901N	41	308325	38	308801-BLK	41
307010C	38	307325	38	307721	41	307910N	40	308326	39	308810	40
307011	39	307326	39	307721-BLK	41	307911N	41	308330	38	308810-BLK	40
307011C	12	307330	38	307721N	41	307920N	40	308331	39	308811	41
307020	38	307331	39	307725	40	307921N	41	308340	38	308811-BLK	41
307021	39	307340	38	307725-BLK	40	307925N	40	308341	39	308820	40
307025	38	307341	39	307725N	40	307926N	41	308400	38	308820-BLK	40
307026	39	307400	38	307726	41	307930N	40	308401	39	308821	41
307030	38	307401	39	307726-BLK	41	307931N	41	308410	38	308821-BLK	41
307031	39	307410	38	307726N	41	307940N	40	308410C	38	308825	40
307040	38	307410C	38	307730	40	307941N	41	308411	39	308825-BLK	40
307041	39	307411	39	307730-BLK	40	308100	38	308411C	12	308826	41
307100	38	307411C	12	307730N	40	308101	39	308420	38	308826-BLK	41
307101	39	307420	38	307731	41	308110	38	308421	39	308830	40
307110	38	307421	39	307731-BLK	41	308110C	38	308425	38	308830-BLK	40
307110C	38	307425	38	307731N	41	308111	39	308426	39	308831	41
307111	39	307426	39	307740	40	308111C	12	308430	38	308831-BLK	41
307111C	12	307430	38	307740-BLK	40	308120	38	308431	39	308840	40
307120	38	307431	39	307740N	40	308121	39	308440	38	308840-BLK	40
307121	39	307440	38	307741	41	308125	38	308441	39	308841	41
307125	38	307441	39	307741-BLK	41	308126	39	308700	40	308841-BLK	41
307126	39	307600N	40	307741N	41	308130	38	308700-BLK	40	308900	40
307130	38	307601N	41	307800	40	308131	39	308701	41	308901	41
307131	39	307610N	40	307800-BLK	40	308140	38	308701-BLK	41	308910	40
307140	38	307611N	41	307801	41	308141	39	308710	40	308911	41
307141	39	307620N	40	307801-BLK	41	308200	38	308710-BLK	40	308920	40
307200	38	307621N	41	307810	40	308201	39	308711	41	308921	41
307201	39	307625N	40	307810-BLK	40	308210	38	308711-BLK	41	308925	40
307210	38	307626N	41	307811	41	308210C	38	308720	40	308926	41
307210C	38	307630N	40	307811-BLK	41	308211	39	308720-BLK	40	308930	40
307211	39	307631N	41	307820	40	30821C	12	308721	41	308931	41
307211C	12	307640N	40	307820-BLK	40	308220	38	308721-BLK	41	308940	40
307220	38	307641N	41	307821	41	308221	39	308725	40	308941	41
307221	39	307700	40	307821-BLK	41	308225	38	308725-BLK	40	310000	38
307225	38	307700-BLK	40	307825	40	308226	39	308726	41	310001	39
307226	39	307700N	40	307825-BLK	40	308230	38	308726-BLK	41	310010	38
307230	38	307701	41	307826	41	308231	39	308730	40	310010C	38
307231	39	307701-BLK	41	307826-BLK	41	308240	38	308730-BLK	40	310011	39
307240	38	307701N	41	307830	40	308241	39	308731	41	310011C	12
307241	39	307710	40	307830-BLK	40	308300	38	308731-BLK	41	310040	38
307300	38	307710-BLK	40	307831	41	308301	39	308740	40	310041	39
307301	39	307710N	40	307831-BLK	41	308310	38	308740-BLK	40	310100	38
307310	38	307711	41	307840	40	308310C	38	308741	41	310101	39
307310C	38	307711-BLK	41	307840-BLK	40	308311	39	308741-BLK	41	310110	38
307311	39	307711N	41	307841	41	308311C	12	308800	40	310110C	38
307311C	12	307720	40	307841-BLK	41	308320	38	308800-BLK	40	310111	39

EDP PAGE FINDER (Cont.)

into a desperate game of 'Where's Waldo?' with a minuscule, metallic protagonist. You question your life choices and won-

