Maine Made

CORE CUTTER

SOLID CARBIDE CUTTING TOOLS

544 New Items

2024 Full-Line Product Catalog

(p) 207.588.7519

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corecutterusa.com

OUR COMMITMENT

Est. 2017

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

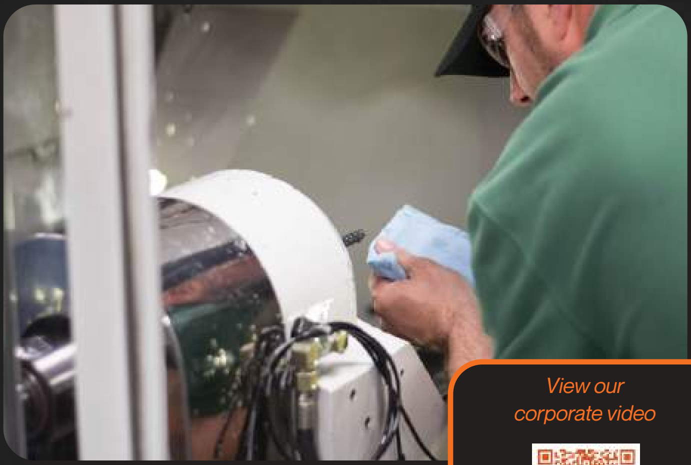
The Core Cutter Family consists of exceptionally skilled engineers, machine operators, quality inspectors, technical support and customer service professionals. We are dedicated to providing you with 100% customer satisfaction from start to finish.

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
SOLID CARBIDE CUTTING TOOLS

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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.


COMMERCIAL AEROSPACE


MILITARY


ENERGY


MEDICAL


ENGINES


AUTOMOTIVE


GENERAL MACHINING


ARMAMENT

TABLE OF CONTENTS

Below is a detailed list of our standard tooling and where to locate them.

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.

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

Materials

- Steel
- Hardened Steel
- Stainless Steel
- Cast Iron
- Super-Alloys
- Titanium

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.

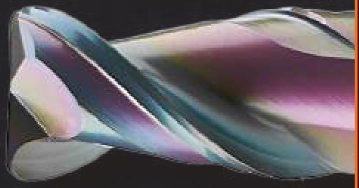
Tool Series Impacted: **VMF, VMF-CB**

Coloration	Hardness (GPa)	Coefficient of Friction	Max. Service Temp (C°)
Light Grey	41-35	0.6	1,100

Materials

- Steel (>45HRC)
- Stainless Steel
- Cast Iron
- Super-Alloys
- Titanium

**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.

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

Materials

- Aluminum
- Copper
- Brass
- CRFP
- Poly
- GFRP

**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.

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

Materials

- Carbon Steel
- Alloy Steel
- Stainless Steel
- Cast Iron
- Super-Alloys
- Titanium

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, HRSAs, titanium, and hardened steels.

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

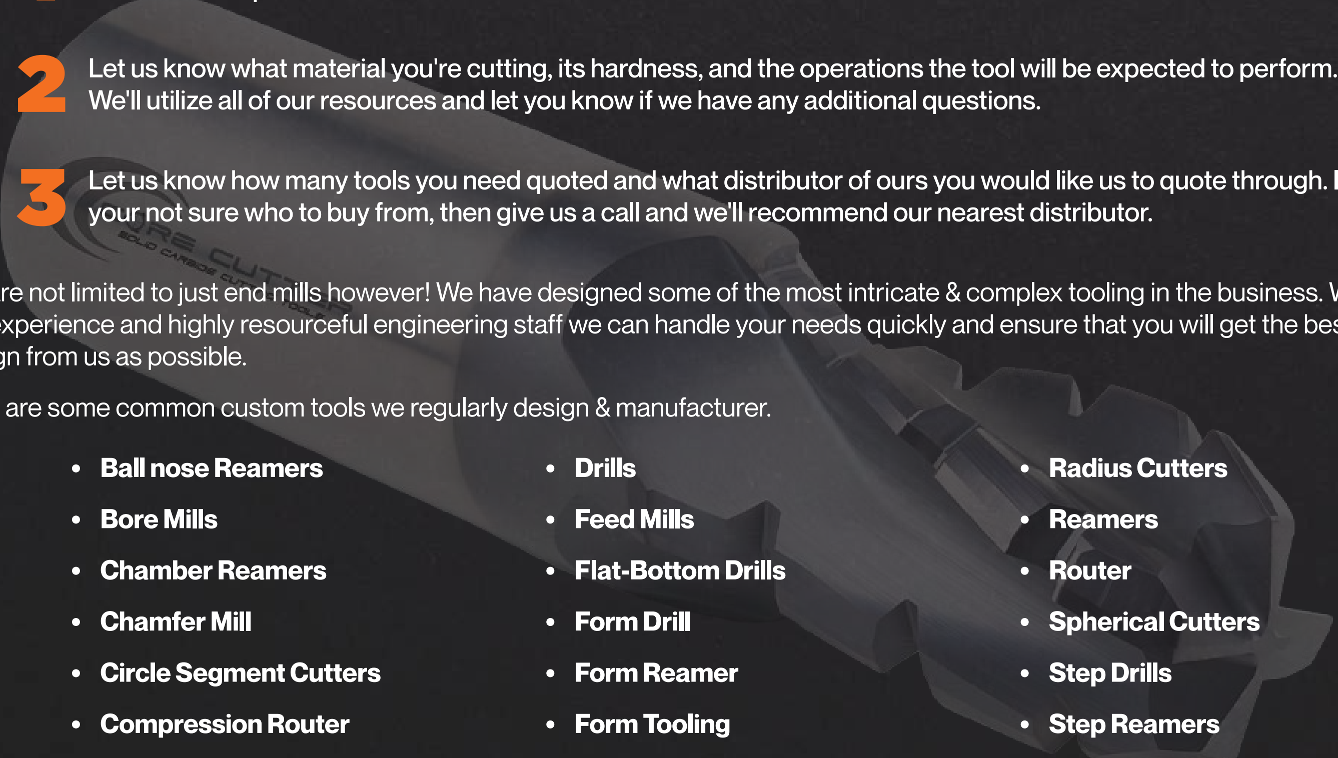
Materials

- High Alloyed Steel
- Stainless Steel
- Super-Alloys
- Titanium

** 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.

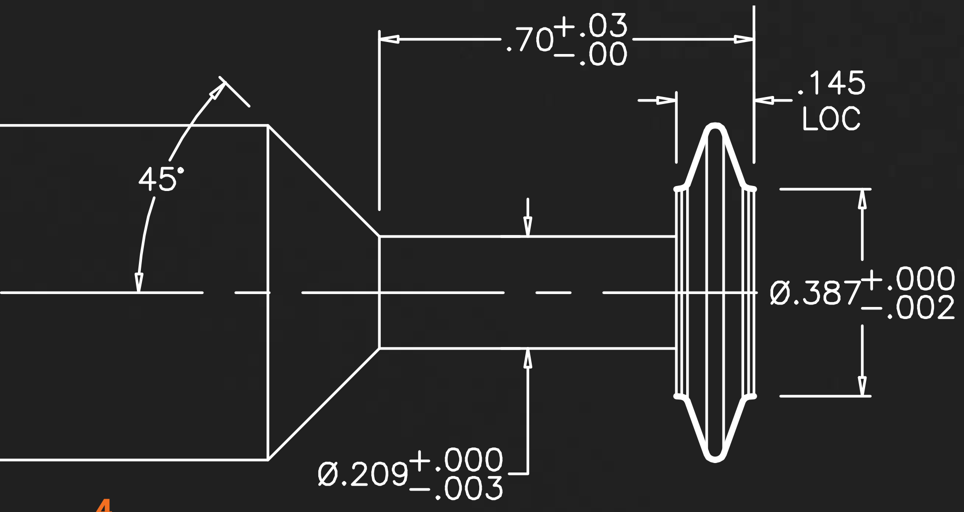
It's as simple as 1, 2, 3 to get an estimate for a custom-made tool from us via our channel partners.

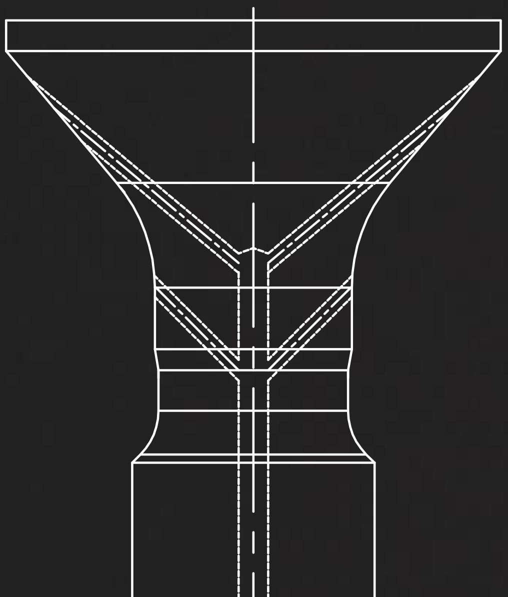
1. Please provide us with a tool sketch, a part print (our favorite), a snippet of feature machining, or, if you have one, draw it on a napkin!
2. Let us know what material you're cutting, its hardness, and the operations the tool will be expected to perform. We'll utilize all of our resources and let 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

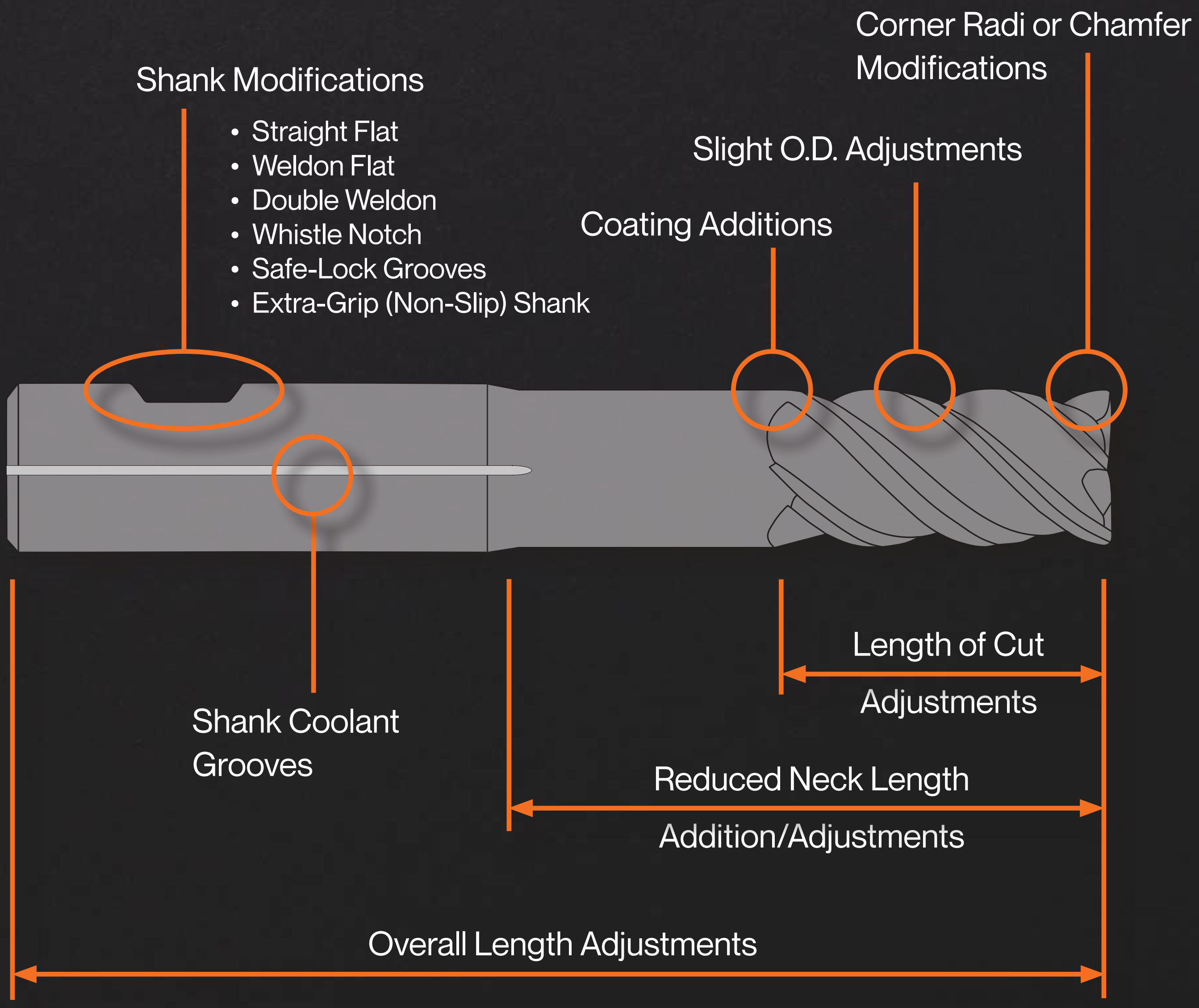
Do you ever need that one little adjustment to a standard tool?

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**
- **Weldon Flats**
- **Double Weldon Flats**
- **Whistle Notch**
- **Haimer Safe-Lock®**
- **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).

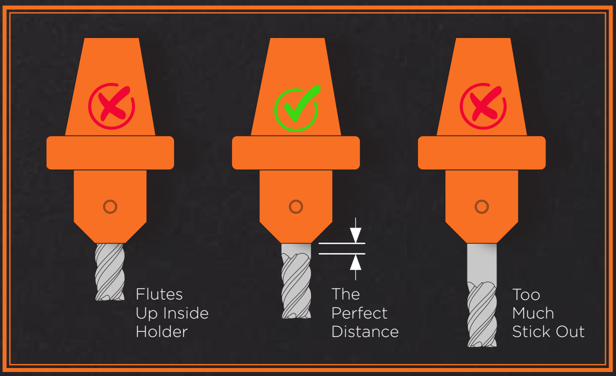


Fig. 1 - Tool Projection w/Weldon Flat

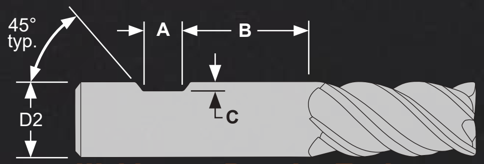
TIP Of course, if you have a specific location that you want your Weldon flats on our tools, just provide us the "B" dimension and we'll be glad to accommodate.

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

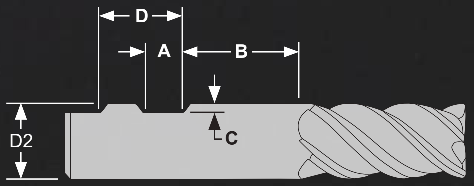
Shank Dia. (D2)	Dim. "A" (+/- .004)	Dim. "B" (+/-.015)	Dim. "C"	Dim. "D"
1/4	.155	.500	.017 (+.005/-.000)	-
5/16	.295	.750	.020 (+.005/-.000)	-
3/8	.295	.750	.050 (+.015/-.000)	-
7/16	.345	.835	.060 (+.015/-.000)	-
1/2	.345	.835	.060 (+.015/-.000)	-
5/8	.415	.900	.065 (+.015/-.000)	-
3/4	.470	.900	.075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

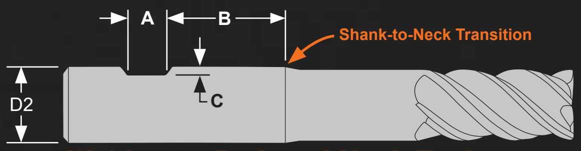
Find more detailed information pertaining to tool holders on p. 76



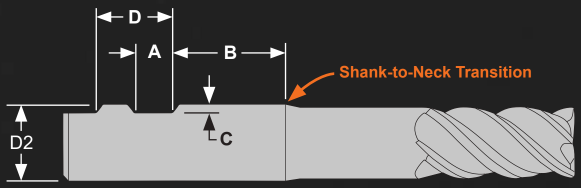
Weldon on Regular Tool



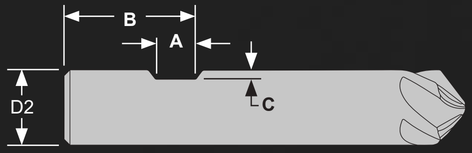
Double Weldon on Regular Tool



Weldon on Reduced Neck Tool



Double Weldon on Reduced Neck Tool



Weldon on Chamfer Mill

ROUGHING PROFILES

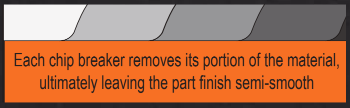
What exactly is the difference between a chip breaker and a serrated rougher?

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).

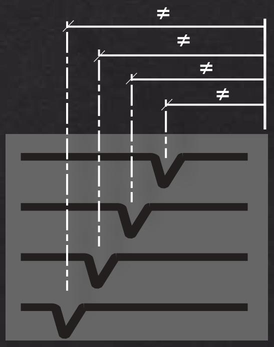
Chipbreakers *(aka Chip Splitters, Semi-Finishers)*

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).



Each chip breaker removes its portion of the material, ultimately leaving the part finish semi-smooth

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.

Fig. 2 - Offset Alignment

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 x 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

Chip breaker grooves are developed by a subtractive grinding operation to the O.D. of the tool.

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.

Peaks are susceptible to failure

Knuckle Rougher Style

Peaks are susceptible to increased damage, decreased tool life and creates a very rugged finish.

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

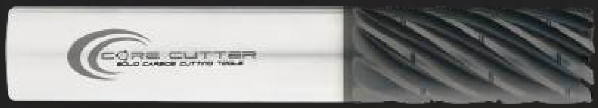
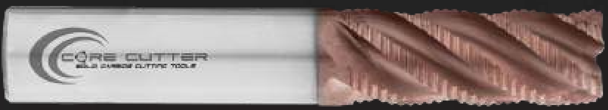
Low-Profile Serrated Style

Truncated (flattened) peaks add strength, increase tool life and reduces such a rugged finish.

