Tech Flyer v2020.1

ULTRATOOL®

High-Performance Solid Carbide Round Tools

Technical & Application Information

American Made
American Designed
American Owned

phone 714.898.9224 / 800.854.2431 / fax 714.891.7816
5451 McFadden Avenue • Huntington Beach, CA 92649
ultra-tool.com

American Made
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American Owned

involve • evolve • resolve
SOLID CARBIDE ULTRA TEAM TOOL HUNTINGTON BEACH
19 72

Creating Value through Efficiency
by utilizing progressive Quality, Manufacturing,
Human Resource & Technological applications.

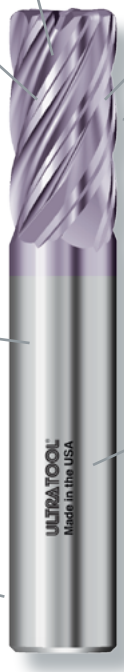
SmoothFlute
Patented Variable Helix design for robust stability in deep axial cuts

SmoothGrind®
Polished cutting surfaces for extreme sharpness and lubricity

SmoothCoat®
Sputter-based SuperNitride PVD coating for superior surface hardness & uniformity

SmoothContricity®
Precision grinding, tool holding, and tolerances for minimized TIR

SmoothEdge®
Surface and edge preparation for lubricity and minimized tool break-in



ULTRA-Grain®
The World's finest, purest sub-micron tungsten carbide powders

Laser etching for permanent tool identification

SFR
Tight tolerance shanks with superior roundness are shrink-fit ready

TA Tool Alliance®

Sales offices in Florida & California
Made in the USA for 45 years
Performance Guaranteed

Process control ID# on product label ensures total traceability

ULTRATOOL® Designed & Manufactured in the USA • ultra-tool.com

USCTI UNITED STATES CUTTING TOOL INSTITUTE
AMT THE ASSOCIATION FOR MANUFACTURING TECHNOLOGY
ISA

ULTRATOOL®

sales@ultra-tool.com • (800) 854-2431

1 ULTRA-Grain® — Components of Guaranteed Quality

COMPONENT #1: Carbide Substrate From being the first Company to introduce MicroGrain carbide to the mass-market round tool industry through the present day, Tool Alliance® has consistently innovated new powder and grade combinations for demanding applications. We recognize that our material is the very first Significant Characteristic. By creating partnerships with a limited number of tungsten powder and cemented-carbide material suppliers, we are able to guarantee that our customers receive precision-tolerance tools ground from only the purest, finest grades available worldwide. The following photographs of Ultra-Carb® 1 and Ultra-Grain® 1 respectively demonstrate the complexity of the compound we commonly refer to as Cemented Carbide. Taken at magnification of 10,000 X through an SEM (Scanning Electron Microscope), the visible grains are tungsten while the cobalt binder appears as dark shadows. The largest tungsten grains appearing in the Ultra-Carb photo are less than one micron in size. Note that these grades are two samples representing more than a dozen different substrates we use throughout our product lines, each having a particular application niche. Compared to other industry participants, you will find that Tool Alliance offers the best month-to-month and year-to-year consistency in carbide grain structure.

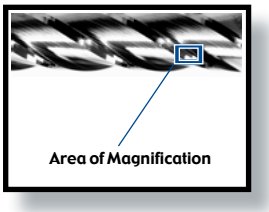
Ultra-Carb® 1
Cobalt Percentage: 6%
Grain Size (µm): ≤ 0.8
Hardness: 93.5 HRa
Fracture Toughness (K_{1c}): 6.6
TRS (GPa): 3.8
Density (gm/cc): 14.90

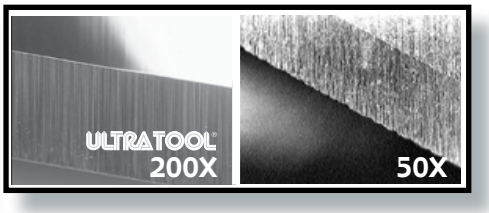
ULTRA-Carb®

Ultra-Grain® 1
Cobalt Percentage: 10%
Grain Size (µm): ≤ 0.7
Hardness: 92.7 HRa
Fracture Toughness (K_{1c}): 7.9
TRS (GPa): 4.1
Density (gm/cc): 14.30

ULTRA-Grain®

2 SmoothGrind®





SmoothGrind® Competitor's

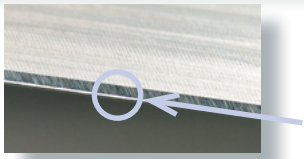
COMPONENT #2: The Grinding Process After selecting the best material available, Tool Alliance has perfected the manufacturing technology to optimize 100% of its physical properties. We call this process SmoothGrind®. Years in development, SmoothGrind is the result of a proprietary combination of material, abrasive, coolant, machine-tool, software, and grinding method technologies that produce cutting tools with superior qualitative characteristics. Sharper and longer lasting cutting edges, enhanced work piece finishes, and much improved lubricity are just some of the benefits brought to you by the latest solid carbide rotary tooling advances from Tool Alliance. The two photos above display an Ultra-Tool end mill primary relief featuring SmoothGrind (left) versus a major competitor's product (right). To fully demonstrate the difference, the Ultra end mill is shown at double the magnification. Note the straight line of our end mill's primary relief in comparison to the jagged edge of the competing product. Keep in mind the competitive end mill is a very good product that has a large following, yet the difference is substantial.

3 SmoothContricity®

SFR
Shrink Fit Ready

COMPONENT #3: The Tooling Process All the best physical ingredients are wasted unless they are all pulled together in a comprehensive system that maximizes their respective attributes. Tool Alliance calls this process SmoothContricity®. Our customer base represents the leading edge of machine tool utilization, and SmoothContricity ensures that optimum results can be obtained in a variety of ways; minimized run-out (TIR), industry-leading tolerances on diameter & radius, and 100% Shrink Fit Ready (SFR) shanks. Combined, these attributes allow our consumers to reach full machining potential and position the cutting tool as a systematic contributor to process consistency and repeatability.

4 SmoothEdge®



.0001 SmoothEdge atop cylindrical margin atop primary relief.

SE

COMPONENT #4: The Edge Preparation Process
Our cutting edges are literally too sharp for certain materials. For our carbide inserts and now increasingly for our solid carbide round tools, proper edge preparation can yield huge productivity improvements to "out of the box" tool application. Using a treatment we call SmoothEdge® and performed on machine tools developed in our own R&D lab, we've taken the mystery out of tool "break-in" and provided a consistency that can be counted on time and again. The processes range from a microblasting treatment using extremely fine aluminum oxide powder to a diamond-lapping compound to brushes. All are application-specific to sound and run smooth from the first cut and protect your tooling investment from unnecessary potential for chipping during your initial tooling paths. Big productivity gains can be achieved in certain applications as well due to improved chip formation and evacuation. Learn more about SmoothEdge on Page #5.