EDP#	Pg.										
31011C	12	391240	38	397101	39	401141	46	402221C	14	403401	46
310140	38	391241	39	397110	38	401201	46	402241	46	403411	46
310141	39	393200	38	397110C	38	401211	46	402301	46	403416	46
310200	38	393201	39	397111	39	401216	46	402311	46	403421	46
310201	39	393210	38	397111C	12	401221	46	402321	46	403421C	14
310210	38	393211	39	397120	38	401221C	14	402321C	14	403431	46
310210C	38	393220	38	397121	39	401231	46	402341	46	403436	46
310211	39	393220C	38	397125	38	401241	46	402601N	47	403441	46
310211C	12	393221	39	397126	39	401301	46	402611N	47	403601N	47
310240	38	393221C	12	397130	38	401311	46	402621N	47	403611N	47
310241	39	393230	38	397131	39	401316	46	402641N	47	403616N	47
310700	40	393231	39	397140	38	401321	46	402801	47	403621N	47
310701	41	393235	38	397141	39	401321C	14	402811	47	403631N	47
310710	40	393236	39	400001	46	401331	46	402821	47	403636N	47
310711	41	393240	38	400011	46	401341	46	402841	47	403641N	47
310740	40	393241	39	400011C	14	401601	47	403001	46	403701	47
310741	41	395300	38	400041	46	401601N	47	403011	46	403711	47
310800	40	395301	39	400101	46	401611	47	403016	46	403716	47
310801	41	395310	38	400111	46	401611N	47	403021	46	403721	47
310810	40	395311	39	400111C	14	401616	47	403021C	14	403731	47
310811	41	395320	38	400141	46	401616N	47	403031	46	403736	47
310840	40	395320C	38	400201	46	401621	47	403036	46	403741	47
310841	41	395321	39	400211	46	401621N	47	403041	46	403801	47
387200	38	395321C	12	400211C	14	401631	47	403101	46	403811	47
387201	39	395330	38	400241	46	401631N	47	403111	46	403816	47
387210	38	395331	39	400701	47	401641	47	403116	46	403821	47
387210C	11	395335	38	400711	47	401641N	47	403121	46	403831	47
387211	39	395336	39	400741	47	401701	47	403121C	14	403836	47
387211C	12	395340	38	400801	47	401711	47	403131	46	403841	47
387220	38	395341	39	400811	47	401716	47	403136	46	403901	47
387221	39	395350	38	400841	47	401721	47	403141	46	403911	47
387225	38	395351	39	400901	47	401731	47	403201	46	403916	47
387226	39	396200	38	400911	47	401741	47	403211	46	403921	47
387230	38	396201	39	400941	47	401801	47	403216	46	403931	47
387231	39	396210	38	401001	46	401811	47	403221	46	403936	47
387240	38	396210C	38	401011	46	401816	47	403221C	14	403941	47
387241	39	396211	39	401016	46	401821	47	403231	46	405001	46
391200	38	396211C	12	401021	46	401831	47	403236	46	405011	46
391201	39	396220	38	401021C	14	401841	47	403241	46	405021	46
391210	38	396221	39	401031	46	402101	46	403301	46	405021C	14
391211	39	396225	38	401041	46	402111	46	403311	46	405031	46
391220	38	396226	39	401101	46	402121	46	403316	46	405036	46
391220C	38	396230	38	401111	46	402121C	14	403321	46	405041	46
391221	39	396231	39	401116	46	402141	46	403321C	14	405051	46
391221C	12	396240	38	401121	46	402201	46	403331	46	405101	46
391230	38	396241	39	401121C	14	402211	46	403336	46	405111	46
391231	39	397100	38	401131	46	402221	46	403341	46	405121	46

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der if finding that needle is the universe's way of testing your problem-solving skills. Friends offer advice like 'Use a magnet.'