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

Maine Made

ROUGHING Tools

	Available Surface Treatment	ISO Mat'l Group	Catalog Page(s)
AL3-CB 3-Flute High-Performance Chipbreaker Endmill 	✓ Uncoated ✓ D-Max Coating	N	10 - 12
VST4-CB 4-Flute High-Performance Chipbreaker Endmill 	✓ A-Max Coating	P M K S	13 - 14
VST5-CB 5-Flute High-Performance Chipbreaker Endmill 	✓ P-Max Coating	P M K S	15 - 16
VST6-CB 6-Flute High-Performance Chipbreaker Endmill  NEW Series	✓ T-Max Coating	P M K S	17 - 18
VMF-CB 7, 9, and 11 Flute High-Performance Chipbreaker Endmill 	✓ C-Max Coating	P M K S	19 - 20
VXR 4 & 5 Flute High-Performance Low-Profile Serrated Roughing Endmill  NEW Series	✓ T-Max Coating	P M K S H	21 - 22

Cutting Parameters, pages 23 - 24

AL3-CB

Our Proven High-Performance 3-Flute Chipbreaker Geometry

Center-Cutting End Geometry

With Corner Radius Only

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

Extra-Fine Grain Cemented Carbide

37° Helix

Offset "Flute-to-Flute" Chipbreaker Design

Strengthened Core Diameter

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

CNC Ground in the USA

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)

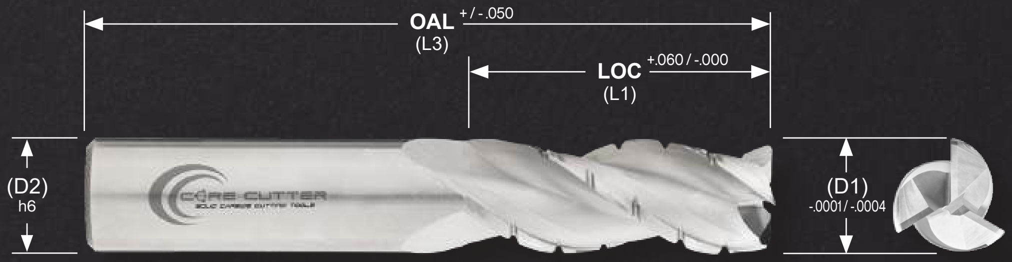
3-Flute High-Performance Uncoated Endmill w/Chipbreakers

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
		1.250	3.00	3	AL3-M-0250-CB		301320C
5/16	5/16	.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
		1.500	4.00	3	AL3-L-0375-CB		303420C
1/2	1/2	.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
		1.625	4.00	3	AL3-SP-0500-CB		395320C
		2.000	4.00	3	AL3-L-0500-CB		305420C
5/8	5/8	.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
		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
3/4	3/4	1.000	3.00	3	AL3-S-0750-CB		307010C
		1.500	4.00	3	AL3-SR-0750-CB		307110C
		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)

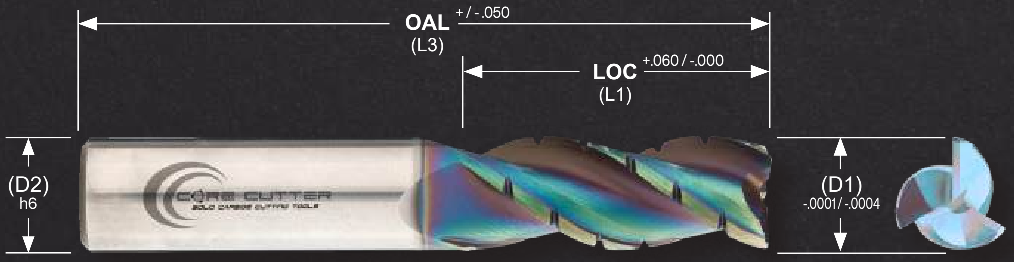
3-Flute High-Performance D-Max Coated Endmill w/Chipbreakers

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	.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
		1.250	3.000	3	AL3-M-0250-CB		301321C
5/16	5/16	.500	2.000	3	AL3-SR-0312-CB		302121C
		.750	2.500	3	AL3-R-0312-CB		302221C
		1.250	3.000	3	AL3-M-0312-CB		302321C
3/8	3/8	.500	2.000	3	AL3-S-0375-CB		303021C
		.750	2.500	3	AL3-SR-0375-CB		303121C
		.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
1/2	1/2	.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
		2.000	4.000	3	AL3-L-0500-CB		305421C
5/8	5/8	.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
		2.000	4.000	3	AL3-M-0625-CB		306311C
		2.500	5.000	3	AL3-L-0625-CB		306411C
3/4	3/4	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
		3.000	6.000	3	AL3-L-0750-CB		307411C
1.0	1.0	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

Maine Made

Our Proven High-Performance 4-Flute Chipbreaker Geometry

With Corner Radius Only

Center-Cutting End Geometry

Extra-Fine Grain Cemented Carbide

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

Offset “Flute-to-Flute” Chipbreaker Design

Variable Flute Indexing

Strengthened Core Diameter

A-Max Coated

CNC Ground in the USA

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

VST4-CB

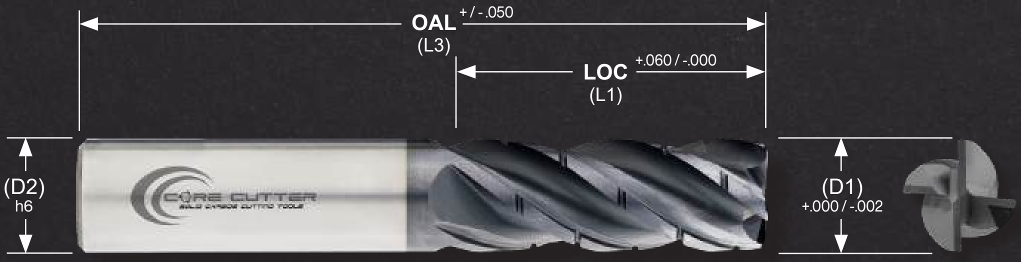
4-Flute High-Performance A-Max Coated Endmill w/Chipbreakers

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

Cutting Parameters
pp. 23 - 24

Permittable ISO Material Categories

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
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

Maine Made

Our Proven High-Performance 5-Flute Chipbreaker Geometry

With Corner Radius Only

Center-Cutting End Geometry

Extra-Fine Grain Cemented Carbide

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

Offset "Flute-to-Flute" Chipbreaker Design

Variable Flute Indexing

Strengthened Core Diameter

P-Max Coated

CNC Ground in the USA

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

VST5-CB

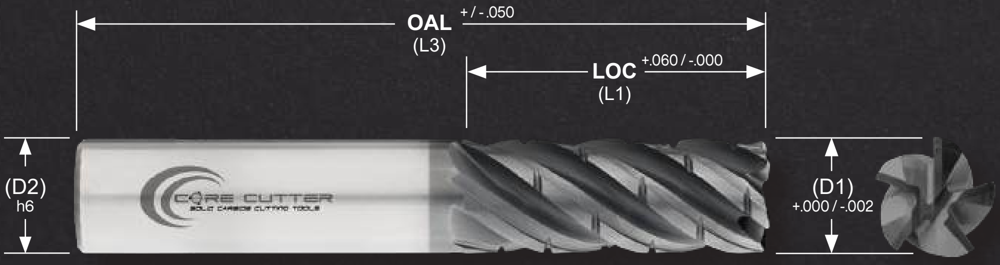
5-Flute High-Performance P-Max Coated Endmill w/Chipbreakers

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

Cutting Parameters
pp. 23 - 24

Permittable ISO Material Categories

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
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
		1.500	4.00	5	VST5-L-0375-CB		503421C
1/2	1/2	.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
		1.625	4.00	5	VST5-SP-0500-CB		595321C
		2.000	4.00	5	VST5-L-0500-CB		505421C
5/8	5/8	.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
		2.000	4.00	5	VST5-M-0625-CB		506311C
		2.500	5.00	5	VST5-L-0625-CB		506411C
3/4	3/4	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
		2.500	5.00	5	VST5-M-0750-CB		507311C
		3.000	6.00	5	VST5-L-0750-CB		507411C
1.0	1.0	1.750	4.00	5	VST5-SR-1000-CB		508111C
		2.500	5.00	5	VST5-R-1000-CB		508211C
		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

Maine Made

Our Proven High-Performance 6-Flute Chipbreaker Geometry

With Corner Radius Only

Center-Cutting End Geometry

Extra-Fine Grain Cemented Carbide

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

Variable Flute Indexing

Offset "Flute-to-Flute" Chipbreaker Design

T-Max Coated

Strengthened Core Diameter

CNC Ground in the USA

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

VST6-CB

NEW!

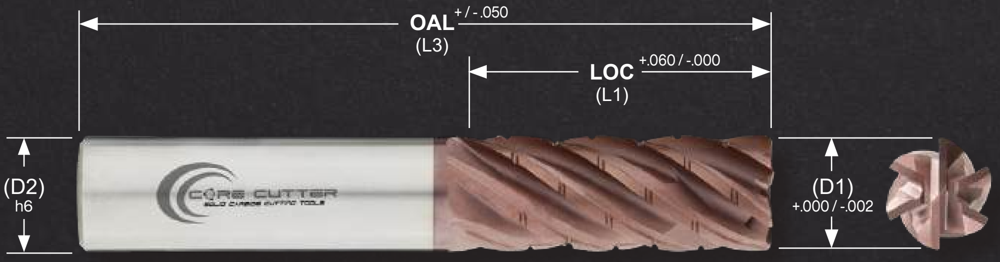
6-Flute High-Performance T-Max Coated Endmill w/Chipbreakers

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
		1.500	4.00	6	VST6-L-0375-CB		603421C
1/2	1/2	.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
		1.625	4.00	6	VST6-SP-0500-CB		695321C
		2.000	4.00	6	VST6-L-0500-CB		605421C
5/8	5/8	.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
		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
3/4	3/4	1.000	3.00	6	VST6-S-0750-CB		607011C
		1.500	4.00	6	VST6-SR-0750-CB		607111C
		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

Maine Made

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

+.000/-.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

CNC Ground in the USA

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

VMF-CB

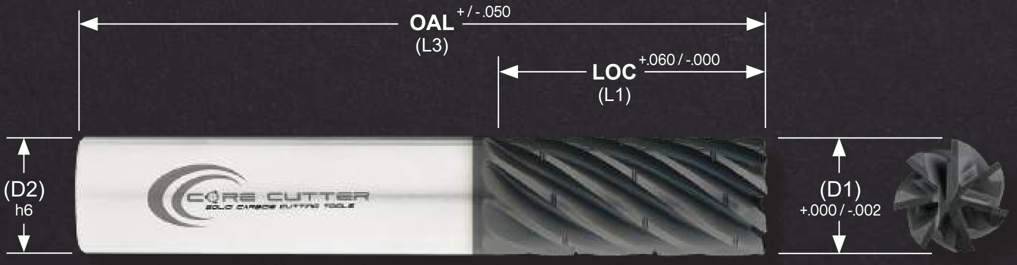
Multi-Flute High-Performance C-Max Coated Endmill w/Chipbreakers

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

Cutting Parameters
pp. 23 - 24

Permittable ISO Material Categories

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
3/8	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
		3.000	6.00	9	VMF9-L-0750-CB		907412
1.0	1.0	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

Maine Made

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

CNC Ground in the USA

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

VXR

NEW!

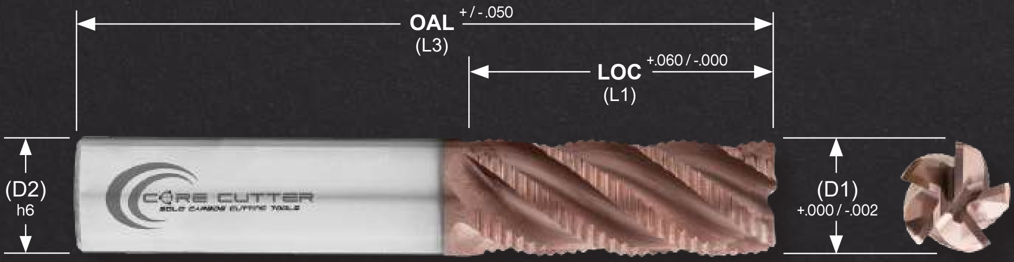
High-Performance T-Max Coated Low-Profile Serrated Rougher

Custom made configurations of the VXR style are available upon request

Cutting Parameters
pp. 23 - 24

Permittable ISO Material Categories

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	.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.

Suggested Initial cut values for all roughing tools.

Roughing Tools

Feed Table (f_z)

ISO Material Categories		SFM	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, AiResist 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*

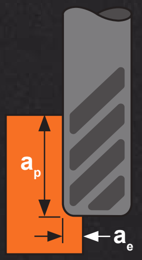
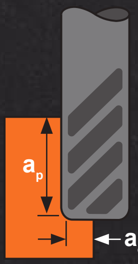
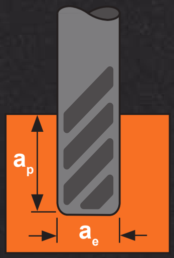
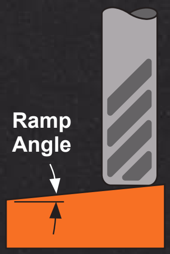
KEY

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_e	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	Up to 3.50 x 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 2.5x 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 Effeciency 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.)

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

Cutting Parameters, pages 29 - 30

QTR3

Our Proven High-Performance 3-Flute Miniature Tool Geometry

Center-Cutting End Geometry

End Construction Options:
- Square Corner
- Corner Radii
- Ball Nose

Variable Flute Indexing
& Variable Helix

Cutting Diameter Tolerance
< 3/16” = .000/-.001
3/16” to 1/4” = .000/-.002

Extra-Fine Grain Cemented Carbide

Need Long Reach? See p. 28

Series Contains all 1/4" Shank Diameters

P-Max Coated

CNC Ground in the USA

h6 Shank Tolerance

Serialization of every tool on shank by lot#

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

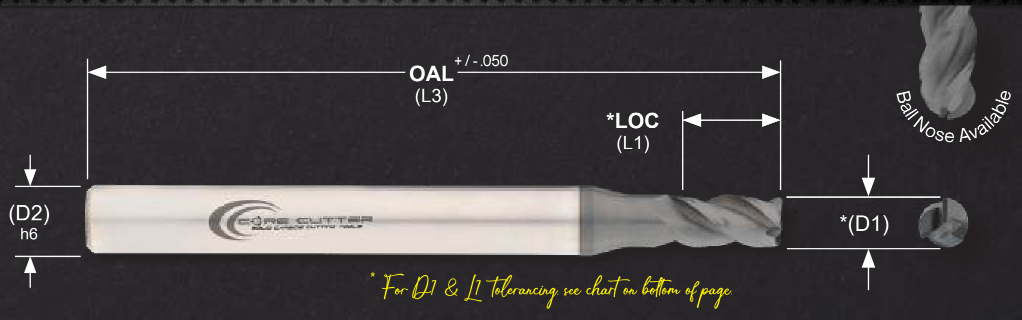
3-Flute High-Performance P-Max Coated Miniature Endmill

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
		.750	2.500	3	4xD	QTR3-0187-4XD	Q1874S		Q1874R	
7/32		.438	2.500	3	2xD	QTR3-0218-2XD	Q2182S		Q2182R	Q2182B
		.656	2.500	3	3xD	QTR3-0218-3XD	Q2183S		Q2183R	Q2183B
		.875	2.500	3	4xD	QTR3-0218-4XD	Q2184S		Q2184R	
1/4		.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"	+.000 / -.001	+.010 / -.000
3/16" -to- 1/4"	+.000 / -.002	+.060 / -.000

QTR3-RN

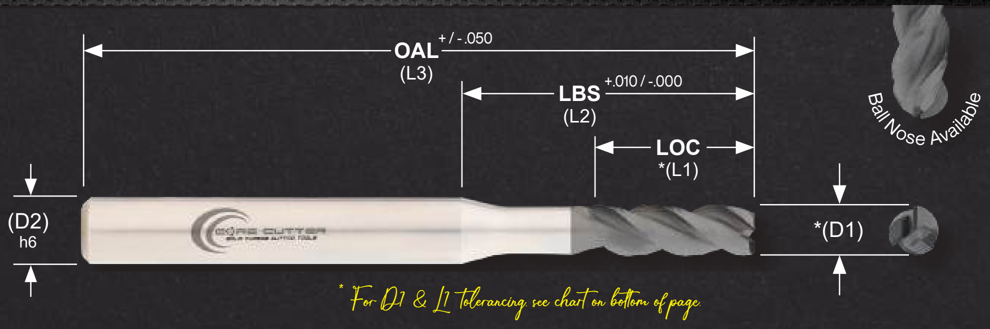
3-Flute High-Performance P-Max Coated (Reduced Neck) Miniature Endmill

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

Cutting Parameters
pp. 29 - 30

Permittable ISO Material Categories

N P M K S H



* For D1 & L1 tolerancing see chart on bottom of page.