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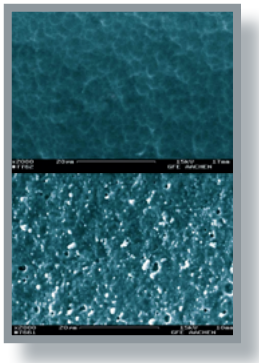


Our coating @ 2,000X (top).
Everybody else's (bottom).

SmoothCoat® 5

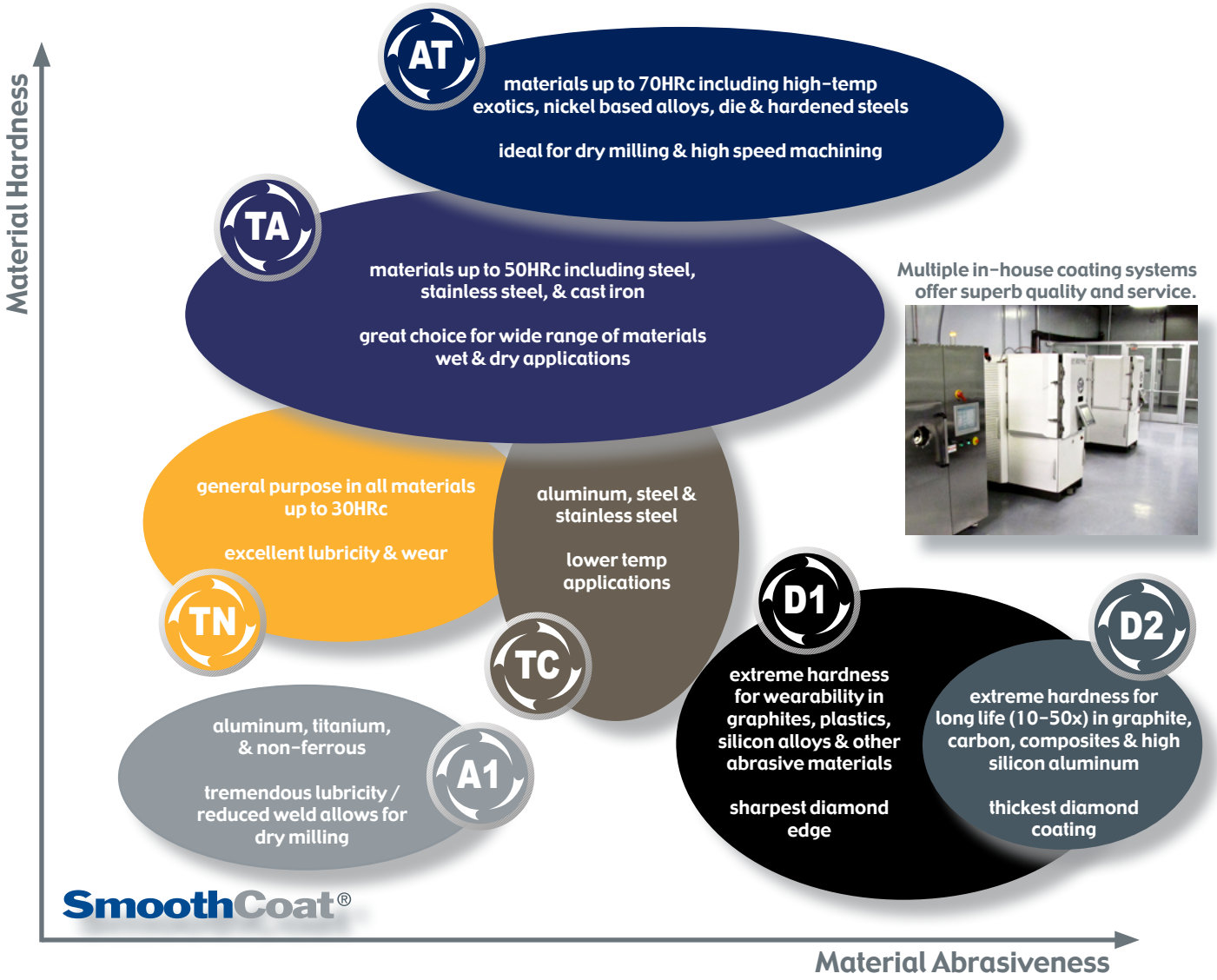
COMPONENT #5: The Coating Process The challenge of finding a coating method to leverage 100% of the inherent assets of our carbide grade and grinding technologies was difficult. What we finally discovered was such a perfect fit and so logical for our product lines that we invested heavily into the process we now call SmoothCoat®. Much more than simply the standard arc-deposited PVD coating, SmoothCoat involves sputter multi-layering and a multi-step prep & post operation called Micro-Blasting. The advantages of this procedure include relieving of tensile stresses underneath the cutting edge, increased stability of the coating surface, and perhaps most importantly, elevating SmoothGrind even another notch by leveling and activating the cemented carbide substrate. The result is a smooth, shiny, tough, and durable surface that can withstand tomorrow's machining requirements and outlast competitive coatings. Additionally, we've made it a standard feature on thousands of our standard catalog items. Our coating services are performed within our own factories for quality & extremely quick turnaround times.

Coating Availability Order by adding the suffix TA, TN, AT, TC, A1, D1, or D2 to the EDP #.

UC	TA	TN	AT	TC	A1	D1	D2
UnCoated	TiAlN	TiN	AlTiN HSN^2	TiCN	TiB2	PVD Diamond	CVD Diamond

Standard Coatings available at "Coated" List Price

Premium Coatings available



Multiple in-house coating systems offer superb quality and service.

ULTRATOOL® Technical Data

SmoothEdge®

Our newest technology can achieve incredible productivity increases in specific applications. Many of our new Series include SmoothEdge as a standard feature, while on others it can be added as a same day post treatment for a small charge. Ask your Inside Sales representative about SmoothEdge today!

The Edge Preparation Process

Our cutting edges are literally too sharp for certain materials. For our carbide inserts and now increasingly for our solid carbide round tools, proper edge preparation can yield huge productivity improvements to "out of the box" tool application. Using a process we call **SmoothEdge®** and performed on machine tools developed in our own R&D lab, we've taken the mystery out of tool "break-in" and provided a consistency that can be counted on time and again. All five types of **SmoothEdge** will yield different benefits dependent upon application. **SmoothEdge** will make your tools sound and run smooth from the first cut and protect your tooling investment from unnecessary potential for chipping during initial tool paths.

Ultra-Tool cutting edge magnified to display SE4 hone measuring .0008 in width.