EDP#	Pg.										
40512C	14	405711-BLK	47	40611C	14	406831-BLK	47	407626N	47	408211	46
405131	46	405711N	47	406121	46	406841	47	407631N	47	408211C	14
405136	46	405721	47	406126	46	406841-BLK	47	407641N	47	408221	46
405141	46	405721-BLK	47	406131	46	406901	47	407701	47	408226	46
405151	46	405721N	47	406141	46	406911	47	407701-BLK	47	408231	46
405201	46	405731	47	406201	46	406921	47	407701N	47	408241	46
405211	46	405731-BLK	47	406211	46	406926	47	407711	47	408301	46
405221	46	405731N	47	406211C	14	406931	47	407711-BLK	47	408311	46
405221C	14	405736	47	406221	46	406941	47	407711N	47	408311C	14
405231	46	405736-BLK	47	406226	46	407001	46	407721	47	408321	46
405236	46	405736N	47	406231	46	407011	46	407721-BLK	47	408326	46
405241	46	405741	47	406241	46	407011C	14	407721N	47	408331	46
405251	46	405741-BLK	47	406301	46	407021	46	407726	47	408341	46
405301	46	405741N	47	406311	46	407026	46	407726-BLK	47	408401	46
405311	46	405751	47	406311C	14	407031	46	407726N	47	408411	46
405321	46	405751-BLK	47	406321	46	407041	46	407731	47	408411C	14
405321C	14	405751N	47	406326	46	407101	46	407731-BLK	47	408421	46
405331	46	405801	47	406331	46	407111	46	407731N	47	408426	46
405336	46	405801-BLK	47	406341	46	407111C	14	407741	47	408431	46
405341	46	405811	47	406401	46	407121	46	407741-BLK	47	408441	46
405351	46	405811-BLK	47	406411	46	407126	46	407741N	47	408701	47
405401	46	405821	47	406411C	14	407131	46	407801	47	408701-BLK	47
405411	46	405821-BLK	47	406421	46	407141	46	407801-BLK	47	408711	47
405421	46	405831	47	406426	46	407201	46	407811	47	408711-BLK	47
405421C	14	405831-BLK	47	406431	46	407211	46	407811-BLK	47	408721	47
405431	46	405836	47	406441	46	407211C	14	407821	47	408721-BLK	47
405436	46	405836-BLK	47	406701	47	407221	46	407821-BLK	47	408726	47
405441	46	405841	47	406701-BLK	47	407226	46	407826	47	408726-BLK	47
405451	46	405841-BLK	47	406711	47	407231	46	407826-BLK	47	408731	47
405601	47	405851	47	406711-BLK	47	407241	46	407831	47	408731-BLK	47
405601N	47	405851-BLK	47	406721	47	407301	46	407831-BLK	47	408741	47
405611	47	405901	47	406721-BLK	47	407311	46	407841	47	408741-BLK	47
405611N	47	405911	47	406726	47	407311C	14	407841-BLK	47	408801	47
405621	47	405921	47	406726-BLK	47	407321	46	407901N	47	408801-BLK	47
405621N	47	405931	47	406731	47	407326	46	407911N	47	408811	47
405631	47	405936	47	406731-BLK	47	407331	46	407921N	47	408811-BLK	47
405631N	47	405941	47	406741	47	407341	46	407926N	47	408821	47
405636	47	405951	47	406741-BLK	47	407401	46	407931N	47	408821-BLK	47
405636N	47	406001	46	406801	47	407411	46	407941N	47	408826	47
405641	47	406011	46	406801-BLK	47	407411C	14	408101	46	408826-BLK	47
405641N	47	406011C	14	406811	47	407421	46	408111	46	408831	47
405651	47	406021	46	406811-BLK	47	407426	46	408111C	14	408831-BLK	47
405651N	47	406026	46	406821	47	407431	46	408121	46	408841	47
405701	47	406031	46	406821-BLK	47	407441	46	408126	46	408841-BLK	47
405701-BLK	47	406041	46	406826	47	407601N	47	408131	46	408901	47
405701N	47	406101	46	406826-BLK	47	407611N	47	408141	46	408911	47
405711	47	406111	46	406831	47	407621N	47	408201	46	408921	47

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as if you have a needle-seeking missile launcher just lying around. Eventually, when you least expect it, there it is – the