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	Q078SRN		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

Dynamic (QTR3) - Miniature Tooling

Feed Table (f_z)

ISO Material Categories		SFM	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	550 800	.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	435 750	.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	300 500	.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	250 350	.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	110 225	.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	275 380	.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	200 300	.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	180 275	.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	325 450	.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	275 375	.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	250 325	.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	175 280	.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, AiResist 13, Stellite	110 165	.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	100 150	.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	75 125	.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)	80 115	.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)	70 100	.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 (fz) based on chip thinning at ≤10% step over, and for SFM, you can take our recommendations x 1.5 - 1.8*

KEY

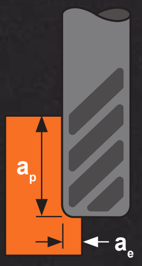
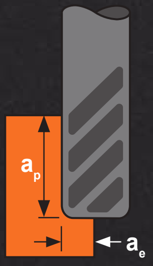
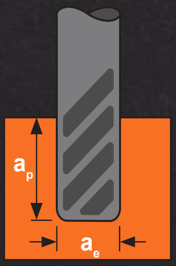
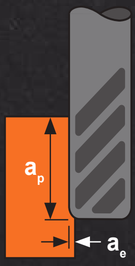
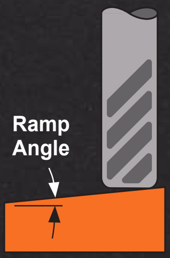
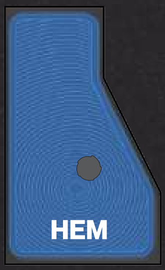
Co	Cobalt (Chemical Element - see p. 79)	HP	Heavy Peripheral (a_e = 30%-to-50% of Dia.)	SFM	Surface Feet per Minute
D1	Tool Cutting Diameter	HEM	High Efficiency Milling (see pp. 84-86)	S	Slotting (a_e = 100% of Dia.)
F	Finishing (see p. 93)	LP	Light Peripheral (a_e = 18%-to-29% of Dia.)	HRC	Rockwell 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)

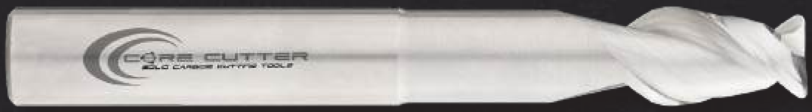
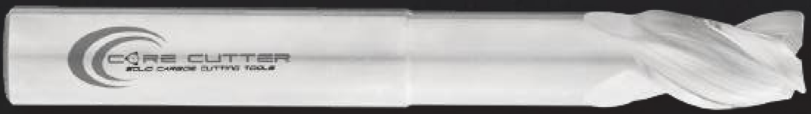
Tool Series												
	Light Peripheral (LP)		**Heavy Peripheral (HP)**		**Slotting (S)**		**Finishing (F)**		**Ramping**		**High Efficiency Milling** *(see pp. 84-86)*	
	a_e	a_p	a_e	a_p	a_e	a_p	a_e	a_p	Angle	Feed	a_e	a_p
QTR3	12% - 20% of D1	Up to 1.0 x D1	20% - 35% of D1	Up to .50 x D	100% of D1	.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	Up to 2.5 x LOC (L1)
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 	✓ Uncoated ✓ D-Max Coating	N	32 - 34
AL2-RN 2-Flute High-Performance (Reduced Neck) Endmill 	✓ Uncoated ✓ D-Max Coating	N	35 - 36
AL3 3-Flute High-Performance Endmill 	✓ Uncoated ✓ D-Max Coating	N	37 - 39
AL3-RN 3-Flute High-Performance (Reduced Neck) Endmill 	✓ Uncoated ✓ D-Max Coating	N	40 - 41

Cutting Parameters, pages 42 - 43

Maine Made

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)

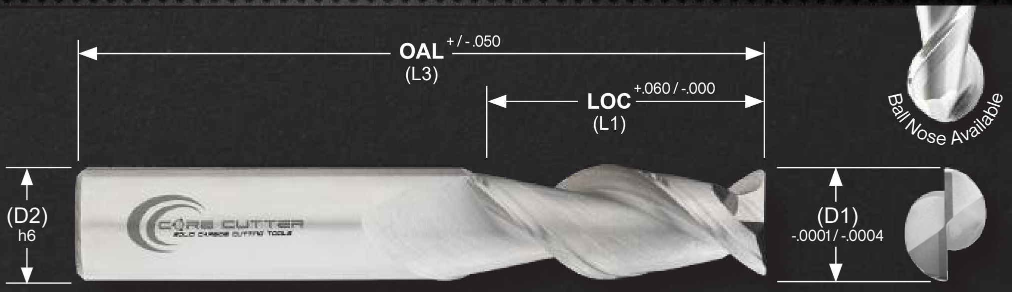
2-Flute High-Performance Uncoated Endmill

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
		1.500	4.00	2	AL2-L-0375	203400	203410	203420	203430		203440
1/2	1/2	.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
		2.000	4.00	2	AL2-L-0500	205400	205410	205420	205430	205440	205450
5/8	5/8	.750	3.00	2	AL2-S-0625	206000		206010	206020	206030	206040
		1.250	3.50	2	AL2-SR-0625	206100		206110	206120	206130	206140
		1.500	3.50	2	AL2-R-0625	206200		206210	206220	206230	206240
		1.625	3.50	2	AL2-SP-0625	296200		296210	296220	296230	296240
		2.000	4.00	2	AL2-M-0625	206300		206310	206320	206330	206340
		2.500	5.00	2	AL2-L-0625	206400		206410	206420	206430	206440
3/4	3/4	1.000	3.00	2	AL2-S-0750	207000		207010	207020	207030	207040
		1.500	4.00	2	AL2-SR-0750	207100		207110	207120	207130	207140
		1.625	4.00	2	AL2-SP-0750	297100		297110	297120	297130	297140
		2.000	5.00	2	AL2-R-0750	207200		207210	207220	207230	207240
		2.500	5.00	2	AL2-M-0750	207300		207310	207320	207330	207340
		3.000	6.00	2	AL2-L-0750	207400		207410	207420	207430	207440
1.0	1.0	1.750	4.00	2	AL2-SR-1000	208100		208110	208120	208130	208140
		2.500	5.00	2	AL2-R-1000	208200		208210	208220	208230	208240
		3.000	6.00	2	AL2-M-1000	208300		208310	208320	208330	208340
		3.500	6.00	2	AL2-L-1000	208400		208410	208420	208430	208440

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)

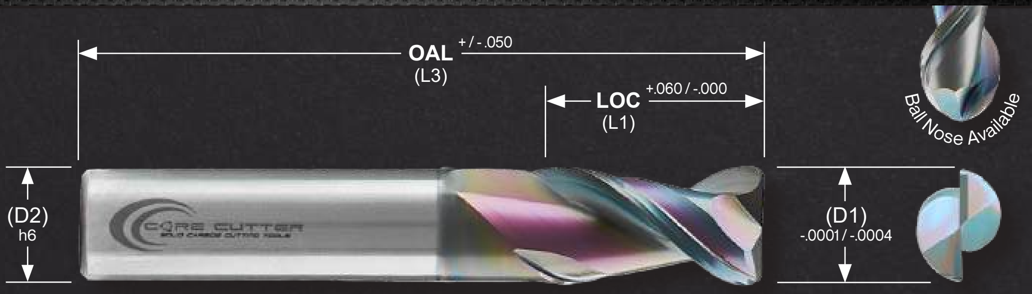
2-Flute High-Performance D-Max Coated Endmill

Custom made configurations of the AL2 style are available upon request

Cutting Parameters
pp. 42 - 43

Permittable ISO Material Categories

N

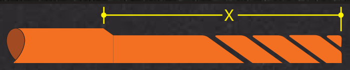


Tool Geometry						EDP #'s by Corner Condition					
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.030R	.060R	.125R	Ball Nose
1/8	1/8	.250	1.50	2	AL2-S-0125	210001	210011				210041
		.375	2.00	2	AL2-SR-0125	210101	210111				210141
		.500	2.50	2	AL2-R-0125	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
		1.500	4.00	2	AL2-L-0375	203401	203411	203421	203431		203441
1/2	1/2	.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
		2.000	4.00	2	AL2-L-0500	205401	205411	205421	205431	205441	205451
5/8	5/8	.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
		2.500	5.00	2	AL2-L-0625	206401		206411	206421	206431	206441
3/4	3/4	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
		3.000	6.00	2	AL2-L-0750	207401		207411	207421	207431	207441
1.0	1.0	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

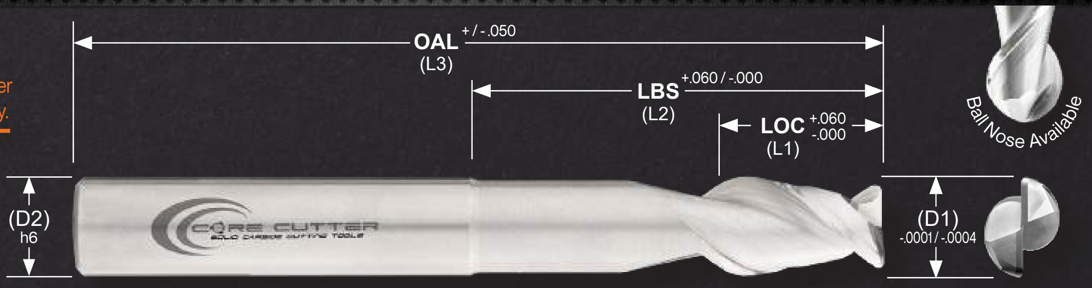


Check out "Un-Necked" in the table below for longer OALs and a custom LBS length you want to specify.

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)

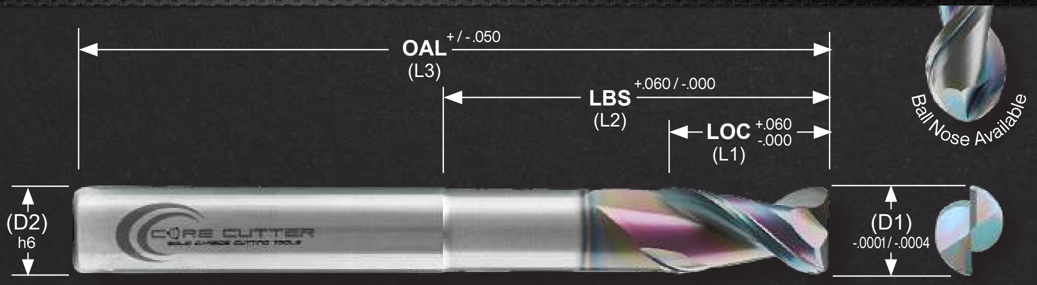
2-Flute High-Performance D-Max Coated (Reduced Neck) Endmill

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
		.750	Un-Necked	8.00	2	AL2-RN-8-0500	205801-BLK	205811-BLK	205821-BLK	205831-BLK	205841-BLK	205851-BLK
5/8	5/8	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
		1.000	Un-Necked	8.00	2	AL2-RN-8-0625	206801-BLK		206811-BLK	206821-BLK	206831-BLK	206841-BLK
3/4	3/4	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
		1.125	Un-Necked	8.00	2	AL2-RN-8-0750	207801-BLK		207811-BLK	207821-BLK	207831-BLK	207841-BLK
1.0	1.0	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

Maine Made

Our Proven High Performance 3-Flute Geometry

End Construction Options:
- Square Corner
- Corner Radii
- Ball Nose

Center-Cutting End Geometry

Extra-Fine Grain Cemented Carbide

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

37° Helix

Need Long Reach? See pp. 40-41

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

CNC Ground in the USA

Need Chipbreakers? See pp. 10-12

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

AL3 (Uncoated)

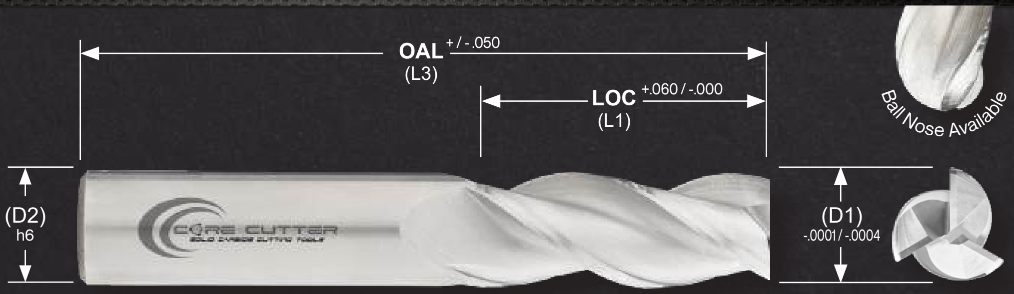
3-Flute High-Performance Uncoated Endmill

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
		1.250	3.00	3	AL3-M-0250	301300	301310	301320	301330			301340
5/16	5/16	.500	2.00	3	AL3-SR-0312	302100	302110	302120				302140
		.750	2.50	3	AL3-R-0312	302200	302210	302220				302240
		1.250	3.00	3	AL3-M-0312	302300	302310	302320				302340
3/8	3/8	.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
		1.500	4.00	3	AL3-L-0375	303400	303410	303420	303430	303435		303440
1/2	1/2	.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
		2.000	4.00	3	AL3-L-0500	305400	305410	305420	305430	305435	305440	305450
5/8	5/8	.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
		2.500	5.00	3	AL3-L-0625	306400		306410	306420	306425	306430	306440
3/4	3/4	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
		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
1.0	1.0	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
		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.

AL3 (Coated)

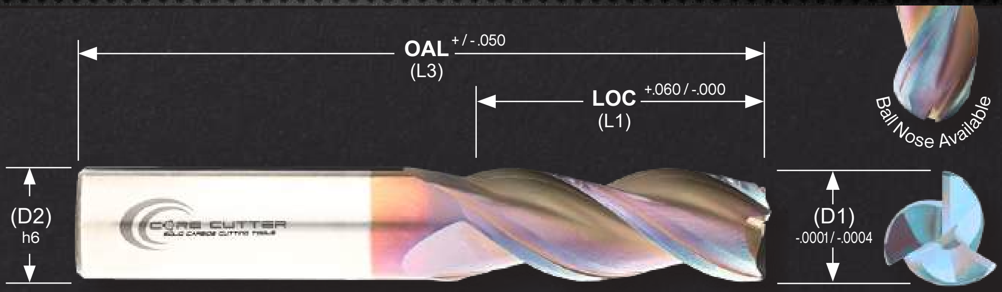
3-Flute High-Performance D-Max Coated Endmill

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
		1.250	3.00	3	AL3-M-0250	301301	301311	301321	301331			301341
5/16	5/16	.500	2.00	3	AL3-SR-0312	302101	302111	302121				302141
		.750	2.50	3	AL3-R-0312	302201	302211	302221				302241
		1.250	3.00	3	AL3-M-0312	302301	302311	302321				302341
3/8	3/8	.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
		1.250	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
1/2	1/2	.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
		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
5/8	5/8	.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
		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
3/4	3/4	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
		3.000	6.00	3	AL3-L-0750	307401		307411	307421	307426	307431	307441
1.0	1.0	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)

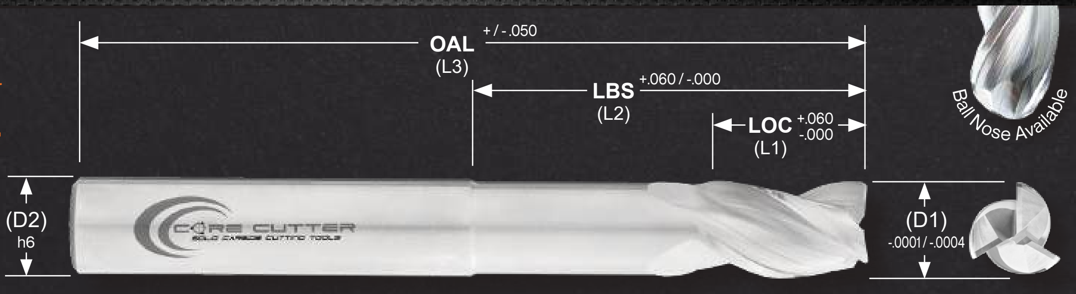
3-Flute High-Performance Uncoated (Reduced Neck) Endmill

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

Cutting Parameters
pp. 42 - 43

Permittable ISO Material Categories

N

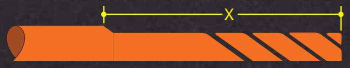


Tool Geometry							EDP #'s by Corner Condition						
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	LBS (L2)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.030R	.060R	.090R	.125R	Ball Nose
1/8	1/8	.188	.500	2.00	3	AL3-RN-R-0125	310700	310710					310740
		.188	.750	2.50	3	AL3-RN-M-0125	310800	310810					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
		.750	1.750	3.00	3	AL3-RN-SR-0500	305600N	305610N	305620N	305630N	305635N	305640N	305650N
		.750	2.000	4.00	3	AL3-RN-R-0500	305700	305710	305720	305730	305735	305740	305750
		.750	2.250	4.00	3	AL3-RN-SP-0500	305700N	305710N	305720N	305730N	305735N	305740N	305750N
		.750	2.500	5.00	3	AL3-RN-M-0500	305800	305810	305820	305830	305835	305840	305850
		.750	3.500	6.00	3	AL3-RN-L-0500	305900	305910	305920	305930	305935	305940	305950
		.750	Un-Necked	7.00	3	AL3-RN-7-0500	305700-BLK	305710-BLK	305720-BLK	305730-BLK	305735-BLK	305740-BLK	305750-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
5/8	5/8	1.000	2.000	4.00	3	AL3-RN-R-0625	306700		306710	306720	306725	306730	306740
		1.000	2.500	5.00	3	AL3-RN-M-0625	306800		306810	306820	306825	306830	306840
		1.000	3.500	5.00	3	AL3-RN-L-0625	306900		306910	306920	306925	306930	306940
		1.000	Un-Necked	7.00	3	AL3-RN-7-0625	306700-BLK		306710-BLK	306720-BLK	306725-BLK	306730-BLK	306740-BLK
		1.000	Un-Necked	8.00	3	AL3-RN-8-0625	306800-BLK		306810-BLK	306820-BLK	306825-BLK	306830-BLK	306840-BLK
3/4	3/4	1.125	1.750	4.00	3	AL3-RN-SR-0750	307600N		307610N	307620N	307625N	307630N	307640N
		1.125	2.000	4.00	3	AL3-RN-R-0750	307700		307710	307720	307725	307730	307740
		1.125	2.500	5.00	3	AL3-RN-SP-0750	307700N		307710N	307720N	307725N	307730N	307740N
		1.125	3.000	6.00	3	AL3-RN-M-0750	307800		307810	307820	307825	307830	307840
		1.125	4.000	6.00	3	AL3-RN-X-0750	307900N		307910N	307920N	307925N	307930N	307940N
		1.125	Un-Necked	7.00	3	AL3-RN-7-0750	307700-BLK		307710-BLK	307720-BLK	307725-BLK	307730-BLK	307740-BLK
		1.125	Un-Necked	8.00	3	AL3-RN-8-0750	307800-BLK		307810-BLK	307820-BLK	307825-BLK	307830-BLK	307840-BLK
1.0	1.0	1.500	2.500	5.00	3	AL3-RN-R-1000	308700		308710	308720	308725	308730	308740
		1.500	3.500	6.00	3	AL3-RN-M-1000	308800		308810	308820	308825	308830	308840
		1.500	4.500	7.00	3	AL3-RN-L-1000	308900		308910	308920	308925	308930	308940
		1.500	Un-Necked	7.00	3	AL3-RN-7-1000	308700-BLK		308710-BLK	308720-BLK	308725-BLK	308730-BLK	308740-BLK
		1.500	Un-Necked	8.00	3	AL3-RN-8-1000	308800-BLK		308810-BLK	308820-BLK	308825-BLK	308830-BLK	308840-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

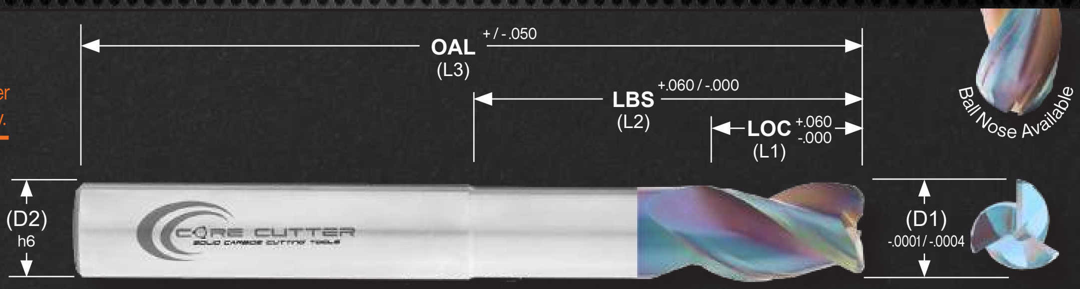


Check out "Un-Necked" in the table below for longer OALs and a custom LBS length you want to specify.

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
		.750	**Un-Necked**	8.00	3	AL3-RN-8-0500	305801-BLK	305811-BLK	305821-BLK	305831-BLK	305836-BLK	305841-BLK	305851-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.