Combine SmoothEdge with our other value added features to design the ultimate cutting solution.

SmoothEdge included on all the following:

ULTRATOOL® PERFORMANCE SERIES

SmoothEdge 1

A microblasting treatment using extremely fine aluminum oxide powder to smooth the carbide surface while generating a very light edge preparation. This feature comes standard with any SmoothCoat® coating.
Uses: Highly recommended for most milling and drilling applications.

SmoothEdge 2

A lapping treatment to create extreme lubricity & smoothness with minimal edge prep on uncoated tools.
Uses: Highly recommended for milling and drilling of aluminum and other non-ferrous applications using UnCoated, A1, or TC coated tools.

SmoothEdge 3

Combines microblasting and lapping for a light hone with extreme lubricity.
Uses: Highly recommended for a wide range of general purpose machining applications using coated tools.

SmoothEdge 4

Adds a proprietary hone to the blasting and lapping cycles for a medium edge prep with excellent lubricity.
Uses: Highly recommended for milling and drilling applications involving general steels, stainless, and cast iron.

SmoothEdge 5

Doubles the honing and lapping cycle for maximum edge strength; a robust edge preparation combined with excellent lubricity characteristics.
Uses: Highly recommended for milling and drilling applications involving stainless, high-temp alloys, and exotics.

SmoothEdge 8

Based on the vast successes of our other edge hones, we designed another specifically for delicate yet diverse applications, with the ability to minutely control & measure size.
Uses: Highly recommended for milling aluminum, drill points, materials common in medical apps, plus adaptable to micro diameters.

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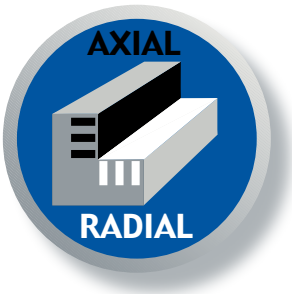
ULTRATOOL® Technical Data

With so many variables present in the machining process, it is essential to optimize every possible factor to achieve world-class efficiency. Your choice of a genuine Ultra-Tool® Solid Carbide product is an excellent first step in the process. Ultra-Tool® Solid Carbide products are high-performance tools that will perform best in a machining environment characterized by rigid fixturing and minimal spindle runout. Attention to proper speed and feed will eliminate vibration, chatter, and overheating as well as extending tool life. Generally speaking, the peripheral speed of solid carbide tools will vary with the hardness of the material being cut. The harder the material, the slower the speed. High speed and insufficient feed will cause work surface glazing and poor tool life. Chipping of cutting edges is an indication of chatter which can be caused by too high of speed, too light of cut, or improper support of the tool or workpiece. Handling is also very important; sharpened cutting edges should never be allowed to come into contact with any hard object (or another tool) in a non-machining environment as they will chip easily. Keep your Ultra-Tool® products in their original protective packaging until ready for use.

The guidelines on the following pages are generalities designed to demonstrate the operating window within which you may experience the best results. The charts and information provided should prove valuable in longer tool life with greatly reduced operational costs. This information is for uncoated product: SmoothCoat products will have significantly higher speed and feed rates. For more information contact an Ultra-Tool® Factory Engineer, Sales Manager or consult our websites at ultra-tool.com and toolalliance.com. eMails can be sent to technical@toolalliance.com.

Ultra-Tool International, Inc. is constantly striving to improve its processes, specifications, and tolerances. As such, products are subject to change without prior notice.

WARNING: Grinding or other use of this tool may produce hazardous dust and fumes which may endanger health. Grinding or modification should be done by professionals only. To avoid adverse health effects, read the material safety data sheet for this product. Utilize adequate ventilation and appropriate protection. Cutting tools may shatter when broken; eye protection in vicinity of use is strongly advised. MSDS available at www.ultra-tool.com.



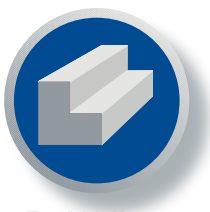
Commonly Used Formulas:

Surface Feet Minute (SFM)=RPM x Diam. x .262
Revolutions Per Minute (RPM)=3.82 x (SFM / Diam.)
Feed Rate (IPM)=IPT x #teeth x RPM
Drilling (IPM)=IPR x RPM
Feed Per Tooth (IPT)=IPM / (#teeth x RPM)
Convert Inches to millimeters: Multiply by 25.4
Convert millimeters to Inches: Multiply by .03937

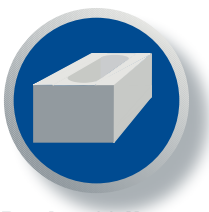
Tech Help Call, eMail us at technical@toolalliance.com, or copy / fax us this page for detailed assistance beyond what printed materials can provide. Please have the following information available to assure we can promptly process a response.

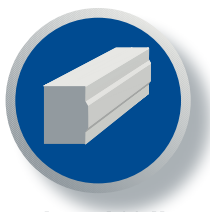
Checklist:
- Tool Description
- Application Description
- Work Piece Material
- Hardness (HRc)
- Current Speed (RPM or SFPM)
- Current Feed (CPT or IPM or FPR)
- Axial DOC
- Radial DOC
- Hole Depth (drilling)
- Machine Tool