EDP#	Pg.										
408926	47	493236	46	501016	51	501821	52	503231	51	505001	51
408931	47	493241	46	501021	51	501831	52	503236	51	505011	51
408941	47	495301	46	501021C	16	501841	52	503241	51	505021	51
410001	46	495311	46	501031	51	502101	51	503301	51	505021C	16
410011	46	495321	46	501041	51	502111	51	503311	51	505031	51
410011C	14	495321C	14	501101	51	502121	51	503316	51	505036	51
410041	46	495331	46	501111	51	502121C	16	503321	51	505041	51
410101	46	495336	46	501116	51	502141	51	503321C	16	505051	51
410111	46	495341	46	501121	51	502201	51	503331	51	505101	51
410111C	14	495351	46	501121C	16	502211	51	503336	51	505111	51
410141	46	496201	46	501131	51	502221	51	503341	51	505121	51
410201	46	496211	46	501141	51	502221C	16	503401	51	505121C	16
410211	46	496211C	14	501201	51	502241	51	503411	51	505131	51
410211C	14	496221	46	501211	51	502301	51	503416	51	505136	51
410241	46	496226	46	501216	51	502311	51	503421	51	505141	51
410701	47	496231	46	501221	51	502321	51	503421C	16	505151	51
410711	47	496241	46	501221C	16	502321C	16	503431	51	505201	51
410741	47	497101	46	501231	51	502341	51	503436	51	505211	51
410801	47	497111	46	501241	51	502601N	52	503441	51	505221	51
410811	47	497111C	14	501301	51	502611N	52	503601N	52	505221C	16
410841	47	497121	46	501311	51	502621N	52	503611N	52	505231	51
473121	22	497126	46	501316	51	502641N	52	503616N	52	505236	51
473221	22	497131	46	501321	51	502801	52	503621N	52	505241	51
475221	22	497141	46	501321C	16	502811	52	503631N	52	505251	51
475326	22	500001	51	501331	51	502821	52	503636N	52	505301	51
477126	22	500011	51	501341	51	502841	52	503641N	52	505311	51
477226	22	500011C	16	501601	52	503001	51	503701	52	505321	51
487201	46	500041	51	501601N	52	503011	51	503711	52	505321C	16
487211	46	500101	51	501611	52	503016	51	503716	52	505331	51
487211C	14	500111	51	501611N	52	503021	51	503721	52	505336	51
487221	46	500111C	16	501616	52	503021C	16	503731	52	505341	51
487226	46	500141	51	501616N	52	503031	51	503736	52	505351	51
487231	46	500201	51	501621	52	503036	51	503741	52	505401	51
487241	46	500211	51	501621N	52	503041	51	503801	52	505411	51
491201	46	500211C	16	501631	52	503101	51	503811	52	505421	51
491211	46	500241	51	501631N	52	503111	51	503816	52	505421C	16
491216	46	500701	52	501641	52	503116	51	503821	52	505431	51
491221	46	500711	52	501641N	52	503121	51	503831	52	505436	51
491221C	14	500741	52	501701	52	503121C	16	503836	52	505441	51
491231	46	500801	52	501711	52	503131	51	503841	52	505451	51
491241	46	500811	52	501716	52	503136	51	503901	52	505601	52
493201	46	500841	52	501721	52	503141	51	503911	52	505601N	52
493211	46	500901	52	501731	52	503201	51	503916	52	505611	52
493216	46	500911	52	501741	52	503211	51	503921	52	505611N	52
493221	46	500941	52	501801	52	503216	51	503931	52	505621	52
493221C	14	501001	51	501811	52	503221	51	503936	52	505621N	52
493231	46	501011	51	501816	52	503221C	16	503941	52	505631	52

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elusive needle, peeking out from the hay as if to say, 'Gotcha!' You triumphantly hold it up, feeling like you've conquered a