Suggested Initial Cut Values for all Non-Ferrous Series Tooling

ISO Material Categories		SFM	Ferrous (& Titanium) Tooling Feed Table (f_z)																			
			D1 ≤ 1/8					D1 ≤ 1/4					D1 ≤ 3/8					D1 ≤ 1/2				
			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
	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
	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

ISO Material Categories		SFM	Ferrous (& Titanium) Tooling Feed Table (f_z)														
			D1 ≤ 5/8					D1 ≤ 3/4					D1 ≤ 1”				
			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	.0078	.0094	.0089	.0058	.0156	.0093	.0113	.0107	.0070	.0188	.0124	.0150	.0143	.0093	.0375
	Cast Aluminum Alloys A356, A360, A380, A390	550 800	.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	.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*

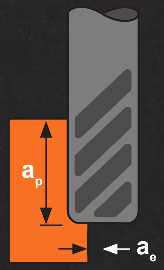
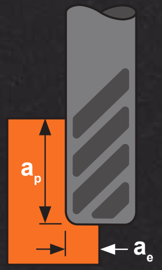
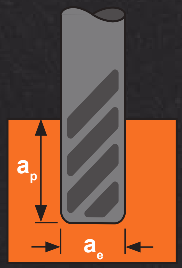
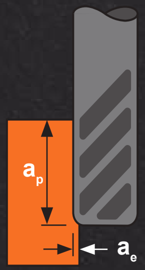
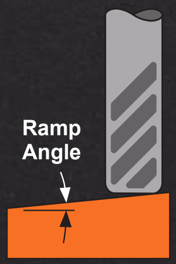
KEY

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** *(see pp. 84-86)*	
	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)

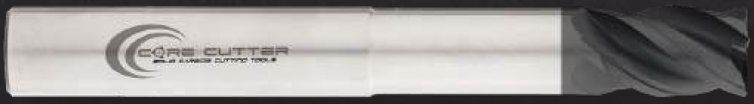
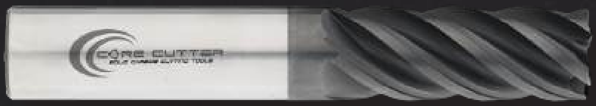
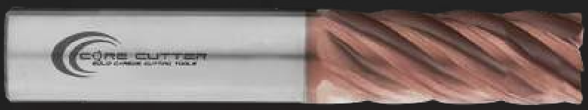
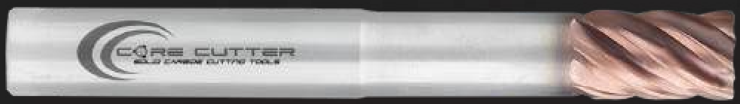
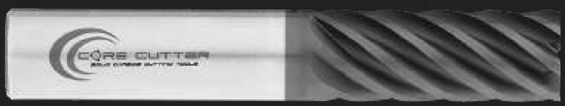
**Note: The depth of cut numbers supplied in this table are estimates only and may need to be changed higher/lower based on your specific application and setup - Core Cutter LLC, assumes no liability.*

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 Effeciency 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.)

Maine Made

Ferrous Tooling (& Titanium)

Catalog Page(s)	ISO Mat'l Group	Available Surface Treatment	Cutting Parameters, pages 58 - 59
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  NEW Series
55	P M K S H	✓ T-Max Coating	**VST6-RN** 6-Flute High-Performance (Reduced Neck) Endmill  NEW Series
56 - 57	P M K S H	✓ C-Max Coating	**VMF** 7, 9, and 11 flute High-Performance Endmill 

VST4

Maine Made

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

+.000/-.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

VST4

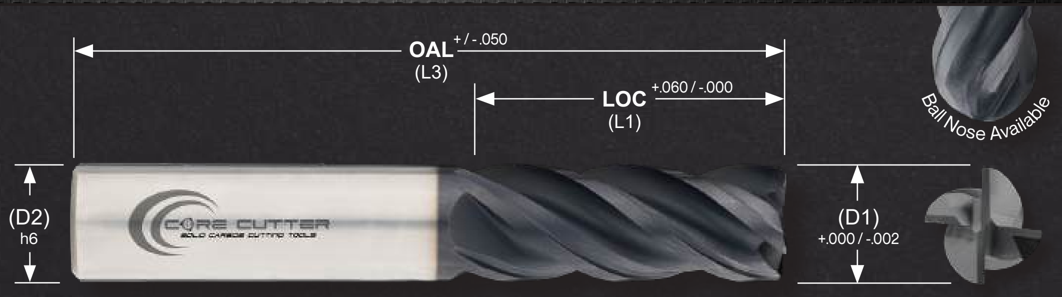
4-Flute High-Performance A-Max Coated Endmill

Custom made configurations of the VST4 style are available upon request

Cutting Parameters
pp. 58 - 59

Permittable ISO Material Categories

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	.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
		1.500	4.00	4	VST4-L-0375	403401	403411	403416	403421	403431	403436		403441
1/2	1/2	.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
		2.000	4.00	4	VST4-L-0500	405401	405411		405421	405431	405436	405441	405451
5/8	5/8	.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
		2.500	5.00	4	VST4-L-0625	406401			406411	406421	406426	406431	406441
3/4	3/4	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
		3.000	6.00	4	VST4-L-0750	407401			407411	407421	407426	407431	407441
1.0	1.0	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.

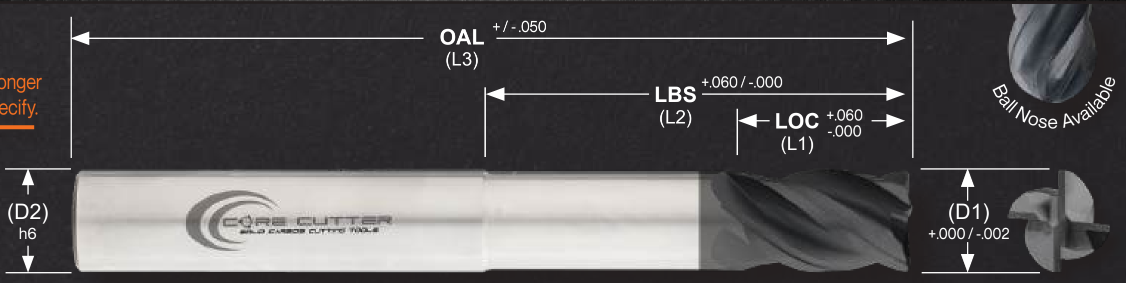
4-Flute High-Performance A-Max Coated (Reduced Neck) Endmill

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.

Maine Made

FEM5

Our Proven High-Performance 5-Flute Finishing Geometry

End Construction Options:
- Square Corner Only

Center-Cutting End Geometry

Extra-Fine Grain Cemented Carbide

+.000/-.002 Cutting Diameter Tolerance

A-Max Coated

Strengthened Core Diameter

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

FEM5

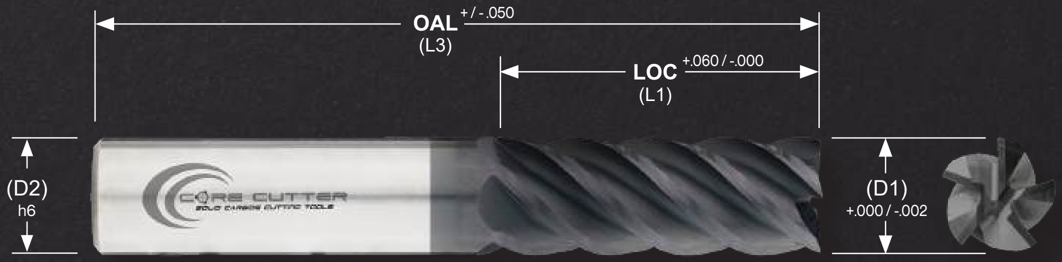
5-Flute High-Performance A-Max Coated Finishing Endmill

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-SR-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

+.000/-.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

VST5

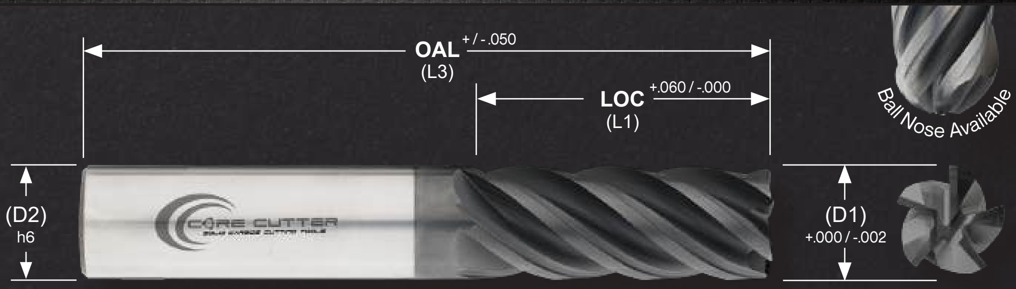
5-Flute High-Performance P-Max Coated Endmill

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**

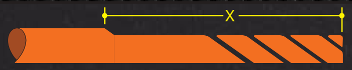


Tool Geometry						EDP #'s by Corner Condition							
Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.020R	.030R	.060R	.090R	.125R	Ball Nose
1/8	1/8	0.250	1.50	5	VST5-S-0125	510001	510011						510041
		0.375	2.00	5	VST5-SR-0125	510101	510111						510141
		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
		1.250	3.00	5	VST5-M-0250	501301	501311	501316	501321	501331			501341
5/16	5/16	0.500	2.00	5	VST5-SR-0312	502101	502111		502121				502141
		0.750	2.50	5	VST5-R-0312	502201	502211		502221				502241
		1.250	3.00	5	VST5-M-0312	502301	502311		502321				502341
3/8	3/8	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
		1.250	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
1/2	1/2	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
		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
5/8	5/8	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
		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
3/4	3/4	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
		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
1.0	1.0	1.750	4.00	5	VST5-SR-1000	508101			508111	508121	508126	508131	508141
		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

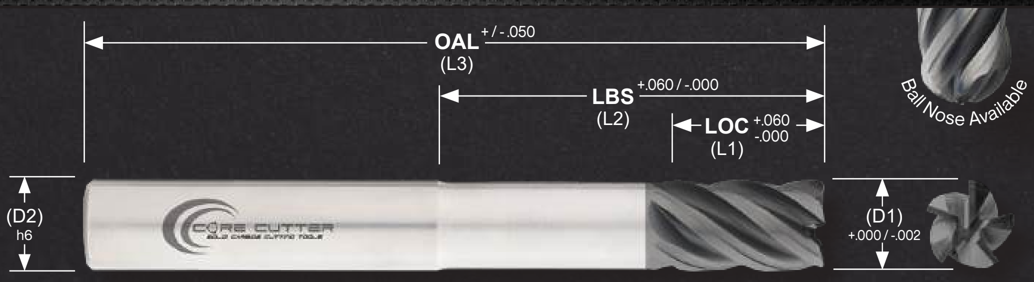


Check out "Un-Necked" in the table below for longer OALs and a custom LBS length you want to specify.

Cutting Parameters
pp. 58 - 59

Permittable ISO Material Categories

P M K S H



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

Maine Made

Our Proven High Performance 6-Flute Geometry

Center-Cutting End Geometry

End Construction Options:
- Square Corner
- Corner Radii
- Ball Nose

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

Extra-Fine Grain Cemented Carbide

Need Long Reach? See p. 55

Variable Flute Indexing

Strengthened Core Diameter

T-Max Coated

Need Chipbreakers? See pp. 17-18

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

VST6

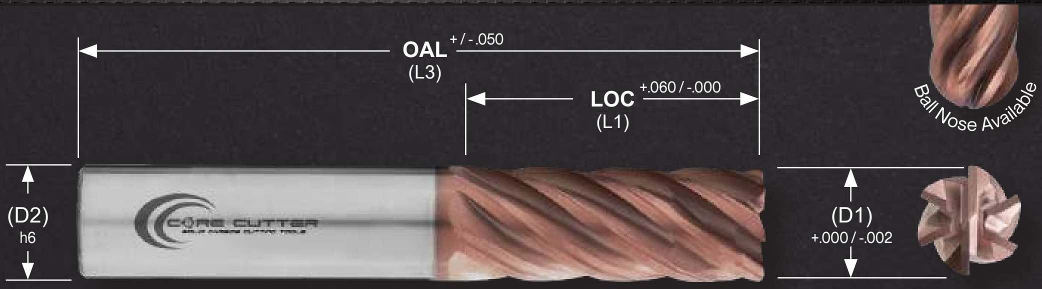
6-Flute High-Performance T-Max Coated Endmill

Custom made configurations of the VST6 style are available upon request

Cutting Parameters
pp. 58 - 59

Permittable ISO Material Categories

P **M** **K** **S** **H**



Cut Dia. (D1)	Shank Dia. (D2)	LOC (L1)	OAL (L3)	Flute Count	Tool Description	Square Corner	.015R	.020R	.030R	.060R	.090R	.125R	Ball Nose
Tool Geometry						**EDP #'s by Corner Condition**							
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
		1.250	3.00	6	VST6-M-0250	601301	601311	601316	601321	601331			601341
5/16	5/16	.500	2.00	6	VST6-SR-0312	602101	602111		602121				602141
		.750	2.50	6	VST6-R-0312	602201	602211		602221				602241
		1.250	3.00	6	VST6-M-0312	602301	602311		602321				602341
3/8	3/8	.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
		.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
1/2	1/2	.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
		2.000	4.00	6	VST6-L-0500	605401	605411		605421	605431	605436	605441	605451
5/8	5/8	.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
		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
3/4	3/4	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
		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
1.0	1.0	1.750	4.00	6	VST6-SR-1000	608101			608111	608121	608126	608131	608141
		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.

VST6-RN

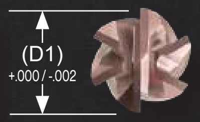
6-Flute High-Performance T-Max Coated (Reduced Neck) Endmill

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							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.

Maine Made

VMF

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

End Construction Options:
- Square Corner
- Corner Radii

Extra-Fine Grain Cemented Carbide

Variable Flute Indexing

C-MAX Coated

Need Chipbreakers?
See pp. 19-20

Serialization of every tool on shank by lot#

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

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

Strong 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
Heavy Peripheral
Light Peripheral
Contouring
Slotting
Ramping
Plunging
Wall Finishing
Floor Finishing
Interpolation
Chamfering
Countersinking
Deburring
Beveling

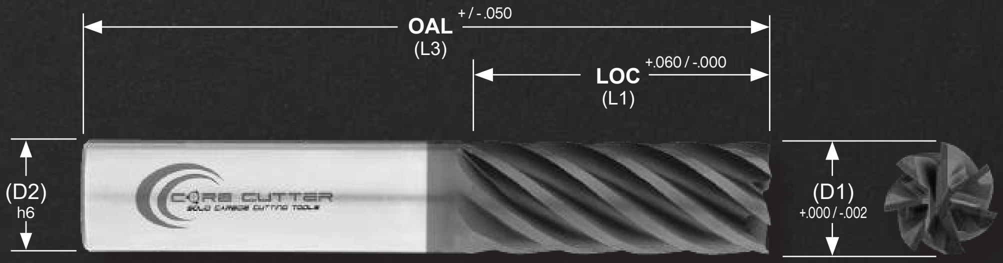
Multi-Flute (7, 9 and 11 Flutes)High-Performance C-Max Coated Endmill

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	VMF-7-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

Ferrous (& Titanium) Tooling

Feed Table (f_z)

ISO Material Categories		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
P	**Free Machining Steels** 1018, 1215, 12L14	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
	Alloys Steels 4130 (Chrome Moly), 4140, 4340, 8620	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
	Tool & Die Steels A2, D2, H13, P20, S7	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	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
	Austenitic Stainless Steel 303, 304, 316, 321	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
	PH Stainless Steel 13-8, 15-5, 17-4	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	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
	Ductile Cast Iron A536 Grade 60-40-18	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
	Malleable Cast Iron 310M8, 22010, M4504	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	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
	HRSA (Co) Rene 41, HS-188, X-40, AiResist 13, Stellite	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
	HRSA (Fe) A286, Incoloy, Udimet, Discaloy	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
	HRSA (Ni) Inconel, MAR-M-247, Udimet-700, Haynes, Monel, Rene 150, Waspaloy	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)	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
	Hardened Steel (>55 HRC)	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 (fz) based on chip thinning at ≤10% step over, and for SFM, you can take our recommendations x 1.5 - 1.8*

KEY

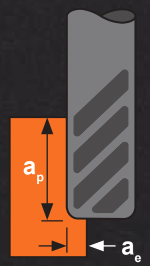
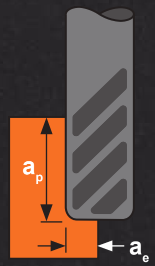
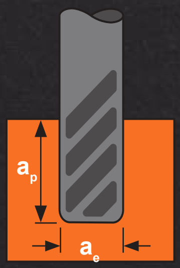
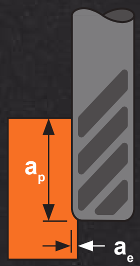
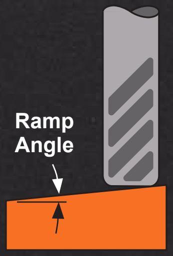
Co	Cobalt (Chemical Element - see p. 79)	HP	Heavy Peripheral (a_e = 30%-to-50% of Dia.)	SFM	Surface Feet per Minute
D1	Tool Cutting Diameter	HEM	High Efficiency Milling (see pp. 84-86)	S	Slotting (a_e = 100% of Dia.)
F	Finishing (see p. 93)	LP	Light Peripheral (a_e = 18%-to-29% of Dia.)	HRC	Rockwell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

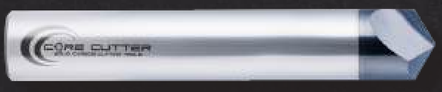
Angle	Ramping angle to utilize	FEED	F_z to use for this operation	LOC	Length of Cut (L1)
D1	Tool Cutting Diameter	HP	Heavy Peripheral (a_e = 30%-to-50% of Dia.)	MRR	Metal Removal Rate (See p. 87)
a_e	Radial Depth of Cut	HEM	High Effeciency Milling (See pp. 84-86)	Ramping	Tool plunges gradually
a_p	Axial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

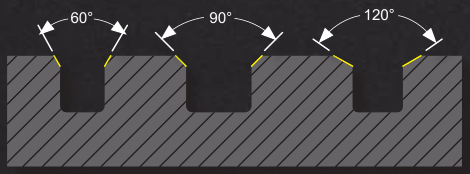
CHAMFER Tooling

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
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

CMS

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



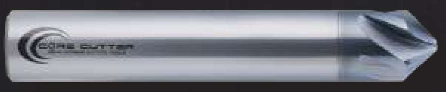


Standard Incl. Angles found in our lineup

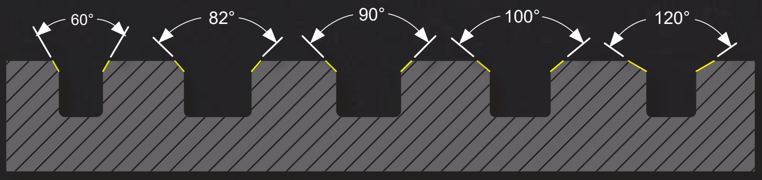
We can custom make the CMS in any configuration you need, just let us know!