Face Milling


End Milling


Slot Milling


Pocket Milling


Peripheral Milling

Application Tips for ULTRATOOL® Solid Carbide Products

Trouble Shooting for Ultra-Tool® Carbide End Mills

Problem	Cause	Solution
Chipping	• Feed rate too high • Up milling (conventional) • Cutting edge too sharp • Chattering • Loose tool • Workpiece rigidity • Tool rigidity • Low cutting speed • Loose toolholder	• Reduce feed rate • Change to down milling (climb) • Hone cutting edge or allow break-in • Reduce RPM • Remove, clean, and retighten • Tighten workpiece holding method • Shorten LOC, place shank further up holder • Increase RPM • Remove from spindle, clean and replace
Wear	• High cutting speed • Low feed rate • Up milling (conventional) • Hard material • Poor chip evacuation • Improper cutter helix • Poor coolant	• Reduce RPM • Increase feed rate • Change to down milling (climb) • Use coated tool • Reposition coolant lines, use air blasting • Change to recommended helix angle • Replace coolant or correct mixture
Breakage	• Feed rate too high • Depth of cut too large • Poor tool rigidity • Tool wear • Poor chip evacuation	• Reduce feed rate • Reduce depth of cut • Shorten LOC, place shank further up holder • Replace/regrind sooner • Reposition coolant lines, use air blasting
Chattering	• Speed and feed too high • Poor toolholder rigidity • Poor spindle rigidity • Workpiece rigidity • Relief angle too high • Depth of cut too large • Poor tool rigidity	• Reduce feed rate • Replace with shorter/more rigid holder • Use larger spindle or different machine tool • Tighten workpiece holding method • Regrind with smaller relief angle • Reduce depth of cut • Shorten LOC, place shank further up holder
Short Life	• Cutter/workpiece friction • Hard material • Poor material condition • Improper cutter angle • Poor coolant	• Use coated tool • Use coated tool • Use coated tool, clean material surface • Regrind with proper primary relief angle • Replace coolant or correct mixture
Chip Packing	• Feed rate too high • Low cutting speed • Insufficient chip room • Insufficient coolant	• Reduce feed rate or increase speed • Increase RPM or reduce feed rate • Use tool with less flutes, increase helix • Increase volume of coolant
Poor Surface Finish	• Feed rate too high • Low cutting speed • Tool wear • Edge build up • Depth of cut too large • Chip welding	• Reduce feed rate • Increase RPM • Replace or regrind tool • Increase RPM, switch to higher helix tool • Reduce depth of cut • Increase volume of coolant
Burring or Workpiece Chipping	• Tool wear • Improper helix angle • Feed rate too high • Depth of cut too large	• Replace or regrind tool • Change to recommended helix angle • Reduce feed rate • Reduce depth of cut
Workpiece Inaccuracy	• Loose/worn toolholder • Poor toolholder rigidity • Poor spindle rigidity • Insufficient number of flutes • Tool deflection	• Repair or replace • Replace with shorter/more rigid toolholder • Use larger spindle or different machine tool • Use tool with higher flute quantity • Shorten LOC, place shank further up holder

Trouble Shooting for Ultra-Tool® Carbide Drills

Problem	Cause	Solution (see key below)
Heavy Wear at Outer Edge	• Insufficient coolant • Incorrect speed & feed	• 5, 6 • 1, 2, 8
Chipping at Outer Cutting Edge	• Loose tool, tool movement • Workpiece movement • Poor coolant conditions • Incorrect speed & feed	• 8, 10, 11, 12, 14, 16, 17, 21 • 8, 12, 13, 21 • 5, 6 • 1, 2, 3, 4
Drill Point Chipping	• Loose tool, tool movement • Incorrect speed & feed • Drill centering	• 10, 11, 12, 14 • 1, 2, 3, 4 • 8, 10, 11, 12, 21
Margin Wear	• Drill margin rubbing wall • Poor chip evacuation • Poor coolant conditions • Workpiece movement	• 20 (check drill for backtaper) • 5, 6, 8, 20 • 5, 6 • 8, 13, 21
Tool Breakage	• Loose tool, tool movement • Workpiece movement • Wrong drill type • Poor coolant conditions • Incorrect speed & feed	• 8, 10, 11, 12, 14, 16, 17, 21 • 8, 12, 13, 21 • 9, 15, 16, 18, 19, 20 • 5, 6 • 1, 2, 3, 4
Poor Tool Life	• Incorrect speed & feed • Poor coolant conditions • Wrong drill point	• 1, 2, 3, 4 • 5, 6 • 8, 21
Drill Walk	• Incorrect speed & feed • Tool wear • Wrong drill point • Material condition	• 1, 2 • 7, 8, 21 • 8, 10, 11, 21 • 11, 12, 15, 16, 17
Chip Welding	• Poor coolant conditions • Wrong drill type	• 5, 6 • 19, 20
Hole Size Inaccuracy	• Incorrect speed & feed • Poor coolant conditions • Loose tool • Wrong drill type	• 1, 2, 3, 4 • 5, 6 • 14 • 9, 18
Non-Cylindrical Hole	• Loose tool, tool movement • Workpiece movement • Incorrect speed & feed • Wrong drill type	• 8, 10, 11, 12, 14, 16, 17 • 13 • 1, 2 • 18, 21
Heavy Burr	• Incorrect speed & feed • Incorrect drill point	• 1, 2 • 8, 21
Blue Chips	• Poor coolant conditions • Tool wear	• 5, 6 • 7, 8
Long Chips	• Poor point grind • Incorrect speed & feed	• 8 • 1, 2

Solutions Key for Drills

1) Reduce RPM
2) Increase feed
3) Increase RPM
4) Reduce feed
5) Increase coolant
6) Increase mixture
7) Add negative hone
8) Repoint drill
9) Correct drill type/size
10) Use self-centering drill
11) Spot/center drill
12) Clean surface
13) Improve rigidity/clamp
14) Tighten holder
15) Use straight flute
16) Use stub length
17) Place further up holder
18) Use three-flute
19) Use slower helix
20) Use parabolic design
21) Change point style

Trouble Shooting for Ultra-Tool® Carbide Reamers

Problem	Cause	Solution
Chatter	• High cutting speed • Feed rate too low • Workpiece movement • Toolholder rigidity • Tool rigidity	• Lower RPM or increase feed rate • Increase feed rate • Tighten workpiece rigidity • Tighten toolholder or reduce float • Use shorter tool, place further up holder
Tool Wear / Chipping	• Incorrect feed rate • Incorrect speed • Poor hole condition • Abrasive material • Poor chip evacuation • Poor coolant • Insufficient coolant • Workpiece alignment • Excessive stock removal	• Increase feed rate (typically) • Reduce speed (typically) • Work-hardened hole; change drilling type • Use proper coolant, coated reamer • Use/increase coolant, use helical reamer • Replace coolant or correct mixture • Increase coolant volume • Use bushing, floating holder, lead chamfer • Use larger diameter starter drill
Tool Breakage	• Incorrect feed rate • Incorrect speed • Tool wear • Bottoming of hole • Coolant conditions • Insufficient stock removal • Poor set up • Excessive stock removal	• Increase feed rate (typically) • Reduce speed (typically) • Sharpen or replace reamer • Adjust stop depth, check preset • Increase, replace, or correct coolant • Use smaller diameter starter drill • Use bushing, floating toolholder • Use larger diameter starter drill

Problem	Cause	Solution
Poor Finish	• Feed rate too low • Insufficient stock removal • Poor hole condition • Poor coolant • Insufficient coolant	• Increase feed rate • Use smaller diameter starter drill • Work-hardened hole; change drilling type • Replace/correct coolant mixture • Increase coolant volume
Hole Tolerance	• Workpiece alignment • Incorrect tool size • Material shrinkage • Tool wear • Toolholder runout	• Use bushing, floating toolholder • Check diameter of tool • Adjust diameter for shrinkage; more coolant • Sharpen or replace tool • Adjust or replace toolholder

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Application Data for High Performance Series 323, 355, 377, & 365 ULTRATOOL® End Mills

The milling data presented below is for the **323**, **355**, **377**, and **365** Series of Ultra end mills. When using SmoothCoat & SmoothEdge surface treatments, Surface Feet or Meters Per Minute can be increased from the stated levels by at least 25%.
Do not use a radial DOC exceeding more than 25% of diameter for Series 355 only.