EDP#	Pg.										
505631N	52	505941	52	506741	52	507341	51	507926N	52	508821	52
505636	52	505951	52	506741-BLK	52	507401	51	507931N	52	508821-BLK	52
505636N	52	506001	51	506801	52	507411	51	507941N	52	508826	52
505641	52	506011	51	506801-BLK	52	507411C	16	508101	51	508826-BLK	52
505641N	52	506011C	16	506811	52	507421	51	508111	51	508831	52
505651	52	506021	51	506811-BLK	52	507426	51	508111C	16	508831-BLK	52
505651N	52	506026	51	506821	52	507431	51	508121	51	508841	52
505701	52	506031	51	506821-BLK	52	507441	51	508126	51	508841-BLK	52
505701-BLK	52	506041	51	506826	52	507601N	52	508131	51	508901	52
505701N	52	506101	51	506826-BLK	52	507611N	52	508141	51	508911	52
505711	52	506111	51	506831	52	507621N	52	508201	51	508921	52
505711-BLK	52	506111C	16	506831-BLK	52	507626N	52	508211	51	508926	52
505711N	52	506121	51	506841	52	507631N	52	508211C	16	508931	52
505721	52	506126	51	506841-BLK	52	507641N	52	508221	51	508941	52
505721-BLK	52	506131	51	506901	52	507701	52	508226	51	510001	51
505721N	52	506141	51	506911	52	507701-BLK	52	508231	51	510011	51
505731	52	506201	51	506921	52	507701N	52	508241	51	510011C	16
505731-BLK	52	506211	51	506926	52	507711	52	508301	51	510041	51
505731N	52	506211C	16	506931	52	507711-BLK	52	508311	51	510101	51
505736	52	506221	51	506941	52	507711N	52	508311C	16	510111	51
505736-BLK	52	506226	51	507001	51	507721	52	508321	51	510111C	16
505736N	52	506231	51	507011	51	507721-BLK	52	508326	51	510141	51
505741	52	506241	51	507011C	16	507721N	52	508331	51	510201	51
505741-BLK	52	506301	51	507021	51	507726	52	508341	51	510211	51
505741N	52	506311	51	507026	51	507726-BLK	52	508401	51	510211C	16
505751	52	506311C	16	507031	51	507726N	52	508411	51	510241	51
505751-BLK	52	506321	51	507041	51	507731	52	508411C	16	510701	52
505751N	52	506326	51	507101	51	507731-BLK	52	508421	51	510711	52
505801	52	506331	51	507111	51	507731N	52	508426	51	510741	52
505801-BLK	52	506341	51	507111C	16	507741	52	508431	51	510801	52
505811	52	506401	51	507121	51	507741-BLK	52	508441	51	510811	52
505811-BLK	52	506411	51	507126	51	507741N	52	508701	52	510841	52
505821	52	506411C	16	507131	51	507801	52	508701-BLK	52	540001	49
505821-BLK	52	506421	51	507141	51	507801-BLK	52	508711	52	540201	49
505831	52	506426	51	507201	51	507811	52	508711-BLK	52	545301	49
505831-BLK	52	506431	51	507211	51	507811-BLK	52	508721	52	546201	49
505836	52	506441	51	507211C	16	507821	52	508721-BLK	52	547101	49
505836-BLK	52	506701	52	507221	51	507821-BLK	52	508726	52	550001	49
505841	52	506701-BLK	52	507226	51	507826	52	508726-BLK	52	550201	49
505841-BLK	52	506711	52	507231	51	507826-BLK	52	508731	52	551001	49
505851	52	506711-BLK	52	507241	51	507831	52	508731-BLK	52	551101	49
505851-BLK	52	506721	52	507301	51	507831-BLK	52	508741	52	551201	49
505901	52	506721-BLK	52	507311	51	507841	52	508741-BLK	52	552101	49
505911	52	506726	52	507311C	16	507841-BLK	52	508801	52	552201	49
505921	52	506726-BLK	52	507321	51	507901N	52	508801-BLK	52	553001	49
505931	52	506731	52	507326	51	507911N	52	508811	52	553201	49
505936	52	506731-BLK	52	507331	51	507921N	52	508811-BLK	52	553301	49

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mythical beast. The haystack may have won a few battles, but in the end, you emerged victorious, armed with a needle and

EDP#	Pg.	EDP#	Pg.								
555001	49	596201	51	601211	54	602301	54	603416	54	605136	54
555101	49	596211	51	601216	54	602311	54	603421	54	605141	54
555201	49	596211C	16	601221	54	602321	54	603421C	18	605151	54
555401	49	596221	51	601221C	18	602321C	18	603431	54	605201	54
556001	49	596226	51	601231	54	602341	54	603436	54	605211	54
556101	49	596231	51	601241	54	602601N	55	603441	54	605221	54
556301	49	596241	51	601301	54	602611N	55	603601N	55	605221C	18
556401	49	597101	51	601311	54	602621N	55	603611N	55	605231	54
557001	49	597111	51	601316	54	602641N	55	603616N	55	605236	54
557201	49	597111C	16	601321	54	602801	55	603621N	55	605241	54
557301	49	597121	51	601321C	18	602811	55	603631N	55	605251	54
573121	22	597126	51	601331	54	602821	55	603636N	55	605301	54
573221	22	597131	51	601341	54	602841	55	603641N	55	605311	54
575221	22	597141	51	601601	55	603001	54	603701	55	605321	54
575326	22	600001	54	601601N	55	603011	54	603711	55	605321C	18
577126	22	600011	54	601611	55	603016	54	603716	55	605331	54
577226	22	600041	54	601611N	55	603021	54	603721	55	605336	54
587201	51	600101	54	601616	55	603021C	18	603731	55	605341	54
587211	51	600111	54	601616N	55	603031	54	603736	55	605351	54
587211C	16	600141	54	601621	55	603036	54	603741	55	605401	54
587221	51	600201	54	601621N	55	603041	54	603801	55	605411	54
587226	51	600211	54	601631	55	603101	54	603811	55	605421	54
587231	51	600241	54	601631N	55	603111	54	603816	55	605421C	18
587241	51	600701	55	601641	55	603116	54	603821	55	605431	54
591201	51	600711	55	601641N	55	603121	54	603831	55	605436	54
591211	51	600741	55	601701	55	603121C	18	603836	55	605441	54
591216	51	600801	55	601711	55	603131	54	603841	55	605451	54
591221	51	600811	55	601716	55	603136	54	603901	55	605601	55
591221C	16	600841	55	601721	55	603141	54	603911	55	605601N	55
591231	51	600901	55	601731	55	603201	54	603916	55	605611	55
591241	51	600911	55	601741	55	603211	54	603921	55	605611N	55
593201	51	600941	55	601801	55	603216	54	603931	55	605621	55
593211	51	601001	54	601811	55	603221	54	603936	55	605621N	55
593216	51	601011	54	601816	55	603221C	18	603941	55	605631	55
593221	51	601016	54	601821	55	603231	54	605001	54	605631N	55
593221C	16	601021	54	601831	55	603236	54	605011	54	605636	55
593231	51	601021C	18	601841	55	603241	54	605021	54	605636N	55
593236	51	601031	54	602101	54	603301	54	605021C	18	605641	55
593241	51	601041	54	602111	54	603311	54	605031	54	605641N	55
595301	51	601101	54	602121	54	603316	54	605036	54	605651	55
595311	51	601111	54	602121C	18	603321	54	605041	54	605651N	55
595321	51	601116	54	602141	54	603321C	18	605051	54	605701	55
595321C	16	601121	54	602201	54	603331	54	605101	54	605701-BLK	55
595331	51	601121C	18	602211	54	603336	54	605111	54	605701N	55
595336	51	601131	54	602221	54	603341	54	605121	54	605711	55
595341	51	601141	54	602221C	18	603401	54	605121C	18	605711-BLK	55
595351	51	601201	54	602241	54	603411	54	605131	54	605711N	55