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.

CMS

Maine Made

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 USA

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

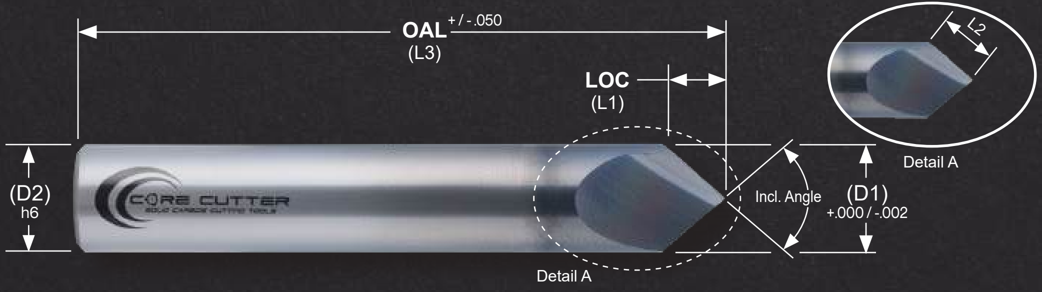
2 & 4 Flute Straight Fluted Chamfer Mills with P-Max Coating

Custom made configurations of the CMS style are available upon request

Cutting Parameters pp. 66 - 67

Permittable ISO Material Categories

N P M K S H



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.

CMH

Maine Made

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/-.002.

Non-Center Cutting

P-Max Coated

High Performance Helical Fluted Design

2, 3 & 5 Flute Options

Extra-Fine Grain Cemented Carbide

CNC Ground in the USA

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

CMH

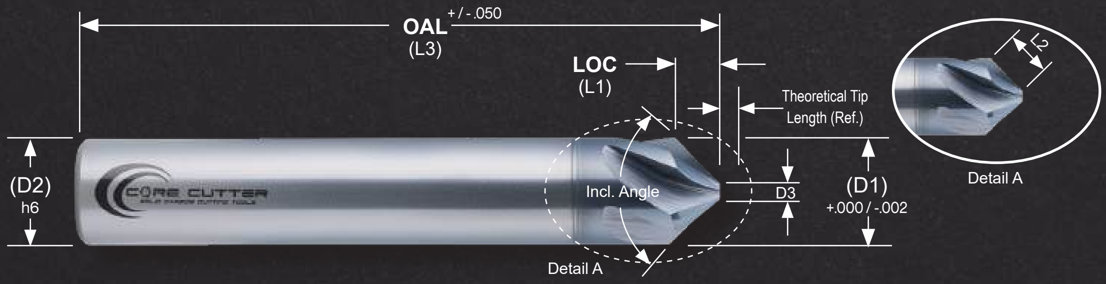
2, 3 or 5 Flute HP Helically Fluted Chamfer Mills with P-Max Coating

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)	LOC (L1)	Cutting Edge Length (L2)	OAL (L3)	Tip Diameter (D3)	Theoretical Tip Length (Ref.)	Flute Count	Tool Description	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
		.055	.110	2.50	.060	.0170	5	CMH120-5-0250					H12053
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...

CMH (Cont.)

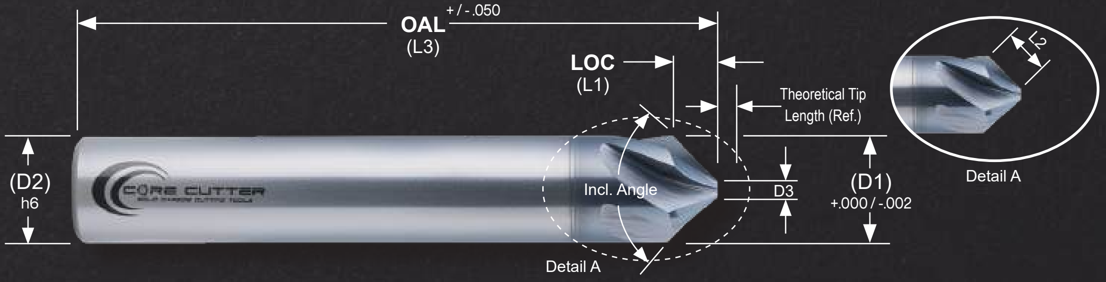
2, 3 or 5 Flute HP Helically Fluted Chamfer Mills with P-Max Coating

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)	LOC (L1)	Cutting Edge Length (L2)	OAL (L3)	Tip Diameter (D3)	Theoretical Tip Length (Ref.)	Flute Count	Tool Description	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
		.154	.309	3.00	.090	.0260	5	CMH120-5-0625					H12056
3/4	3/4	.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

Chamfer Tooling Series

Feed Table (f_z)

ISO Material Categories		SFM	$D1_{eff} \le 1/8$		$D1_{eff} \le 3/16$		$D1_{eff} \le 1/4$		$D1_{eff} \le 3/8$		$D1_{eff} \le 1/2$		$D1_{eff} \le 5/8$		$D1_{eff} \le 3/4$	
			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/-.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.

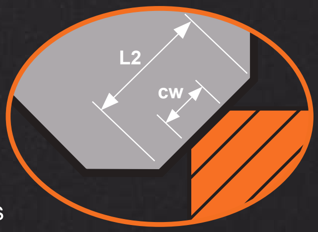


Fig. 1 - Chamfer Saddling

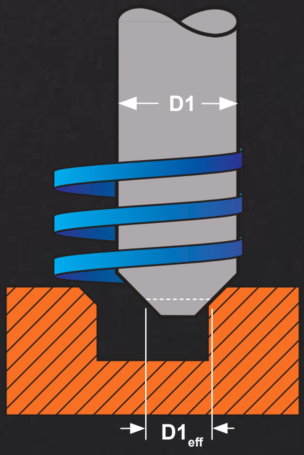


Fig. 2 - Helical Interpolation with our chamfering cutters

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.

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.

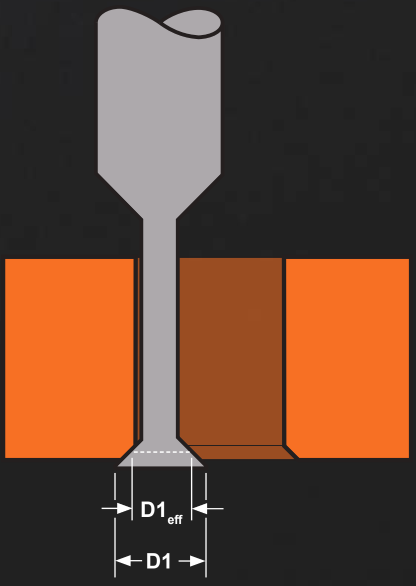


Fig. 3 - Helical Interpolation with a back chamfer tool.

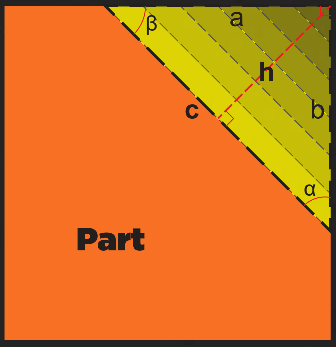


Fig. 4 - Heavy Beveling Strategy

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 x b x c.

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.

TECHNICAL RESOURCES

Need addition technical help?

☎ 207. 588.7519

✉ techsupport@corecutterusa.com

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.

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

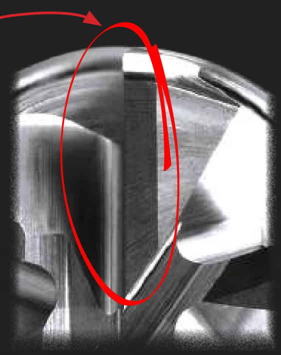
This type of tooling category (aka GP) are commonly manufactured with:

- 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



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.

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 *(Refer to page 87 for further details.)*	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 *(Refer to page 88 for further details.)*	$f_{z\,(adj)}$	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 *(Refer to pages 89-90 for more details.)*	$V_{f\,(adj)}$	Inch	$V_f \times (\text{Hole Ø} - \text{Tool Ø}) \div \text{Hole Ø}$	mm	$V_f \times (\text{Hole Ø} - \text{Tool}) \div \text{Hole Ø}$
Ball Nose Effective Dia. *(Refer to page 92 for further details.)*	D_{eff}	Inch	$D1_{eff} = 2 \times \sqrt{R^2 - (R - a_p)^2}$	mm	$D1_{eff} = 2 \times \sqrt{R^2 - (R - a_{p\,(mm)})^2}$
Floor Finishing *(Refer to page 93 for further details.)*	a_e	Inch	$a_e = (D1 - (2 \times \text{Tool Corner Radius})) \text{ x } .75$	mm	$a_e = (D1 - (2 \times \text{Tool Corner Radius})) \text{ x } .75$
Power Requirements *(Refer to page 75 for further details.)*	HPm	Hp(I)	$\frac{(MRR/K)}{E}$	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)	HPm	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.

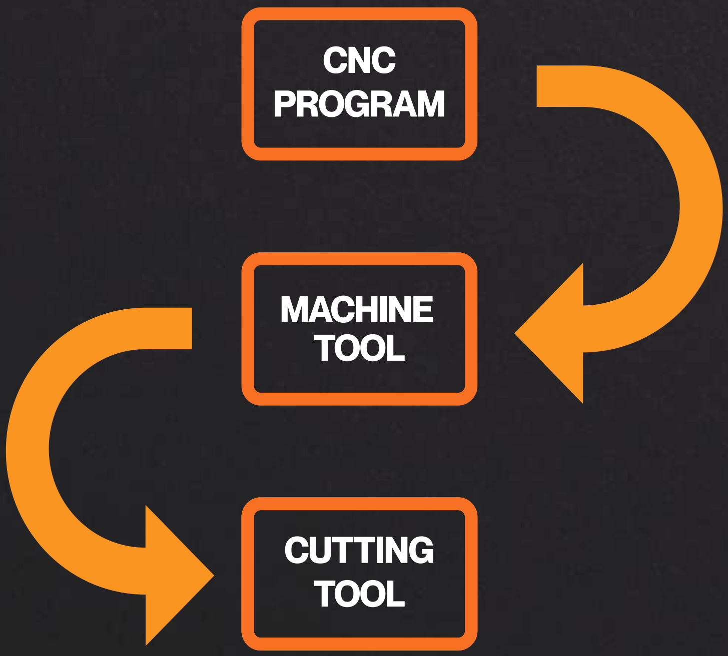


Fig. 1 - Program-to-Tool Hierarchy

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.

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?

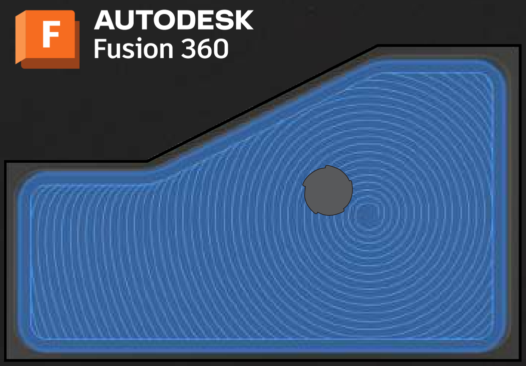


Fig. 2 - HEM Tool Path Example (Shown, is the adaptive clearing tool path generated by Autodesk® Fusion 360™

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

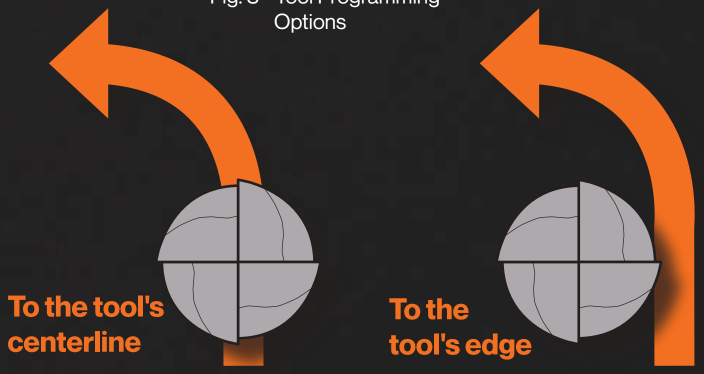
Programming Type - The tool is typically programmed along its centerline (Fig. 3); this practice is acceptable, but it is important to be mindful of it.

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.

Fig. 3 - Tool Programming Options



An Example of a Basic Program

Program Header

Tool Assignment

Safety Commands

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

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

Cutter Comp with table feed adjustment to 36 IPM

%	Start of Program
O0001 (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 GS4	Use Fixture Offset #1.
N5 M8	Coolant On.
N6 GOO 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 GOO 21	Rapid to safe plane.
N17 M5	Spindle Off.
N18 M9	Coolant Off.

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.

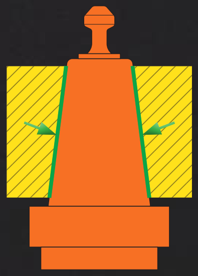


Fig. 1 - Steep Taper

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 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.

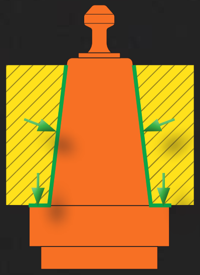


Fig. 2 - Steep Taper w/ Dual Contact

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.

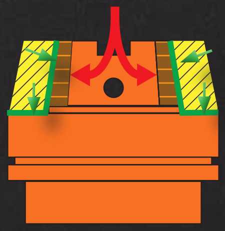


Fig. 3 - HSK Taper

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.

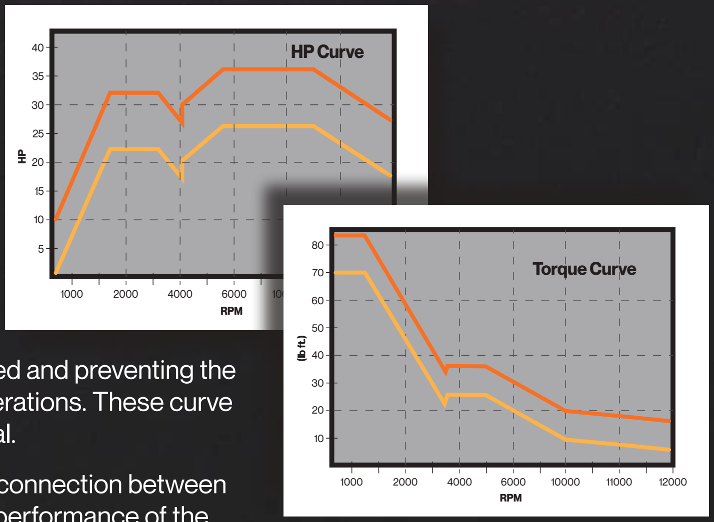


Fig. 4 - Machine Tool HP & Torque Curves

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).

Fig. 5 - Box Way

Fig. 6 - Linear Guides

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.

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 inorder 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.*

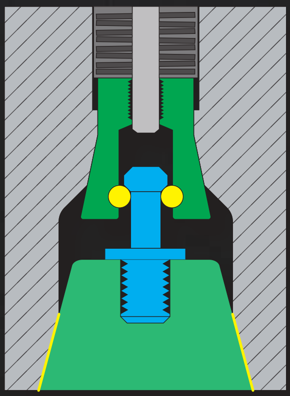


Fig. 2
Draw bar is closed gripping the tool holder

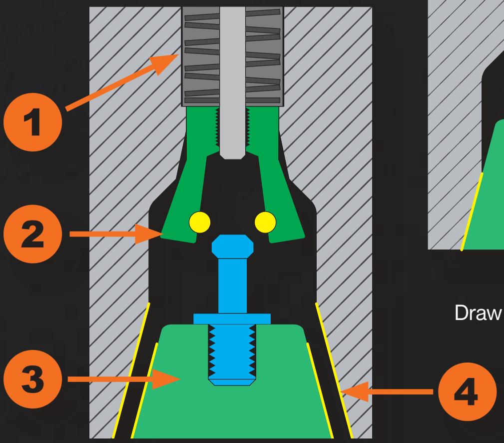


Fig. 3
Draw bar is open and releasing tool holder

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 dynometer.
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.