Peripheral Milling data based on axial depth ≤ 100% of tool diameter & radial depth of ≤ 25% of tool diameter.

Slot Milling data based on axial depth of cut = 50% of tool diameter.

End Mill Specifications:
Diameter: +.000 / −.002
Shank Diameter: +.0000 / −.0003
LOC: +.060 / −.000
OAL: ± .060
Helix: ± 1°

Milling; Fractional

Material	SFPM	SFPM	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"	1"
Steel	**Peripheral**	**Slotting**	**Feed Per Tooth (FPT)**									
1018 / 1020	300 to 600	200 to 400	.0007	.0012	.0015	.0018	.0020	.0025	.0030	.0035	.0040	.0045
4140 / 4340 / P20	250 to 500	200 to 350	.00065	.0010	.0012	.0015	.0018	.0022	.0025	.0030	.0035	.0040
Stainless Steel												
303 / 304 / 316	250 to 400	200 to 350	.0006	.0008	.0010	.0012	.0018	.0022	.0025	.0030	.0035	.0038
410 / 420 / 440C	200 to 300	150 to 250	.0006	.0008	.0010	.0012	.0018	.0022	.0025	.0030	.0035	.0038
15-5/17-4 ≤ 32HRc	200 to 350	150 to 300	.0006	.0008	.0010	.0012	.0018	.0022	.0025	.0030	.0035	.0038
15-5/17-4 ≥ 32HRc	150 to 250	150 to 250	.0004	.0006	.0008	.0010	.0015	.0020	.0020	.0025	.0030	.0035
Tool Steel												
A2/D2/H13 ≤ 32HRc	200 to 300	150 to 250	.0005	.0008	.0010	.0012	.0018	.0022	.0025	.0030	.0035	.0035
A2/D2/H13 ≥ 32HRc	150 to 250	100 to 200	.0004	.0006	.0008	.0010	.0015	.0020	.0020	.0025	.0030	.0035
Titanium												
6Al-4V	150 to 300	125 to 225	.0005	.0008	.0010	.0010	.0012	.0020	.0025	.0025	.0030	.0040
High Temp Alloys												
Inconel 625	100 to 150	75 to 125	.0005	.0007	.0010	.0012	.0012	.0018	.0020	.0020	.0025	.0030
Inconel 718	70 to 150	50 to 100	.0005	.0007	.0008	.0009	.0012	.0018	.0020	.0020	.0030	.0040
Cast Iron												
Gray Iron ≤ 32HRc	150 to 400	150 to 300	.0005	.0007	.0010	.0012	.0015	.0018	.0020	.0030	.0040	.0045

Application Data for Series 323, 355, 377, and 365 High Performance End Mills (continued); Peel Milling

Recommendations are based upon a **radial cut depth of 10%** of the end mill's diameter and **axial cut depth of 50–85%** of the tool's LOC.

Peel milling can be performed wet or dry (with AT coating); please consult **technical@toolalliance.com** for specific application data.

See it run now!
Scan the Quick Code and watch the Series 365 milling various materials on the Tool Alliance YouTube channel.

Series 323, 355, 377, and 365 Peel Milling
Surface Feet Per Minute (**SFPM**) and Feed Per Tooth (**FPT**) recommendations by tool diameter and material:

Material	SFPM	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"	1"
Steel	**Peripheral**	**Feed Per Tooth (FPT)**									
1018 / 1020	400 to 600	.001-.003	.001-.004	.0015-.005	.002-.008	.002-.008	.003-.010	.003-.010	.003-.010	.004-.012	.004-.012
4140 / 4340 / P20	350 to 500	.001-.002	.001-.003	.001-.004	.0015-.006	.0015-.006	.002-.007	.002-.007	.002-.007	.0025-.008	.0025-.008
Stainless Steel											
303 / 304 / 316	300 to 500	.001-.002	.001-.003	.0015-.004	.002-.006	.002-.006	.003-.008	.003-.008	.003-.008	.003-.010	.003-.010
410 / 420 / 440C	250 to 400	.001-.002	.001-.003	.0015-.004	.002-.006	.002-.006	.003-.008	.003-.008	.003-.008	.003-.010	.003-.010
15-5/17-4 ≤ 32HRc	300 to 500	.001-.002	.001-.003	.0015-.004	.002-.006	.002-.006	.003-.008	.003-.008	.003-.008	.003-.010	.003-.010
15-5/17-4 ≥ 32HRc	200 to 300	.0005-.002	.0005-.002	.001-.003	.0015-.005	.0015-.005	.002-.006	.002-.006	.002-.006	.003-.008	.003-.008
Tool Steel											
A2/D2/H13 ≤ 32HRc	250 to 350	.001-.002	.001-.003	.0015-.004	.002-.006	.002-.006	.003-.008	.003-.008	.003-.008	.003-.010	.003-.010
A2/D2/H13 ≥ 32HRc	200 to 300	.001-.002	.001-.003	.0015-.004	.002-.006	.002-.006	.003-.008	.003-.008	.003-.008	.003-.010	.003-.010
Titanium											
6Al-4V	250 to 300	.001-.002	.001-.003	.0015-.004	.002-.006	.002-.006	.003-.008	.003-.008	.003-.008	.003-.010	.003-.010
High Temp Alloys											
Inconel 625	125 to 200	.0005-.002	.0005-.002	.001-.003	.0015-.005	.0015-.005	.002-.006	.002-.006	.002-.006	.003-.008	.003-.008
Inconel 718	100 to 150	.0005-.002	.0005-.002	.001-.003	.0015-.005	.0015-.005	.002-.006	.002-.006	.002-.006	.003-.008	.003-.008
Cast Iron											
Gray Iron ≤ 32HRc	250 to 500	.001-.002	.001-.003	.001-.004	.0015-.006	.0015-.006	.002-.007	.002-.007	.002-.007	.0025-.008	.0025-.008

Application Data for Standard ULTRATOOL® End Mills

The milling data presented below is for all "standard" Series of Ultra end mills (data is presented separately on each respective product page for our application-specific high performance designs). Note: When using SmoothCoat & SmoothEdge surface treatments, Surface Feet or Meters Per Minute can be increased from the stated levels by at least 25%.

Peripheral Milling data based on axial depth ≤ 100% of tool diameter & radial depth of ≤ 25% of tool diameter.

Slot Milling data based on axial depth of cut = 50% of tool diameter.