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a newfound appreciation for the challenges of haystack exploration." Verily, herein doth lie one of the main reasons

EDP#	Pg.	EDP#	Pg.								
605721	55	606126	54	606841-BLK	55	607641N	55	608226	54	610001	54
605721-BLK	55	606131	54	606901	55	607701	55	608231	54	610011	54
605721N	55	606141	54	606911	55	607701N	55	608241	54	610011C	18
605731	55	606201	54	606921	55	607711	55	608301	54	610041	54
605731-BLK	55	606211	54	606926	55	607711-BLK	55	608311	54	610101	54
605731N	55	606211C	18	606931	55	607711N	55	608311C	18	610111	54
605736	55	606221	54	606941	55	607721	55	608321	54	610111C	18
605736-BLK	55	606226	54	607001	54	607721-BLK	55	608326	54	610141	54
605736N	55	606231	54	607011	54	607721N	55	608331	54	610201	54
605741	55	606241	54	607011C	18	607726	55	608341	54	610211	54
605741-BLK	55	606301	54	607021	54	607726-BLK	55	608401	54	610211C	18
605741N	55	606311	54	607026	54	607726N	55	608411	54	610241	54
605751	55	606311C	18	607031	54	607731	55	608411C	18	610701	55
605751-BLK	55	606321	54	607041	54	607731-BLK	55	608421	54	610711	55
605751N	55	606326	54	607101	54	607731N	55	608426	54	610741	55
605801	55	606331	54	607111	54	607741	55	608431	54	610801	55
605801-BLK	55	606341	54	607111C	18	607741-BLK	55	608441	54	610811	55
605811	55	606401	54	607121	54	607741N	55	608701	55	610841	55
605811-BLK	55	606411	54	607126	54	607801	55	608701-BLK	55	687201	54
605821	55	606411C	18	607131	54	607801-BLK	55	608711	55	687211	54
605821-BLK	55	606421	54	607141	54	607811	55	608711-BLK	55	687211C	18
605831	55	606426	54	607201	54	607811-BLK	55	608721	55	687221	54
605831-BLK	55	606431	54	607211	54	607821	55	608721-BLK	55	687226	54
605836	55	606441	54	607211C	18	607821-BLK	55	608726	55	687231	54
605836-BLK	55	606701	55	607221	54	607826	55	608726-BLK	55	687241	54
605841	55	606701-BLK	55	607226	54	607826-BLK	55	608731	55	691201	54
605841-BLK	55	606711	55	607231	54	607831	55	608731-BLK	55	691211	54
605851	55	606711-BLK	55	607241	54	607831-BLK	55	608741	55	691216	54
605851-BLK	55	606721	55	607301	54	607841	55	608741-BLK	55	691221	54
605901	55	606721-BLK	55	607311	54	607841-BLK	55	608801	55	691221C	18
605911	55	606726	55	607311C	18	607901N	55	608801-BLK	55	691231	54
605921	55	606726-BLK	55	607321	54	607911N	55	608811	55	691241	54
605931	55	606731	55	607326	54	607921N	55	608811-BLK	55	693201	54
605936	55	606731-BLK	55	607331	54	607926N	55	608821	55	693211	54
605941	55	606741	55	607341	54	607931N	55	608821-BLK	55	693216	54
605951	55	606741-BLK	55	607401	54	607941N	55	608826	55	693221	54
606001	54	606801	55	607411	54	608101	54	608826-BLK	55	693221C	18
606011	54	606801-BLK	55	607411C	18	608111	54	608831	55	693231	54
606011C	18	606811	55	607421	54	608111C	18	608831-BLK	55	693236	54
606021	54	606811-BLK	55	607426	54	608121	54	608841	55	693241	54
606026	54	606821	55	607431	54	608126	54	608841-BLK	55	695301	54
606031	54	606821-BLK	55	607441	54	608131	54	608901	55	695311	54
606041	54	606826	55	607601N	55	608141	54	608911	55	695321	54
606101	54	606826-BLK	55	607611N	55	608201	54	608921	55	695321C	18
606111	54	606831	55	607621N	55	608211	54	608926	55	695331	54
606111C	18	606831-BLK	55	607626N	55	608211C	18	608931	55	695336	54
606121	54	606841	55	607631N	55	608221	54	608941	55	695341	54