MATERIAL KNOWLEDGE

Being familar 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
- **HRB** = Rockwell "B" Hardness
- **HRC** = Rockwell "C" 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.*

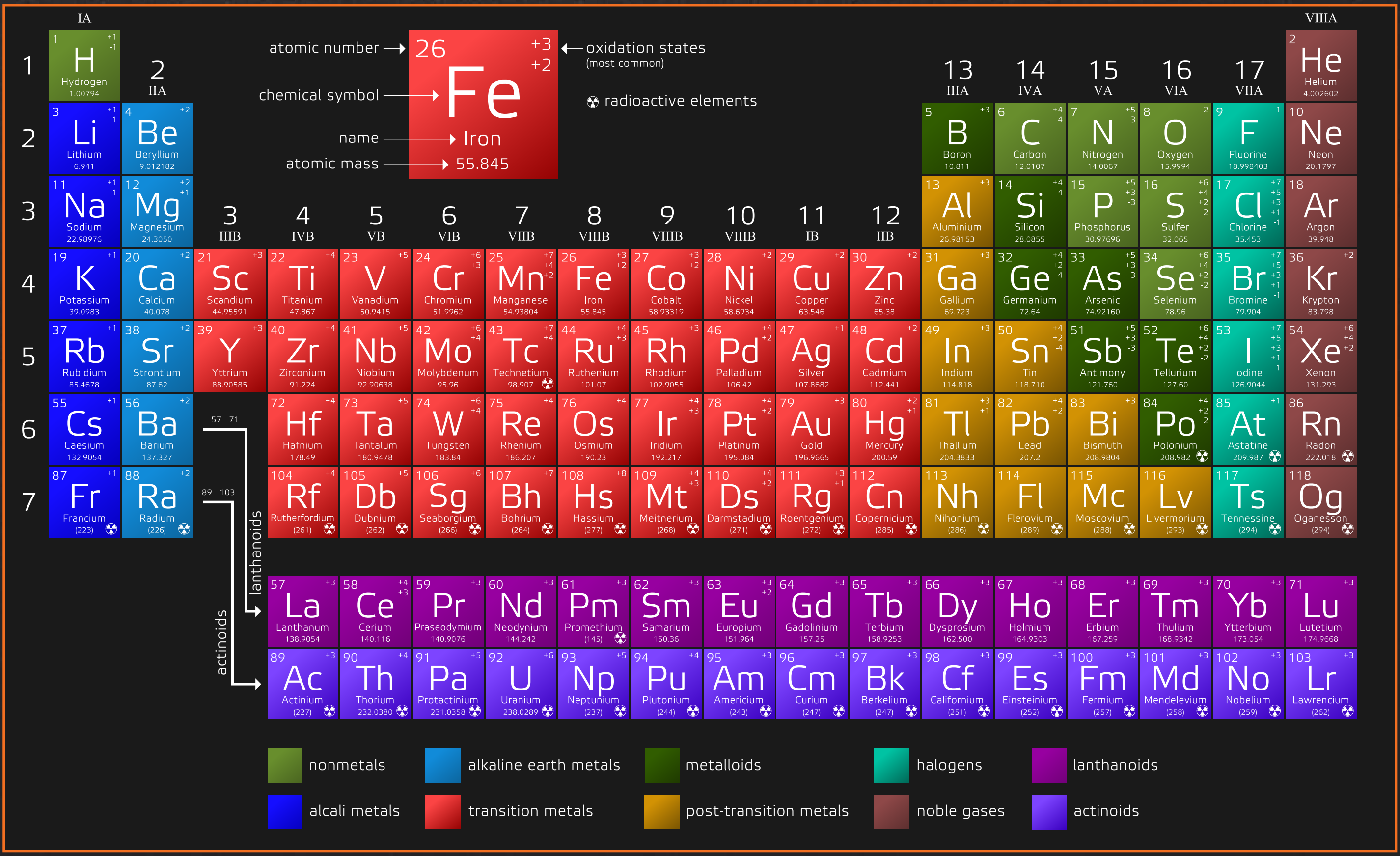
Work-Hardenability: If the material you are working with contains elements such as silicon, manganese, nickel, chromium, and molybdenum, problems could arise the longer you stay in the cut! The degree of hardening depends on the amount of heat generated during the cutting action as well as the properties 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
chemical symbol → Fe
name → Iron
atomic mass → 55.845
+3 +2 ← oxidation states (most common)
☢ radioactive elements

	IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	VIIIA
1	1 H +1 -1 Hydrogen 1.00794																	2 He Helium 4.002602
2	3 Li +1 -1 Lithium 6.941	4 Be +2 Beryllium 9.012182											5 B +3 Boron 10.811	6 C +4 -4 Carbon 12.0107	7 N +5 -3 Nitrogen 14.0067	8 O -2 Oxygen 15.9994	9 F -1 Fluorine 18.998403	10 Ne Neon 20.1797
3	11 Na +1 -1 Sodium 22.98976	12 Mg +2 +1 Magnesium 24.3050											13 Al +3 Aluminium 26.98153	14 Si +4 -4 Silicon 28.0855	15 P +5 +3 -3 Phosphorus 30.97696	16 S +6 +4 +2 -2 Sulfer 32.065	17 Cl +7 +5 +3 +1 -1 Chlorine 35.453	18 Ar Argon 39.948
4	19 K +1 Potassium 39.0983	20 Ca +2 Calcium 40.078	21 Sc +3 Scandium 44.95591	22 Ti +4 Titanium 47.867	23 V +5 Vanadium 50.9415	24 Cr +6 +3 Chromium 51.9962	25 Mn +7 +4 +2 Manganese 54.93804	26 Fe +3 +2 Iron 55.845	27 Co +3 +2 Cobalt 58.93319	28 Ni +2 Nickel 58.6934	29 Cu +2 Copper 63.546	30 Zn +2 Zinc 65.38	31 Ga +3 Gallium 69.723	32 Ge +4 +2 -4 Germanium 72.64	33 As +5 +3 -3 Arsenic 74.92160	34 Se +6 +4 +2 -2 Selenium 78.96	35 Br +7 +5 +3 +1 -1 Bromine 79.904	36 Kr +2 Krypton 83.798
5	37 Rb +1 Rubidium 85.4678	38 Sr +2 Strontium 87.62	39 Y +3 Yttrium 88.90585	40 Zr +4 Zirconium 91.224	41 Nb +5 Niobium 92.90638	42 Mo +6 +4 Molybdenum 95.96	43 Tc +7 +4 Technetium 98.907 ☢	44 Ru +4 +3 Ruthenium 101.07	45 Rh +3 Rhodium 102.9055	46 Pd +4 +2 Palladium 106.42	47 Ag +1 Silver 107.8682	48 Cd +2 Cadmium 112.441	49 In +3 Indium 114.818	50 Sn +4 +2 -4 Tin 118.710	51 Sb +5 +3 -3 Antimony 121.760	52 Te +6 +4 +2 -2 Tellurium 127.60	53 I +7 +5 +3 +1 -1 Iodine 126.9044	54 Xe +6 +4 +2 Xenon 131.293
6	55 Cs +1 Caesium 132.9054	56 Ba +2 Barium 137.327	57 - 71	72 Hf +4 Hafnium 178.49	73 Ta +5 Tantalum 180.9478	74 W +6 +4 Tungsten 183.84	75 Re +4 Rhenium 186.207	76 Os +4 Osmium 190.23	77 Ir +4 +3 Iridium 192.217	78 Pt +4 +2 Platinum 195.084	79 Au +3 Gold 196.9665	80 Hg +2 +1 Mercury 200.59	81 Tl +3 +1 Thallium 204.3833	82 Pb +4 +2 Lead 207.2	83 Bi +3 Bismuth 208.9804	84 Po +4 +2 -2 Polonium 208.982 ☢	85 At +1 Astatine 209.987 ☢	86 Rn Radon 222.018 ☢
7	87 Fr +1 Francium (223) ☢	88 Ra +2 Radium (226) ☢	89 - 103	104 Rf +4 Rutherfordium (261) ☢	105 Db +5 Dubnium (262) ☢	106 Sg +6 Seaborgium (266) ☢	107 Bh +7 Bohrium (264) ☢	108 Hs +8 Hassium (277) ☢	109 Mt +4 +3 Meitnerium (268) ☢	110 Ds +4 +2 Darmstadium (271) ☢	111 Rg +3 +1 Roentgenium (272) ☢	112 Cn Copernicium (285) ☢	113 Nh Nihonium (286) ☢	114 Fl Flerovium (289) ☢	115 Mc Moscovium (288) ☢	116 Lv Livermorium (293) ☢	117 Ts Tennessine (294) ☢	118 Og Oganesson (294) ☢
lanthanoids			57 La +3 Lanthanum 138.9054	58 Ce +4 +3 Cerium 140.116	59 Pr +3 Praseodymium 140.9076	60 Nd +3 Neodymium 144.242	61 Pm +3 Promethium (145) ☢	62 Sm +3 Samarium 150.36	63 Eu +3 +2 Europium 151.964	64 Gd +3 Gadolinium 157.25	65 Tb +3 Terbium 158.9253	66 Dy +3 Dysprosium 162.500	67 Ho +3 Holmium 164.9303	68 Er +3 Erbium 167.259	69 Tm +3 Thulium 168.9342	70 Yb +3 Ytterbium 173.054	71 Lu +3 Lutetium 174.9668	
actinoids			89 Ac +3 Actinium (227) ☢	90 Th +4 Thorium 232.0380 ☢	91 Pa +5 Protactinium 231.0358 ☢	92 U +6 Uranium 238.0289 ☢	93 Np +5 Neptunium (237) ☢	94 Pu +4 Plutonium (244) ☢	95 Am +3 Americium (243) ☢	96 Cm +3 Curium (247) ☢	97 Bk +3 Berkelium (247) ☢	98 Cf +3 Californium (251) ☢	99 Es +3 Einsteinium (252) ☢	100 Fm +3 Fermium (257) ☢	101 Md +3 Mendelevium (258) ☢	102 No +3 Nobelium (259) ☢	103 Lr +3 Lawrencium (262) ☢	

🟩 nonmetals
🟦 alkaline earth metals
🟩 metalloids
🟩 halogens
🟪 lanthanoids
🟦 alcali 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:

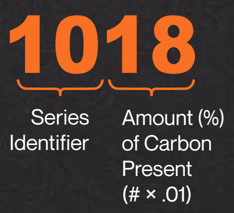
(Cr) Chromium: In terms of hardness, this fourth transition metal on the periodic table ranks third, just after carbon (diamond) and boron. Used to increase the corrosion resistance, tensile strength, and high temperature strength of steels, particularly stainless steel. Cutting tool life is reduced, 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

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%
Nickel Chromium Molybdenum Steel	**43XX**	Ni 1.82%, Cr 0.50-0.80%, Mo 0.25%
	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%

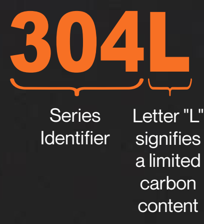
AISI Steel	Code	Specification
Chromium Steel	**50XX**	Cr 0.27-0.65%
	51XX	Cr 0.80-1.05%
	50XXX	Cr 0.50%, C 1.00% min
	51XXX	Cr 1.02%, C 1.00% min
	52XXX	Cr 1.45%, C 1.00% min
Chromium Vanadium	**61XX**	Cr 0.60-0.95%, V 0.10-0.15%
Tungsten Chromium Steel	**72XX**	W 1.75%, Cr 0.75%
Nickel Chromium Molybdenum 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%

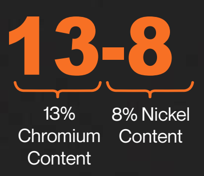
TIP *The "L" in carbon and alloy steel designations typically stands for the addition of .15-.35% lead for machining, however, in stainless steel such as 304L, indicates that carbon content is limited to 0.03 percent. Remember, while higher carbon content generally improves hardness and wear resistance,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

AISI Stainless Steel Material Grades

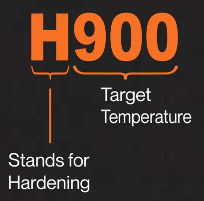
Stainless steel is available in five distinct classifications: austenitic, ferritic, martensitic, duplex, and precipitation hardening. The names are derived from the crystal structure of the steels, which provides insights into their behavior throughout metalworking processes.

- **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.

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.

$$\text{Ti-}\underbrace{\text{6Al}}_{\substack{\text{6\%}\\ \text{Aluminum}\\ \text{Content}}}\text{-}\underbrace{\text{4V}}_{\substack{\text{4\%}\\ \text{Vanadium}\\ \text{Content}}}$$

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)
Carbon Steel			
1010	.66	(C) .08 - .13	(Mn) .30 - .60
1018	.78	(C) .14 - .20	(Mn) .30 - .60
1020	.80	(C) .17 - .23	(Mn) .30 - .60
1040	.64	(C) .37 - .44	(Mn) .60 - .09
1050	.54	(C) .48 - .55	(Mn) .60 - .09
1137	.72	(C) .32 - .39	(Mn) 1.35 - 1.65
1141 (ANNEALED)	.70	(C) .37 - .45	(Mn) 1.35 - 1.65
1144	.76	(C) .40 - .48	(Mn) 1.35 - 1.65
1144 (STRESS-PROOF)	.83	(C) .40 - .48	(Mn) 1.35 - 1.65, (P) .040
1212	.100	(C) ≤0.13	(Mn) .70 - 1.0, (P).07 - .12
12L14	1.70	(C) .15	(Mn) .85 - 1.15, (P) .04 - .09, (Pb) .15 - .35
Alloy Steel			
4130	.69	(C) .28 - .33	(Mn) .40 - .60, (Cr) .80 - 1.10
4140	.61	(C) .38 - .43	(Mn) .75 - 1.00, (Cr) .80 - 1.10
4340	.57	(C) .37 - .43	(Cr) .80 - 1.10, (Ni) 1.65 - 2.00
5130	.68	(C) .28 - .33	(Cr) .80 - 1.10, (Si).15 - .30
52100	.40	(C) .98 - 1.10	(Cr) 1.30 - 1.60
8620	.66	(C) .18 - .23	(Cr) .40 - .60, (Si).15 - .35, (Ni) .40 - .70
9310	.51	(C) .07 - .13	(Cr) 1.00 - 1.40,(Ni) 3.00 - 3.50
Tool & Mold Steel			
A2	.42	(C) .95 - 1.05	(Cr) 4.75 - 5.50
D2	.27	(C) 1.40 - 1.60	(Cr) 11.00 - 13.00
H13	.55	(C) .32 - .45	(Cr) 4.75 - 5.50, (Mo) 1.10 - 1.75
S7	.75	(C) .45 - .55	(Cr) 3.00 - 3.50, (Mo) 1.30 - 1.80
P20	.65	(C) .28 - .40	(Mn) .60 - 1.00, (Cr) 1.40 - 2.00
Maraging C300	.57	(C) .30	(Ni) 18.50, (Mo) 4.8, (Co) 9.00
Austenitic Stainless Steel			
303	.78	(C) <0.10	(Cr) 17.00 - 19.00,(Ni) 8.00 - 10.00
304	.45	(C) <0.08	(Cr) 18.00 - 20.00,(Ni) 8.00 - 10.50
316	.45	(C) <0.08	(Cr) 16.00 - 18.00,(Ni) 10.00 - 14.00
321	.36	(C) <0.08	(Cr) 17.00 - 19.00,(Ni) 9.00 - 12.00
347	.36	(C) <0.08	(Cr) 17.00 - 19.00,(Ni) 9.00 - 12.00, (Nb) ≤1.00
Ferritic Stainless Steel			
405	.60	(C) <0.08	(Cr) 11.50 - 14.50
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

AISI/SAE Designation	Machinability Rating	Carbon Content	Notable Alloy(s)
Martensitic Stainless Steel			
410	.55	(C) <0.15	(Cr) 11.50 - 13.50, (Ni) ≤.75
416	.85	(C) <0.15	(Cr) 12.00 - 14.00, (Ni) ≤.60, (Mn) ≤1.25
420	.45	(C) <0.15	(Cr) 15.00 - 16.00, (Ni) .15 - .25
440C	.40	(C) <0.15	(Cr) 12.00 - 14.00, (Si) ≤1.00
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
Precipitation Hardened Steels			
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
15-5PH	.45	(C) <0.05	(Cr) 14.00 - 15.50, (Ni) 3.50 - 5.50, (Cu) 2.50 - 4.50
17-4PH	.48	(C) <0.07	(Cr) 15.00 - 17.50, (Ni) 3.50 - 5.00, (Cu) 3.00 - 5.00
Super-Alloys			
Inconel 625	.12	(C) <0.01	(Ni) 58.00, (Cr) 20.00 - 23.00, (Mb) 8.0 - 10.0
Inconel 718	.12	(C) <0.08	(Ni) 50.00 - 55.00, (Cr) 17.00 - 21.00
Inconel X-750	.12	(C) <0.08	(Ni) 36.00, (Cr) 14.00 - 17.00, (Ti) 2.25 - 2.75
Invar 36	.55	(C) <0.10	(Ni) 35.00 - 38.00
Alloy C (C-276)	.18	(C) <0.10	(Ni) 50.00 - 52.00, (Cr) 14.50 - 16.50, (Mb) 15.0 - 17.0
Kovar	.22	(C) <0.02	(Ni) 29.00, (Co) 17.00, (Mb) 15.0 - 17.0
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
A286	.54	(C) <0.04	(Ni) 25.50, (Cr) 19.00 - 21.00, (Cu) 3.00 - 4.00, (Mo) 2.00 - 3.00
Maraging 300	.60	(C) <0.03	(Ni) 18.50, (Co) 9.00, (Mo) 4.80
Grey Cast Iron			
Class 20	.73	(C) 3.25 - 3.50	(Si) 1.80 - 2.30
Class 25	.55	(C) 3.25 - 3.50	(Si) 1.80 - 2.30, (Ni) .05 - .20
Class 30	.48	(C) 3.25 - 3.50	(Si) 1.80 - 2.30, (Ni) .05 - .20, (Cr) .05 - .45
Class 45	.36	(C) 3.25 - 3.50	(Si) 2.10 - 2.30
Nodular (Ductile) Iron			
60-40-18	.61	(C) 3.40 - 3.80	(Si) 2.00 - 2.50, (Mg) .025 - .055, (Cr) ≤ .08
65-45-12	.61	(C) 3.40 - 3.80	(Si) 2.35 - 2.75, (Mg) .025 - .055, (Cr) ≤ .08
80-55-06	.39	(C) 3.40 - 3.80	(Si) 2.35 - 2.75, (Mg) .025 - .055, (Cr) ≤ .08
Aluminum/Magnesium Alloys			
Aluminum (Wrought)	3.6	n/a	Depends on individual grade
Aluminum (Cast)	4.5	n/a	Depends on individual grade
Aluminum (Die Cast)	.76	n/a	Depends on individual grade
Magnesium (Cold Drawn)	4.8	n/a	Depends on individual grade
Magnesium (Cast)	4.8	n/a	Depends on individual grade

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
- Fixture Plates and Tombstones
- Collet Systems
- Clamping Systems
- Magnetic Work holding
- Vacuum Work holding
- Zero-Point Clamping
- Pallet Changers
- 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 EFFECIENCY MILLING

High effeciency 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_e) -** HEM often utilizes a more shallow depth of cut (a_e) 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_e) may lead some to believe that we are sacrificing efficiency, we compensate for this by increasing the axial engagement (ap), which also enables us to utilize more of the length of cut (L1). If you 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 EFFECIENCY MILLING (Cont.)

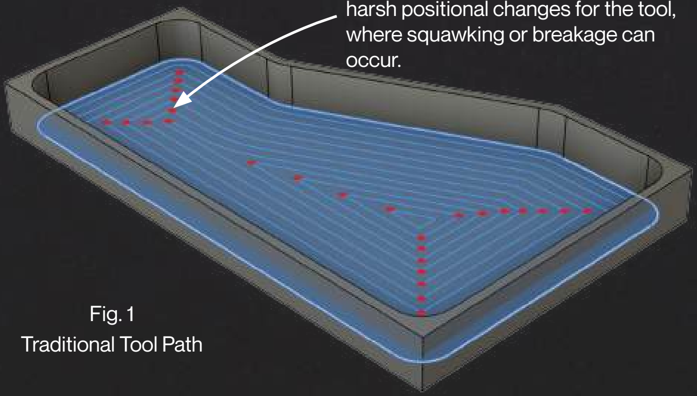
larity with and is considered a strategy whose primary goals are to maintain or

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!



Red highlighted areas represent harsh positional changes for the tool, where squawking or breakage can occur.

Fig. 1
Traditional Tool Path

AUTODESK Fusion

All tool path illustrations in this catalog have been generated using Autodesk Fusion®

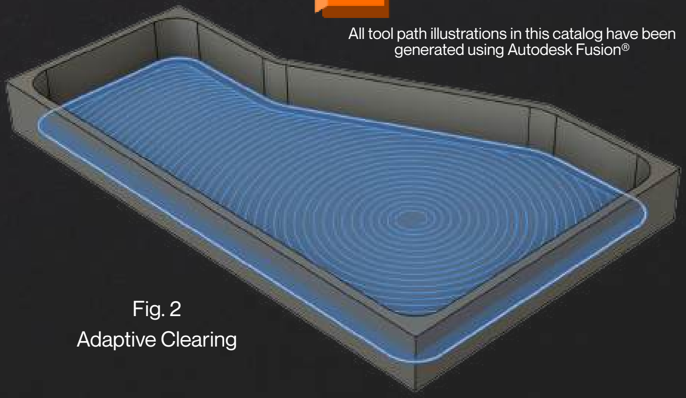


Fig. 2
Adaptive Clearing

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 EFFECIENCY 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 Radi -** 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.