End Mill Specifications:
Diameter: +.000 / -.002
Shank Diameter: +.0000 / -.0003
LOC: +.060 / -.000
OAL: ± .060
Helix: ± 1°

Milling; Fractional

Material	SFPM	SFPM	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"	1"
Steel	**Peripheral**	**Slotting**					**Feed Per Tooth (FPT)**					
1018 / 1020	150 to 350	150 to 300	.0005	.0010	.0015	.0018	.0020	.0025	.0030	.0035	.0040	.0045
4140 / 4340 / P20	150 to 300	125 to 225	.0005	.0007	.0010	.0012	.0015	.0018	.0020	.0025	.0030	.0040
Stainless Steel												
303 / 304 / 316	150 to 300	125 to 250	.0005	.0007	.0010	.0012	.0015	.0018	.0020	.0030	.0040	.0040
410 / 420 / 440C	150 to 300	125 to 250	.0005	.0007	.0010	.0012	.0015	.0018	.0020	.0025	.0035	.0038
15-5/17-4 ≤ 32HRc	125 to 250	100 to 225	.0005	.0007	.0010	.0012	.0015	.0018	.0020	.0025	.0030	.0038
15-5/17-4 ≥ 32HRc	100 to 150	100 to 150	.0003	.0005	.0010	.0012	.0015	.0015	.0015	.0020	.0030	.0038
13-8 / 316L	125 to 300	125 to 250	.0005	.0007	.0010	.0012	.0015	.0018	.0020	.0030	.0040	.0040
Tool Steel												
A2/D2/H13 ≤ 32HRc	125 to 250	100 to 200	.0005	.0007	.0010	.0012	.0015	.0018	.0020	.0025	.0030	.0035
A2/D2/H13 ≥ 32HRc	100 to 150	100 to 125	.0003	.0005	.0010	.0012	.0015	.0015	.0015	.0020	.0030	.0035
Titanium												
6Al-4V	120 to 250	100 to 175	.0005	.0007	.0010	.0012	.0012	.0018	.0020	.0020	.0030	.0040
High Temp Alloys												
Inconel 625	50 to 150	50 to 125	.0005	.0007	.0010	.0012	.0012	.0018	.0020	.0020	.0025	.0030
Inconel 718	50 to 150	50 to 125	.0003	.0005	.0010	.0012	.0012	.0015	.0015	.0020	.0025	.0025
Cast Iron												
Gray Iron ≤ 32HRc	150 to 350	125 to 300	.0005	.0007	.0010	.0012	.0015	.0018	.0020	.0030	.0040	.0045
Ductile Iron	150 to 300	125 to 250	.0005	.0007	.0010	.0012	.0015	.0018	.0020	.0025	.0035	.0045
Non-Ferrous												
6061 T6 Aluminum	up to 2000	up to 1500	.0010	.0020	.0020	.0025	.0030	.0035	.0040	.0050	.0060	.0070
Copper,Brass,Bronze	up to 1200	up to 1000	.0010	.0010	.0020	.0022	.0025	.0028	.0030	.0040	.0040	.0050
Plastic	up to 2000	up to 1500	.0010	.0020	.0030	.0035	.0040	.0050	.0060	.0080	.0100	.0120

Metric End Mill Specifications:
Diameter (mm): +.000 / -.051mm
Shank Diameter(mm): +.000 / -.007mm
LOC: +1.52 / -0.00mm
OAL: ±1.52mm

Metric

Material	SMPM	SMPM	2 mm	3 mm	4 mm	6 mm	8 mm	10 mm	12 mm	16 mm	20 mm	25 mm
Steel	**Peripheral**	**Slotting**					**Feed Per Tooth (FPT)**					
1018 / 1020	45 to 110	45 to 90	0.010	0.012	0.025	0.038	0.045	0.050	0.080	0.090	0.100	0.120
4140 / 4340 / P20	45 to 90	40 to 70	0.010	0.012	0.018	0.025	0.030	0.038	0.050	0.065	0.080	0.100
Stainless Steel												
303 / 304 / 316	45 to 90	40 to 75	0.010	0.012	0.018	0.025	0.030	0.038	0.050	0.080	0.100	0.100
410 / 420 / 440C	45 to 90	40 to 75	0.010	0.012	0.018	0.025	0.030	0.038	0.050	0.065	0.080	0.100
15-5/17-4 ≤ 32HRc	38 to 75	30 to 70	0.010	0.012	0.018	0.025	0.030	0.038	0.050	0.065	0.080	0.100
15-5/17-4 ≥ 32HRc	30 to 45	30 to 45	0.005	0.007	0.012	0.025	0.030	0.038	0.038	0.050	0.080	0.100
13-8 / 316L	38 to 90	40 to 75	0.010	0.012	0.018	0.025	0.030	0.038	0.050	0.080	0.100	0.100
Tool Steel												
A2/D2/H13 ≤ 32HRc	38 to 75	30 to 60	0.010	0.012	0.018	0.025	0.030	0.038	0.050	0.065	0.080	0.090
A2/D2/H13 ≥ 32HRc	30 to 45	30 to 40	0.005	0.007	0.012	0.025	0.030	0.038	0.038	0.050	0.080	0.090
Titanium												
6Al-4V	35 to 75	30 to 53	0.010	0.012	0.018	0.025	0.030	0.038	0.050	0.065	0.080	0.100
High Temp Alloys												
Inconel 625	15 to 45	15 to 38	0.010	0.012	0.018	0.025	0.030	0.038	0.050	0.050	0.065	0.070
Inconel 718	15 to 45	15 to 38	0.005	0.007	0.012	0.025	0.030	0.038	0.038	0.050	0.065	0.065
Cast Iron												
Gray Iron ≤ 32HRc	45 to 110	40 to 90	0.010	0.012	0.018	0.025	0.030	0.038	0.050	0.080	0.100	0.120
Ductile Iron	45 to 90	40 to 75	0.010	0.012	0.018	0.025	0.030	0.038	0.050	0.065	0.090	0.120
Non-Ferrous												
6061 T6 Aluminum	up to 600	up to 450	0.020	0.025	0.050	0.050	0.064	0.080	0.100	0.130	0.150	0.180
Copper,Brass,Bronze	up to 365	up to 300	0.020	0.025	0.025	0.050	0.056	0.065	0.080	0.100	0.100	0.130
Plastic	up to 600	up to 450	0.020	0.025	0.050	0.080	0.089	0.100	0.150	0.200	0.250	0.300

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ultra-tool.com

Application Data for High Performance Series 330AL and 333AL ULTRATOOL® End Mills

The milling data presented below is for the 330AL and 333AL Series of Ultra end mills. When using SmoothCoat & SmoothEdge surface treatments, Surface Feet or Meters Per Minute may be increased from the stated levels.
Do not use a radial DOC exceeding more than 50% of diameter.

Peripheral Milling data based on axial depth ≤ 150% of tool diameter & radial depth of ≤ 50% of tool diameter.

Slot Milling data based on axial depth of cut ≤ 100% of tool diameter.