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for the creation of this locator, crafted solely for thou. Now, venture forth and seeketh thine tool.

EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.	EDP#	Pg.
695351	54	708112	20	H08254	64	Q0624S	27	Q1562S	27	S06023	62
696201	54	708201	57	H08255	64	Q0782B	27	Q1563B	27	S06024	62
696211	54	708211	57	H08256	65	Q0782R	27	Q1563BN	28	S06025	62
696211C	18	708212	20	H09021	64	Q0782S	27	Q1563R	27	S06026	62
696221	54	708301	57	H09022	64	Q0783B	27	Q1563RN	28	S06043	62
696226	54	708311	57	H09033	64	Q0783BN	28	Q1563S	27	S06044	62
696231	54	708312	20	H09034	64	Q0783R	27	Q1563SN	28	S06045	62
696241	54	797101	57	H09035	64	Q0783RN	28	Q1564R	27	S06046	62
697101	54	797111	57	H09036	65	Q0783S	27	Q1564S	27	S09021	62
697111	54	797112	20	H09037	64	Q0783SN	28	Q1872B	27	S09022	62
697111C	18	907101	57	H09053	64	Q0784R	27	Q1872R	27	S09023	62
697121	54	907111	57	H09054	64	Q0784S	27	Q1872S	27	S09024	62
697126	54	907112	20	H09055	64	Q0932B	27	Q18733B	27	S09025	62
697131	54	907301	57	H09056	65	Q0932R	27	Q18733R	27	S09026	62
697141	54	907311	57	H09057	65	Q0932S	27	Q18733S	27	S09043	62
703101	57	907312	20	H10021	64	Q0933B	27	Q1873B	27	S09044	62
703111	57	907401	57	H10022	64	Q0933BN	28	Q1873BN	28	S09045	62
703112	20	907411	57	H10033	64	Q0933R	27	Q1873R	27	S09046	62
703201	57	907412	20	H10034	64	Q0933RN	28	Q1873RN	28	S12021	62
703211	57	908101	57	H10035	64	Q0933S	27	Q1873S	27	S12022	62
703212	20	908111	57	H10036	65	Q0933SN	28	Q1873SN	28	S12023	62
705101	57	908112	20	H10053	64	Q0934R	27	Q1874R	27	S12024	62
705121	57	908201	57	H10054	64	Q0934S	27	Q1874S	27	S12025	62
705122	20	908211	57	H10055	64	Q1092B	27	Q2182B	27	S12026	62
705201	57	908212	20	H10056	65	Q1092R	27	Q2182R	27	S12043	62
705221	57	908301	57	H12021	64	Q1092S	27	Q2182S	27	S12044	62
705222	20	908311	57	H12022	64	Q1093B	27	Q2183B	27	S12045	62
705301	57	908312	20	H12033	64	Q1093BN	28	Q2183BN	28	S12046	62
705321	57	H06021	64	H12034	64	Q1093R	27	Q2183R	27	S12024	62
705322	20	H06022	64	H12035	64	Q1093RN	28	Q2183RN	28	S12024	62
706101	57	H06033	64	H12036	65	Q1093S	27	Q2183S	27	S12025	62
706111	57	H06034	64	H12037	64	Q1093SN	28	Q2183SN	28	S12025	62
706112	20	H06035	64	H12053	64	Q1094R	27	Q2184R	27	S12026	62
706301	57	H06036	65	H12054	64	Q1094S	27	Q2184S	27	S12026	62
706311	57	H06037	64	H12055	64	Q1252B	27	Q2502B	27	S12043	62
706312	20	H06053	64	H12056	65	Q1252R	27	Q2502R	27	S12043	62
707101	57	H06054	64	H12057	64	Q1252S	27	Q2502S	27	S12044	62
707111	57	H06055	64	Q0622B	27	Q1253B	27	Q2503B	27	S12044	62
707112	20	H06056	65	Q0622R	27	Q1253BN	28	Q2503BN	28	S12045	62
707301	57	H06057	64	Q0622S	27	Q1253R	27	Q2503R	27	S12045	62
707311	57	H08221	64	Q0623B	27	Q1253RN	28	Q2503RN	28	S12046	62
707312	20	H08222	64	Q0623BN	28	Q1253S	27	Q2503S	27	S12046	62
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707411	57	H08234	64	Q0623RN	28	Q1254R	27	Q2504R	27		
707412	20	H08235	64	Q0623S	27	Q1254S	27	Q2504S	27		
708101	57	H08236	65	Q0623SN	28	Q1562B	27	S06021	62		
708111	57	H08253	64	Q0624R	27	Q1562R	27	S06022	62		