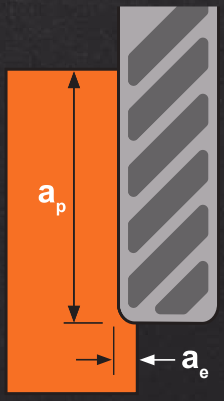


Fig. 1 - Illustration of a HEM light Radial DOC (a_e) and Heavy Axial DOC (a_p)

High Efficiency Milling (HEM) DOC Guidelines

	Flute Count	Tool Series	Axial Depth of Cut (Ap)	Radial Depth of Cut (Ae)
N	3f	AL3	Up to 3.5 × Tool Diameter	10%-to-25% of the Diameter
		AL3-CB	Up to 3.5 × Tool Diameter	12%-to-30% of the Diameter
		AL3-RN	Up to full length of cut (L1)	10%-to-25% of the Diameter
P M K S H	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
	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
	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
	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
	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

TIP 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 (in^3/min.) or (mm^3/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.

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

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 (ae) adjustment during a HEM application utilizing a 1/2" tool with a 7% (.035) radial depth of cut (ae); 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×D (a_p)
MRR:	.25 × .50 × 27 ipm = 3.38 In^3 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×D (a_p)
MRR:	.050 × 1.00 × 106 ipm = 5.30 In^3 min.

Impressive Improvement

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

- ✓ 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, your 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% × 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).

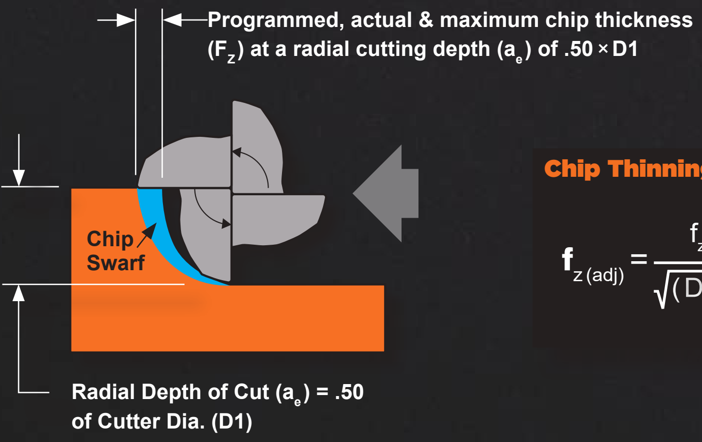


Fig. 1 - Step Over (a_e) ≥ .50 x D1

Chip Thinning Calculation

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

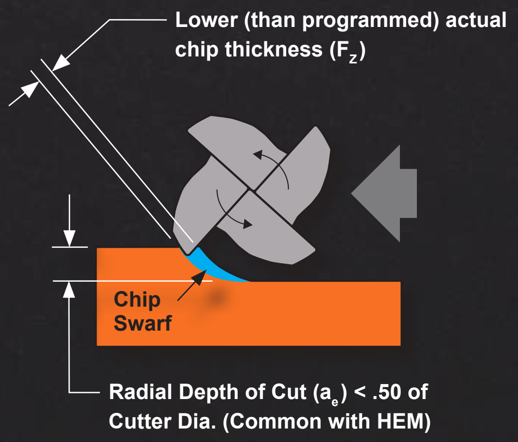


Fig. 2 - Step Over (a_e) < .50 x D

Tool Engagement Angle (TEA)

Knowing your TEA

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

Knowing your width of cut

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

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

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.

Fig. 3

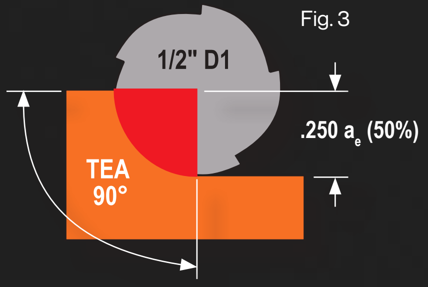


Fig. 4

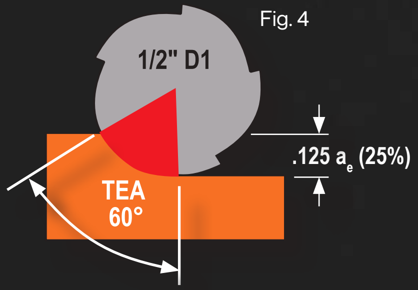
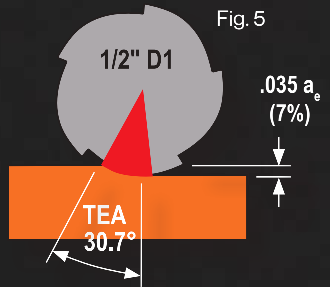


Fig. 5



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

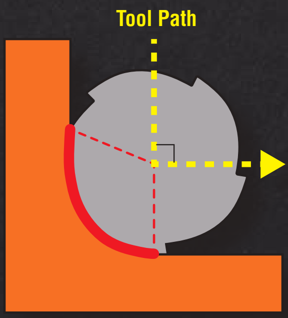


Fig. 6 - TEA > 90°

Managed TEA Angle (≤90°)

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

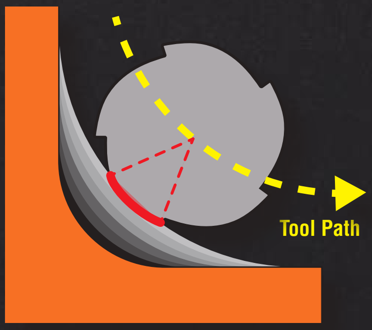


Fig. 7 - TEA ≤ 90°

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.

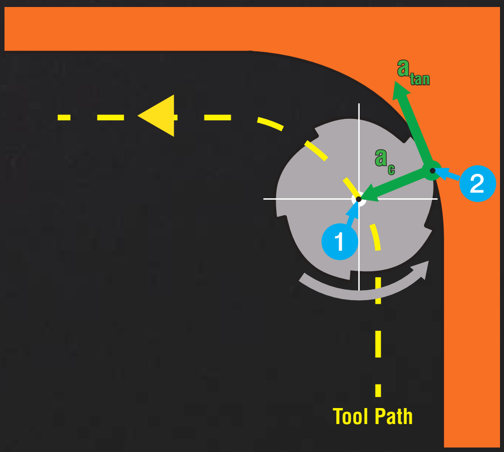
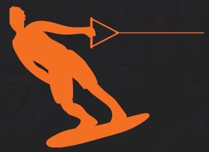


Fig. 8 - Acceleration on Inside Corner

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 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.

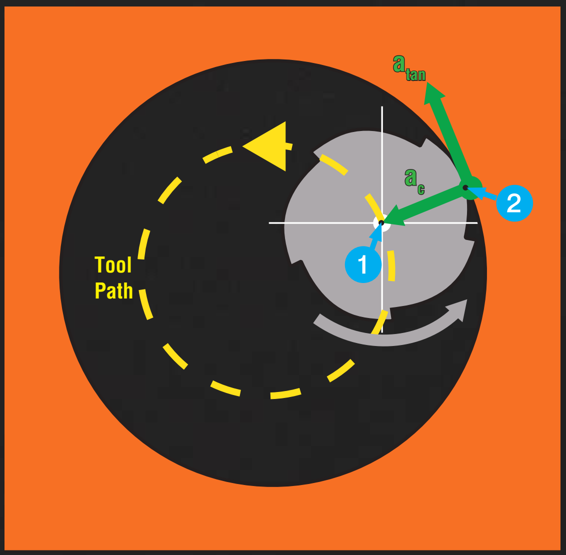


Fig. 9 - Acceleration on Inside Interpolation

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).

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.

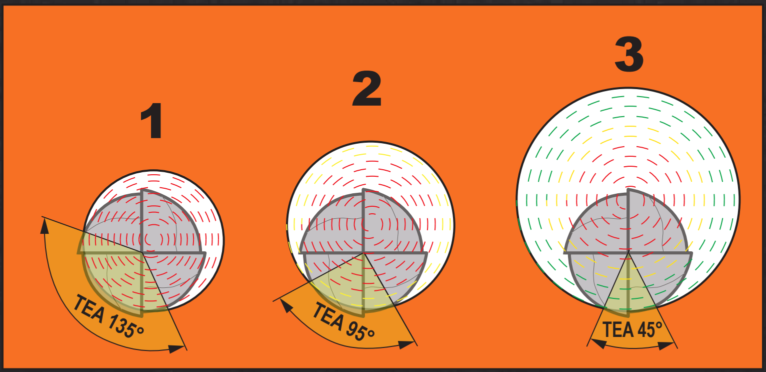


Fig. 10 - Acceleration on Inside Hole Interpolation

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_e) 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, thats 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.

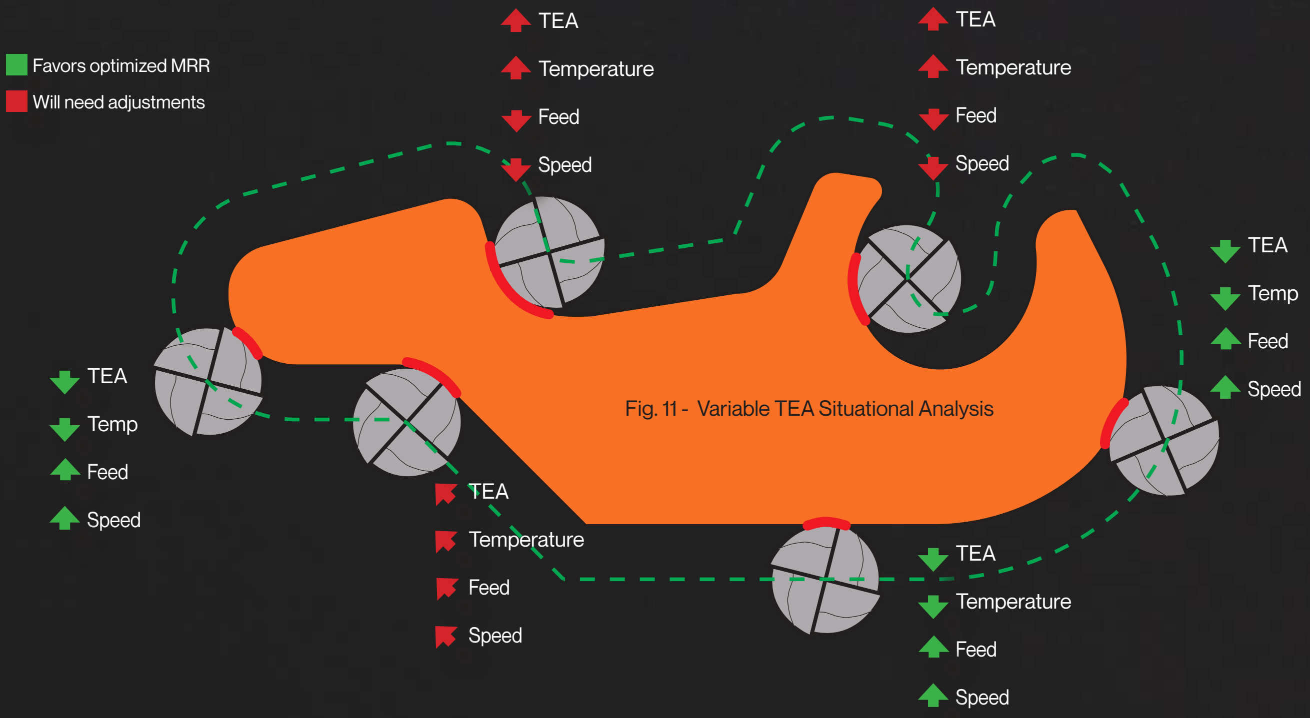


Fig. 11 - Variable TEA Situational Analysis

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;

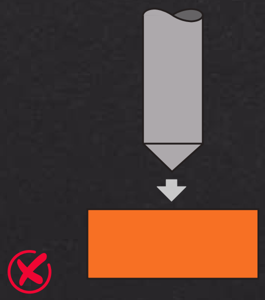


Fig. 1 - Straight Decent

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. 2 - Ramping

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°) 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.

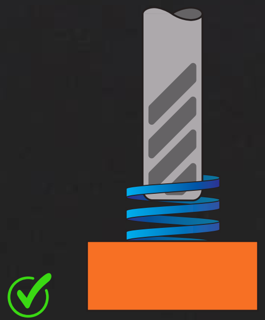


Fig. 3 - Helical Interpolation

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°) with increased feed works well.

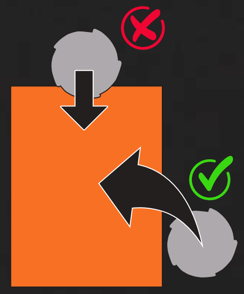


Fig. 4 - Side Entry

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.

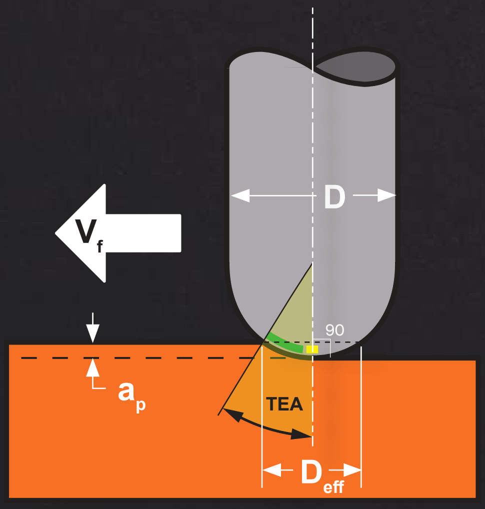
BALL NOSE MILLING

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

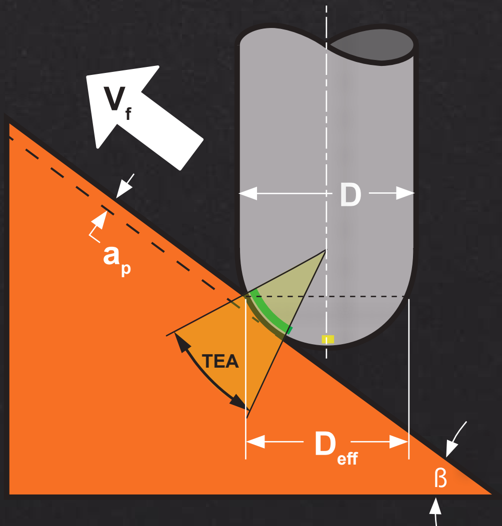
If employing less than the full diameter of the tool, make sure to use the effective cutting diameter (D_{eff}). The effective cutting diameter takes into account the step over or engagement of the tool in the material. If your a_p is less than your ball nose radius, it's important to base your tool's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

$$D_{eff} = D1 \times \sin\left(ß + \text{arc cos}\left(1 - \frac{2 \times a_p}{D}\right)\right)$$

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 ($f_{z\ (adj)}$) 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.

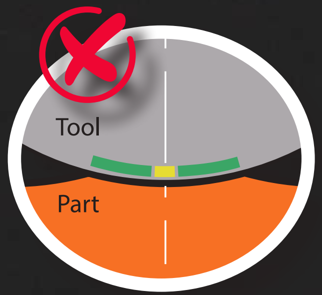


Fig. 3

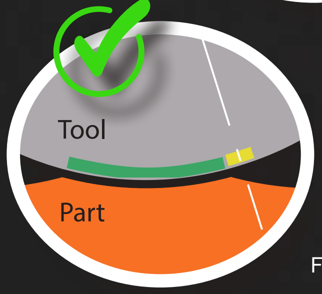


Fig. 4

UNDERSTANDING SURFACE FINISH

Here's a brief overview on surface finishing, symbols, calcuations 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.

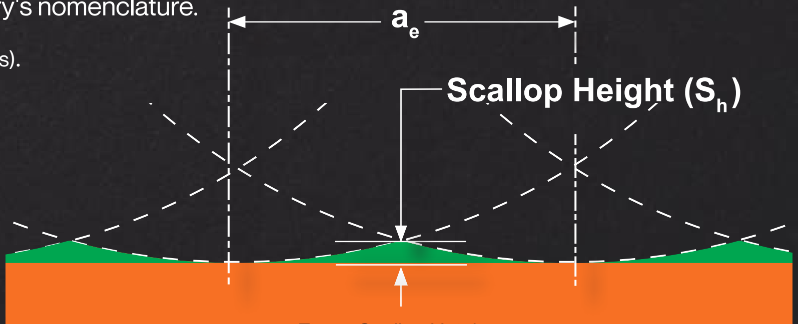


Fig. 1 - Scallop Height

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:

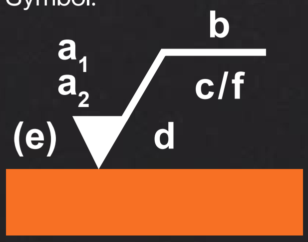
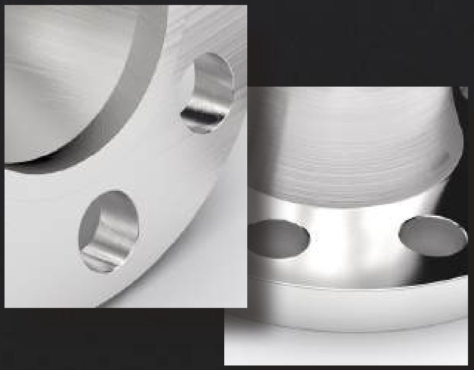


Fig. 2 - Finish Symbol

a) Roughness value in Ra [micrometer]
(if only one value is shown, then it equals the high limit)
a_1: Ra - High Limit
a_2: 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 (Ap) 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 (ae) 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 (ap) by 25%.

To calculate step over (a_e) for bull nose facing

a_e = (D1 - (2× Tool Corner Radius)) x .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.

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.