End Mill Specifications:
Diameter: +.0000 / -.0003
Shank Diameter: +.0000 / -.0003
LOC: +.060 / -.000
OAL: ± .060
Helix: ± 1°

Milling; Fractional

Material	Type	SFPM	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"	1"
			Feed Per Tooth (FPT)									
Wrought Aluminum 6061 / 7075 / 2024	Peripheral	1200 to 2000	.0015	.0025	.0030	.0035	.0050	.0055	.0060	.0065	.0070	.0090
	Slotting	1200 to 2000	.0010	.0018	.0025	.0025	.0035	.0040	.0045	.0050	.0060	.0080
Cast Aluminum 319 / 355 / 390	Peripheral	750 to 1200	.0015	.0025	.0030	.0035	.0050	.0055	.0060	.0065	.0070	.0090
	Slotting	750 to 1200	.0010	.0018	.0025	.0025	.0035	.0040	.0045	.0050	.0060	.0080
Copper Alloys Bronze / Brass	Peripheral	500 to 1200	.0009	.0015	.0020	.0025	.0035	.0035	.0040	.0050	.0050	.0060
	Slotting	500 to 1200	.0008	.0012	.0020	.0020	.0030	.0040	.0040	.0050	.0050	.0060

330AL and 333AL Tech Tip: Start with these recommended values for standard length tools. For stub LOC's, speeds and feeds may be increased. Longer LOC's and OAL's may require reductions in FPT and DOC. Our Monolith Series operating parameters should be adjusted to maintain a stable cut and reduced chatter (due to extended reach lengths).

SE8

ULTRATOOL® PERFORMANCE SERIES

TC UC A1

Ultra-Tool offers 2 world class coatings as standard for our aluminum tools!

Simply add a "TC" or "A1" suffix to the EDP#. For UnCoated, either use no suffix or add "UC."

SmoothEdge 8 is included!

The newest SmoothEdge® for our Aluminum end mills contributes to amazing surface finishes on milled parts.

Application Data for ULTRATOOL® Drills

Drilling speeds and feeds are based upon hole depth of up to 3X diameter. For deeper hole ratios reduce speeds and feeds by 10% to 25%.

Drilling; Fractional

Material	SFPM	SFPM	1/16"	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"
Steel	UnCoated	SmoothCoat	Feed Rate: Inches Per Rev (IPR)									
1018 / 1020	100 to 250	100 to 300	.0010	.0030	.0050	.0070	.0090	.0100	.0110	.0120	.0140	.0160
4140 / 4340 / P20	60 to 230	60 to 260	.0010	.0030	.0050	.0070	.0090	.0100	.0110	.0120	.0140	.0160
Stainless Steel												
303 / 304 / 316	60 to 150	60 to 200	.0010	.0030	.0050	.0060	.0070	.0080	.0090	.0100	.0120	.0140
410 / 420 / 440C	40 to 100	40 to 150	.0010	.0030	.0050	.0060	.0070	.0080	.0090	.0100	.0120	.0140
15-5/17-4 ≤ 32HRc	75 to 175	75 to 200	.0010	.0015	.0025	.0040	.0050	.0060	.0070	.0080	.0090	.0100
15-5/17-4 ≥ 32HRc	50 to 125	50 to 150	.0005	.0010	.0015	.0025	.0030	.0035	.0038	.0040	.0050	.0060
13-8 / 316L	60 to 150	60 to 200	.0010	.0030	.0050	.0060	.0070	.0080	.0090	.0100	.0120	.0140
Tool Steel												
A2/D2/H13 ≤ 32HRc	60 to 150	60 to 200	.0010	.0015	.0025	.0040	.0050	.0060	.0070	.0080	.0090	.0100
A2/D2/H13 ≥ 32HRc	40 to 100	40 to 150	.0005	.0010	.0015	.0025	.0028	.0030	.0035	.0040	.0050	.0060
Titanium												
6Al-4V	40 to 150	40 to 175	.0005	.0010	.0020	.0025	.0028	.0030	.0035	.0040	.0050	.0060
High Temp Alloys												
Inconel 625	30 to 70	30 to 80	.0010	.0015	.0025	.0040	.0050	.0060	.0070	.0080	.0090	.0100
Inconel 718	30 to 45	30 to 50	.0005	.0010	.0020	.0025	.0028	.0030	.0035	.0040	.0050	.0060
Cast Iron												
Gray Iron ≤ 32HRc	150 to 300	150 to 350	.0010	.0030	.0050	.0070	.0085	.0100	.0110	.0120	.0140	.0160
Ductile Iron	150 to 300	150 to 350	.0010	.0030	.0050	.0070	.0085	.0100	.0110	.0120	.0140	.0160
Non-Ferrous												
6061 T6 Aluminum	250 to 750	250 to 1000	.0010	.0030	.0050	.0070	.0085	.0100	.0110	.0120	.0140	.0160
Copper,Brass,Bronze	150 to 400	150 to 500	.0010	.0030	.0050	.0070	.0085	.0100	.0110	.0120	.0140	.0160
Plastic	250 to 1000	250 to 1000	.0010	.0030	.0050	.0070	.0085	.0100	.0110	.0120	.0140	.0160

Drill Specifications:
Diameter: +.0000 / -.0003
LOC: +.060 / -.090
OAL: +.060 / -.090
Point Angle: ±1°
Helix Angle: ±1°
Note: Series 560 Combined Drill/C'sink:
Body Diameter: +.0000 / -.0003
Drill Diameter: +.003 / -.000

Ultra-Tool® drills feature diameter tolerances 40% tighter than industry standards. Plus, all shanks are SFR (shrink-fit ready).

Try our drills with standard SmoothCoat for a superb leap in lubricity, productivity, and tool life.

new! Complete range of Brad Point drills with D1 coating!

Application Data for ULTRATOOL® Burrs

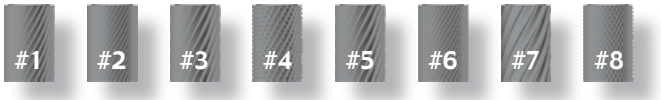
DeBurring

Burr Diam	Diam Metric	# Flutes Std Cut	RPM*	Max. RPM
1/16	1.6 mm	6	60,000 - 90,000	100,000
1/8	3.2 mm	12	40,000 - 70,000	80,000
3/16	4.8 mm	15	35,000 - 60,000	70,000
1/4	6.3 mm	16	30,000 - 50,000	60,000
5/16	8.0 mm	18	20,000 - 40,000	52,000
3/8	9.5 mm	20	20,000 - 40,000	52,000
7/16	11.0 mm	22	15,000 - 40,000	50,000
1/2	12.7 mm	24	15,000 - 40,000	45,000
5/8	16.0 mm	28	12,000 - 25,000	30,000
3/4	19.0 mm	30	10,000 - 20,000	24,000
1"	25.4 mm	36	7,500 - 20,000	22,000

*Speeds are for Standard Cut. Reduce by approximately 25% with addition of Dura-Cut. Fine Cut increases flute count approximately 50%. Decrease speed accordingly. Coarse Cut decreases flute count approximately 20%. Increase speed accordingly. Lower listed speeds when cutting harder ferrous materials.