TERMS AND CONDITIONS

Working with us is straightforward, but there are some key criteria to follow.

Authorized Distribution

The Core Cutter product line is distributed via a countrywide network of independent industrial distributors. These distributors were chosen for their dedication to customer service, technological competence, and devotion to quality. Please contact customer support to locate your nearest authorized distributor.

Commitment to Quality

Core Cutter, LLC is committed to creating high-quality, high-performance carbide tools. In the interest of servicing our clients, we retain the right to make any necessary changes to our goods to guarantee they continue to satisfy our strict quality requirements. As a result, any assumptions made in this catalog may not be validated by current tooling standards or definitions that have been changed after its release date.

Product Safety

Any cutting tool has the potential to break and/or shatter if used improperly or subjected to other mechanical interactions (as shown on page 71). Safety glasses and other protective equipment are required by government rules in the neighborhood of usage. Furthermore, the use of cutting instruments may generate potentially harmful dust and/or mists, the particles of which might cause health problems. Always utilize appropriate ventilation and see the safety data sheet for any suggestions to avoid harmful heat effects.

This product may contain materials and/or chemicals such as arsenic, lead, and others that are known by the state of California to cause cancer and/or reproductive problems. For more information, visit www.P65Warnings.ca.gov

Product Warranty

For a maximum of one (1) year from the date of purchase, Core Cutter, LLC will fix or replace any of our goods that are assessed and found to be flawed in terms of craftsmanship, materials, or both. Any Core Cutter product that has been modified, reconditioned, resharpened, reinstalled, mishandled, or subjected to incorrect or non-recommended operating parameters and/or techniques is not covered by this warranty.

Pricing

Pricing for all items is determined, maintained, and established by Core Cutter LLC, which also has the right to alter it at any time.

Returned Product

Core Cutter, LLC offers full refunds on new, unmodified, excellent-condition returned standard catalog tooling acquired within six (6) months and within one (1) year of purchase, new, unmodified, quality-standard catalog tooling may be returned for merchandise credit and is subject to a 5% restocking charge.

All returned items must be accompanied by a returned merchandise authorization (RMA) issued by Core Cutter. Custom-made, modified, used, and/or damaged tooling will not be accepted for return unless the product is under warranty. To get an RMA number, please contact our customer service department.

Damaged Product

All products are shipped FOB to the factory via freight and third-party parcel carriers. The recipient is obligated to promptly inform Core Cutter in the event that a shipment is absent or damaged. You will receive assistance from our customer service department in initiating claim proceedings directly with the carrier. When applicable, please retain the damaged packaging and/or photographs to ensure prompt resolution.

Over and Under Shipments

All custom-made and modified tooling is subject to an over/under shipping policy of +/- 10% (or 1 piece). If your client requires an accurate shipment-to-order outcome, it must be quoted as such.

Product Improvements and updates

Core Cutter LLC. may, at any time without notice, make changes (whether in design, materials, improvements or otherwise) in any catalog goods, and may discontinue the manufacture of any catalog goods, all in its sole discretion, without incurring any obligations of any kind as a result thereof, whether for failure to fill an order of Buyer or otherwise.



Performance in Motion



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