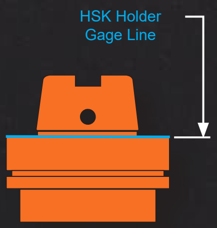


Fig. 1

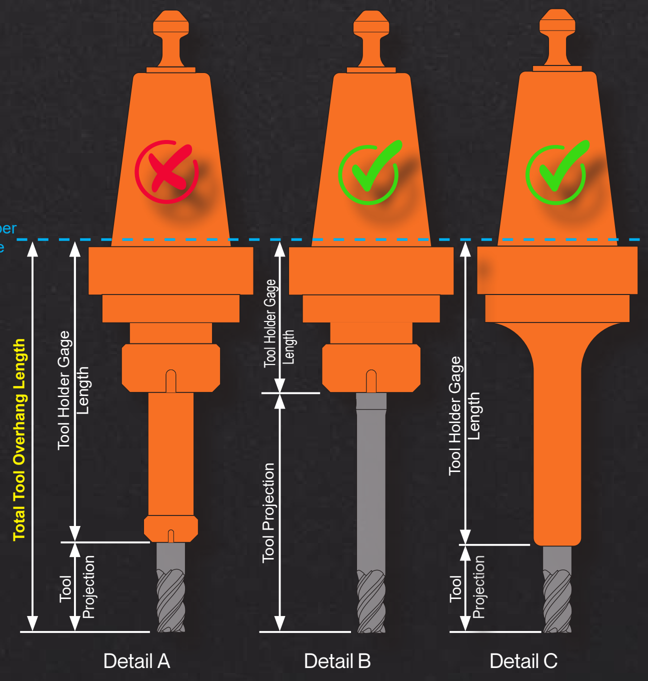


Fig. 2

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]

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.

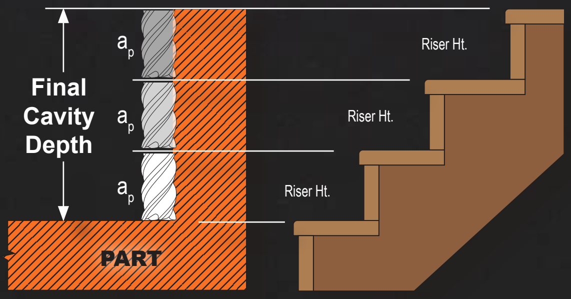


Fig. 3 - An example of reduced neck (RN) step down milling

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 (ae) 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 (4xD). 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 (1.5xD) while maintaining a considerable radial depth of cut (ae). This will guarantee maximum efficiency by controlling the metal removal rate (MRR) and simultaneously maximizing your productivity.

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**

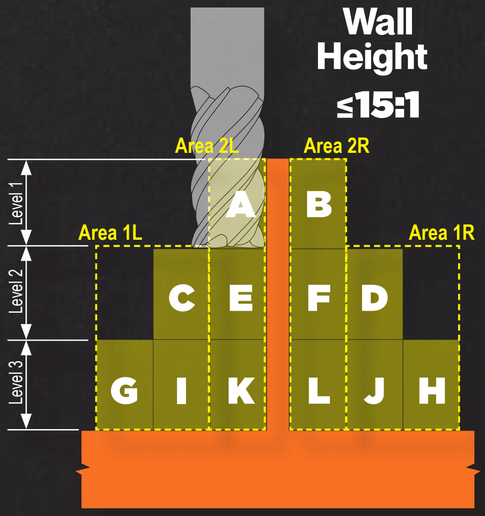


Fig. 4 - Material Removal Strategy ≤15:1

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 ≤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.

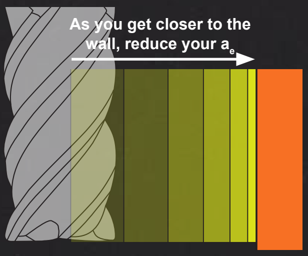


Fig. 5 - Radial DOC (a_e) Strategy

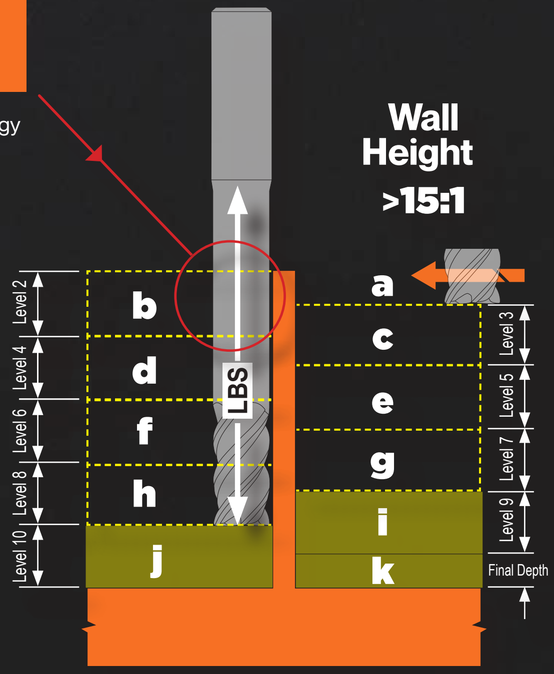


Fig. 6 - Material Removal Strategy **>15**:1

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***

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.

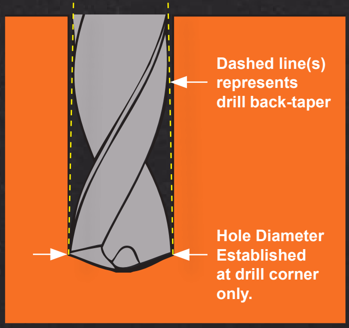
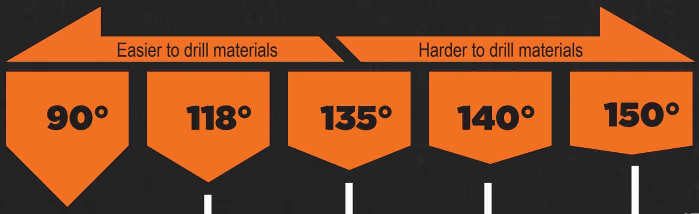


Fig. 1 - Drill Back-taper runs along entire flute length minimizing friction

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.

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 indepth 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.

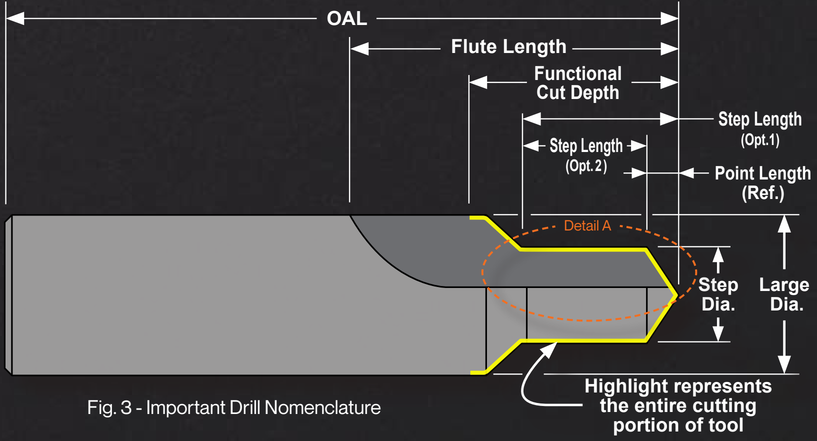
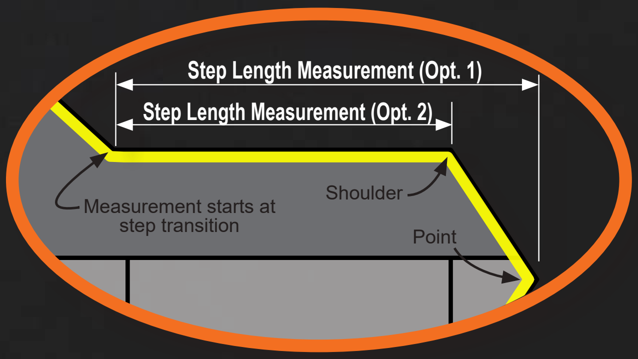


Fig. 3 - Important Drill Nomenclature

- **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.



Detail A - Closeup of Step Length Measurement

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 (Vf) 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.*

TOOL TROUBLESHOOTING

For your convienence, 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 futher 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_e, a_p) 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 futher 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 maintan 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_p) 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.)

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

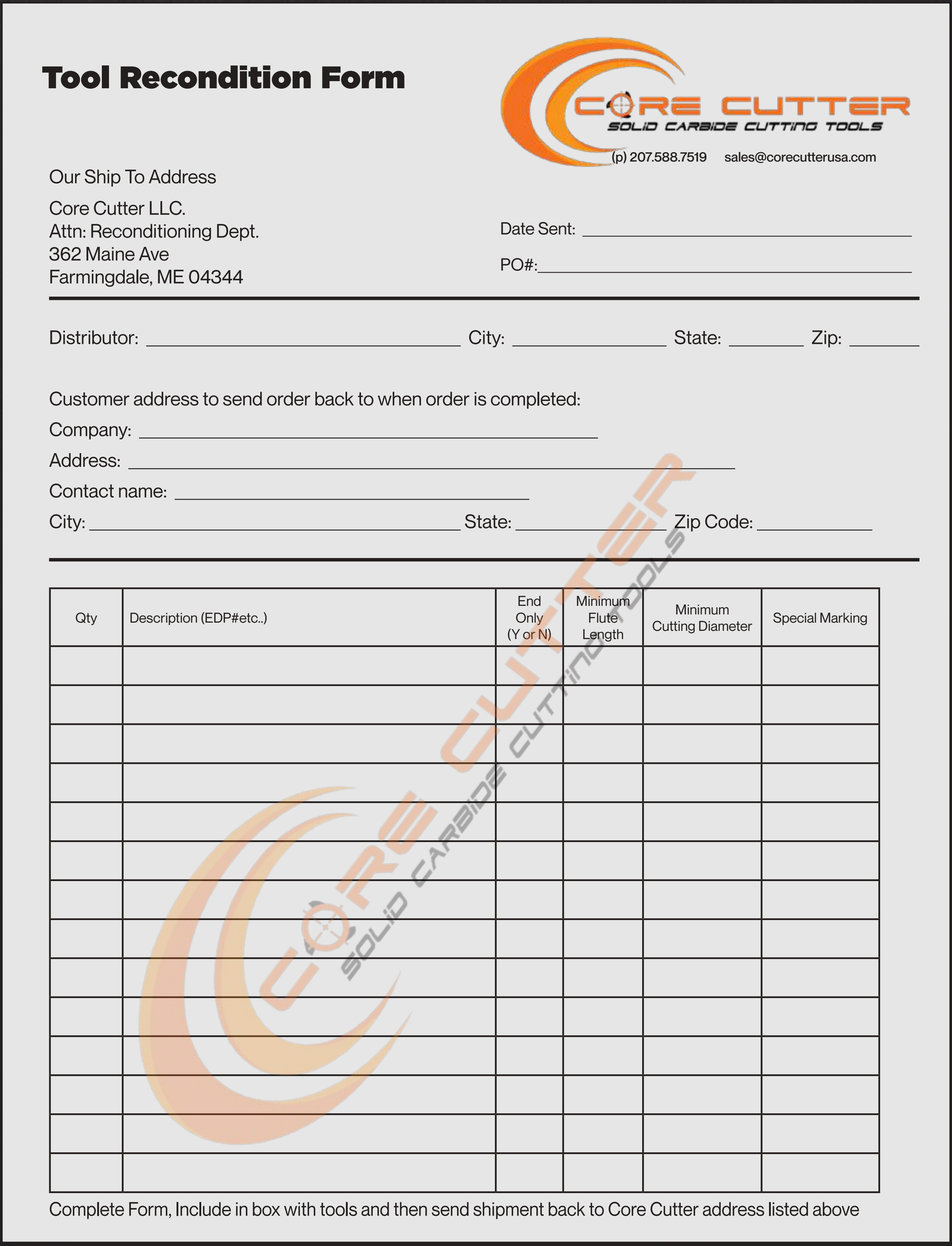
Testing Objective

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_e)				
	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				

TOOL RECONDITIONING FORM

We provide a comprehensive reconditioning program, there's also a brochure available!



Tool Recondition Form

CORE CUTTER
SOLID CARBIDE CUTTING TOOLS
(p) 207.588.7519 sales@corecutterusa.com

Our Ship To Address

Core Cutter LLC.
Attn: Reconditioning Dept.
362 Maine Ave
Farmingdale, ME 04344

Date Sent: ______________________________

PO#: ______________________________

Distributor: ____________________ City: ____________ State: ______ Zip: ______

Customer address to send order back to when order is completed:

Company: ______________________________

Address: ______________________________

Contact name: ______________________________

City: ____________________ State: ____________ Zip Code: __________

Qty	Description (EDP#etc..)	End Only (Y or N)	Minimum Flute Length	Minimum Cutting Diameter	Special Marking

Complete Form, Include in box with tools and then send shipment back to Core Cutter address listed above

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

EDP#	Pg.
118101	57
118111	57
118112	20
118201	57
118211	57
118212	20
118301	57
118311	57
118312	20
200000	33
200001	34
200010	33
200011	34
200040	33
200041	34
200100	33
200101	34
200110	33
200111	34
200140	33
200141	34
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200201	34
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200211	34
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200241	34
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200701	36
200710	35
200711	36
200740	35
200741	36
200800	35
200801	36
200810	35
200811	36
200840	35
200841	36
200900	35
200901	36
200910	35
200911	36
200940	35
200941	36
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201001	34
201010	33
201011	34
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201211	34
201220	33
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201230	33
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201240	33
201241	34
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201301	34
201310	33
201311	34
201320	33
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201341	34
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201611N	36
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201621N	36
201630	35
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201631	36
201631N	36
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201640N	35
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201720	35
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201730	35
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201801	36
201810	35
201811	36
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201821	36
201830	35
201831	36
201840	35
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202120	33
202121	34
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202141	34
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202211	34
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202311	34
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202341	34
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202601N	36
202610N	35
202611N	36
202620N	35
202621N	35
202640N	35
202641N	36
202800	35
202801	36
202810	35
202811	36
202820	35
202821	36
202840	35
202841	36
203000	33
203001	34
203010	33
203011	34
203020	33
203021	34
203030	33
203031	34
203040	33
203041	34
203100	33
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205121	34
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205131	34
205140	33
205141	34
205150	33
205151	34
205200	33
205201	34
205210	33

EDP PAGE FINDER (Cont.)

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

EDP#	Pg.
205211	34
205220	33
205221	34
205230	33
205231	34
205240	33
205241	34
205250	33
205251	34
205300	33
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205351	34
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205411	34
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205421	34
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205431	34
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205451	34
205600	35
205600N	35
205601	36
205601N	36
205610	35
205610N	35
205611	36
205611N	36
205620	35
205620N	35
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205630N	35
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205640	35
205640N	35
205641	36
205641N	36
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207001	34
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207011	34
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207410	33
207411	34
207420	33
207421	34
207430	33
207431	34
207440	33
207441	34
207600N	35
207601N	36
207610N	35

EDP PAGE FINDER (Cont.)

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.
207611N	36
207620N	35
207621N	36
207630N	35
207631N	36
207640N	35
207641N	36
207700	35
207700-BLK	35
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207701	36
207701-BLK	36
207701N	36
207710	35
207710-BLK	35
207710N	35
207711	36
207711-BLK	36
207711N	36
207720	35
207720-BLK	35
207720N	35
207721	36
207721-BLK	36
207721N	36
207730	35
207730-BLK	35
207730N	35
207731	36
207731-BLK	36
207731N	36
207740	35
207740-BLK	35
207740N	35
207741	36
207741-BLK	36
207741N	36
207800	35
207800-BLK	35
207801	36
207801-BLK	36
207810	35
207810-BLK	35
207811	36
207811-BLK	36
207820	35
207820-BLK	35
207821	36
207821-BLK	36
207830	35
207830-BLK	35
207831	36
207831-BLK	36
207840	35
207840-BLK	35
207841	36
207841-BLK	36
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207901N	36
207910N	35
207911N	36
207920N	35
207921N	36
207930N	35
207931N	36
207940N	35
207941N	36
208100	33
208101	34
208110	33
208111	34
208120	33
208121	34
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208221	34
208230	33
208231	34
208240	33
208241	34
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301020C	38
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301021C	12
301030	38
301031	39
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.
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301241	39
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305220C	38
305221	39
305221C	12
305230	38

EDP PAGE FINDER (Cont.)

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

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307000	38

EDP PAGE FINDER (Cont.)

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

EDP#	Pg.
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307010C	38
307011	39
307011C	12
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307311C	12

EDP#	Pg.
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310010C	38
310011	39
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310040	38
310041	39
310100	38
310101	39
310110	38
310110C	38
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.
310111C	12
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310141	39
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310201	39
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310210C	38
310211	39
310211C	12
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405021	46
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405031	46
405036	46
405041	46
405051	46
405101	46
405111	46
405121	46

EDP PAGE FINDER (Cont.)

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.
405121C	14
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407141	46
407201	46
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407241	46
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408831-BLK	47
408841	47
408841-BLK	47
408901	47
408911	47
408921	47

EDP PAGE FINDER (Cont.)

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
408931	47
408941	47
410001	46
410011	46
410011C	14
410041	46
410101	46
410111	46
410111C	14
410141	46
410201	46
410211	46
410211C	14
410241	46
410701	47
410711	47
410741	47
410801	47
410811	47
410841	47
473121	22
473221	22
475221	22
475326	22
477126	22
477226	22
487201	46
487211	46
487211C	14
487221	46
487226	46
487231	46
487241	46
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491211	46
491216	46
491221	46
491221C	14
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491241	46
493201	46
493211	46
493216	46
493221	46
493221C	14
493231	46

EDP#	Pg.
493236	46
493241	46
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495311	46
495321	46
495321C	14
495331	46
495336	46
495341	46
495351	46
496201	46
496211	46
496211C	14
496221	46
496226	46
496231	46
496241	46
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497111	46
497111C	14
497121	46
497126	46
497131	46
497141	46
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500011C	16
500041	51
500101	51
500111	51
500111C	16
500141	51
500201	51
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500211C	16
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500701	52
500711	52
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500801	52
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500911	52
500941	52
501001	51
501011	51

EDP#	Pg.
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501801	52
501811	52
501816	52

EDP#	Pg.
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502321C	16
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502611N	52
502621N	52
502641N	52
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503011	51
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503121C	16
503131	51
503136	51
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503221	51
503221C	16

EDP#	Pg.
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503936	52
503941	52

EDP#	Pg.
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505021C	16
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505601N	52
505611	52
505611N	52
505621	52
505621N	52
505631	52

EDP PAGE FINDER (Cont.)

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.
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550001	49
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551001	49
551101	49
551201	49
552101	49
552201	49
553001	49
553201	49
553301	49

EDP PAGE FINDER (Cont.)

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

EDP#	Pg.
555001	49
555101	49
555201	49
555401	49
556001	49
556101	49
556301	49
556401	49
557001	49
557201	49
557301	49
573121	22
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575221	22
575326	22
577126	22
577226	22
587201	51
587211	51
587211C	16
587221	51
587226	51
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591231	51
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593216	51
593221	51
593221C	16
593231	51
593236	51
593241	51
595301	51
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a newfound appreciation for the challenges of haystack exploration." Verily, herein doth lie one of the main reasons

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EDP PAGE FINDER (Cont.)

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

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S12046	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.

Maine Made

Performance in Motion

CORE CUTTER
SOLID CARBIDE CUTTING TOOLS

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Our Website

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