Ultra-Tool® Burrs feature higher hardness and a greater flute count than most competing brands for increased tool life.

Burr heads and solid carbide burrs are manufactured from Ultra-Carb®. Shanks are high speed steel hardened to a rating of 45-48 Rockwell C.



#1 Standard, #2 Fine, #3 Coarse, #4 DuraCut, #5 CoarseDura #6 FineDura, #7 Fast Mill, #8 Diamond. In the event of extended lead times the next closest cut style within the same pricing category may be substituted to enhance service levels.

Burr Specifications:
Standard cylindrical helix angle: 30° ± 2°
Cutting Diameter: ± .010
Flute Count: ±1
Shank Diameter: +0 / - .0005, TIR max .002
Brazed Burr TIR: max .005
Taper Angles: ± 1°

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Application Data for ULTRATOOL® Reamers

Spiral flutes produce the best hole finish. Right-hand spiral should be used for blind holes, while left-hand spiral is excellent for thru-hole applications. Straight flute is appropriate for all general reaming requirements.

Reaming; Fractional

Material	SFPM (UC)	SFPM (TA)	1/16"	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"
	UnCoated	SmoothCoat	Feed Rate: Inches Per Rev (IPR)									
Steel												
1018 / 1020	50 to 125	50 to 150	.0040	.0050	.0050	.0060	.0070	.0080	.0090	.0100	.0100	.0100
4140 / 4340 / P20	40 to 120	40 to 140	.0040	.0040	.0040	.0040	.0050	.0050	.0050	.0060	.0060	.0060
Stainless Steel												
303 / 304 / 316	30 to120	30 to 140	.0040	.0050	.0050	.0060	.0070	.0080	.0090	.0100	.0100	.0100
410 / 420 / 440C	20 to 80	20 to 100	.0040	.0050	.0050	.0060	.0070	.0080	.0090	.0100	.0100	.0120
15-5/17-4 ≤ 32HRc	40 to 140	40 to 160	.0040	.0040	.0040	.0040	.0050	.0050	.0050	.0060	.0070	.0080
15-5/17-4 ≥ 32HRc	25 to 100	25 to 120	.0020	.0020	.0030	.0030	.0040	.0040	.0050	.0050	.0060	.0060
13-8 / 316L	30 to 120	30 to 140	.0040	.0050	.0050	.0060	.0070	.0080	.0090	.0100	.0100	.0100
Tool Steel												
A2/D2/H13 ≤ 32HRc	30 to 120	30 to 120	.0040	.0040	.0040	.0040	.0050	.0050	.0050	.0060	.0070	.0080
A2/D2/H13 ≥ 32HRc	20 to 80	20 to 100	.0020	.0020	.0030	.0030	.0040	.0040	.0050	.0050	.0060	.0060
Titanium												
6Al-4V	20 to 100	20 to 120	.0020	.0020	.0030	.0030	.0040	.0040	.0060	.0060	.0080	.0100
High Temp Alloys												
Inconel 625	20 to 60	20 to 80	.0020	.0020	.0030	.0030	.0040	.0040	.0050	.0050	.0060	.0060
Inconel 718	20 to 50	20 to 70	.0020	.0020	.0030	.0030	.0040	.0040	.0050	.0050	.0060	.0060
Cast Iron												
Gray Iron ≤ 32HRc	80 to 200	80 to 250	.0060	.0060	.0060	.0060	.0070	.0080	.0100	.0120	.0140	.0150
Ductile Iron	80 to 200	80 to 250	.0060	.0060	.0060	.0060	.0070	.0080	.0100	.0100	.0100	.0120
Non-Ferrous												
6061 T6 Aluminum	100 to 300	100 to 375	.0050	.0050	.0060	.0060	.0070	.0080	.0100	.0120	.0140	.0150
Copper,Brass,Bronze	75 to 200	75 to 250	.0050	.0050	.0060	.0060	.0070	.0080	.0100	.0120	.0140	.0150
Plastic	100 to 350	100 to 350	.0050	.0050	.0060	.0060	.0070	.0080	.0100	.0120	.0140	.0150

Total Stock Removal:
Minimum and Maximum amounts of stock removal should be adhered to for proper reaming action. This is the amount the reamer should be oversized relative to the drilled hole.

Up to 1/16	.003 - .005
1/16 to 1/8	.004 - .008
1/8 to 1/4	.006 - .012
1/4 to 3/8	.008 - .014
3/8 to 1/2	.010 - .015
1/2 to 1"	.012 - .020

Reamer Specifications (decimal):
Cutting Diameter: +.0002 / -0
Shank Diameter: ±.0005
LOC: ±.030
OAL: ±.060
Helix (RH & LH): 12°
Lead Angle: 45°

All Ultra-Tool® reamer products are manufactured from Ultra-Carb®. Carbide reamers constructed with steel shank are induction-brazed (using controlled-frequency amplification) and slow-cooled in our own factory for maximum strength. All products are manufactured with centers (male, female, or both) for high concentricity characteristics and resharpening capabilities. Also, shanks are ground to the next smallest common fractional diameter for effective tool-holding and practicality. Note: Series 411 has oversized shank with clearance neck and does not feature centers.

new! Now available with TA coating!

Application Data for ULTRATOOL® Slitting Saws

All Ultra-Tool® Saw products are manufactured from Ultra-Carb®. Use a higher RPM and lower feed ratios than in most cutting tool applications. Use light viscosity coolants at most; dry running is acceptable and/or preferred. Concentricity is the single most determining factor in an efficient slotting operation.

new! Now available with standard SmoothCoat!

Saw Specifications:
Diameter: ±.015
Hole (ID): +.0005 / -.0000
Thickness: ±.00025

Slitting

Material Group	Speed SFPM
Aluminum/Related Alloys	700-1000
Brass/Bronze	450-750
Cast Iron (soft)	250-450
Cast Iron (medium)	150-350
Cast Iron (hard)	100-200
Magnesium	800-1200
Monel/Nickel Alloys	150-225
Steel-Heat Treated (35-40Rc)	150-250
Steel-Heat Treated (40-45Rc)	100-200
Steel-Heat Treated (45+Rc)	75-135
Steel-Low Carbon	250-425
Stainless-Soft	200-300
Stainless-Hard	100-200
Titanium Alloys	150-275

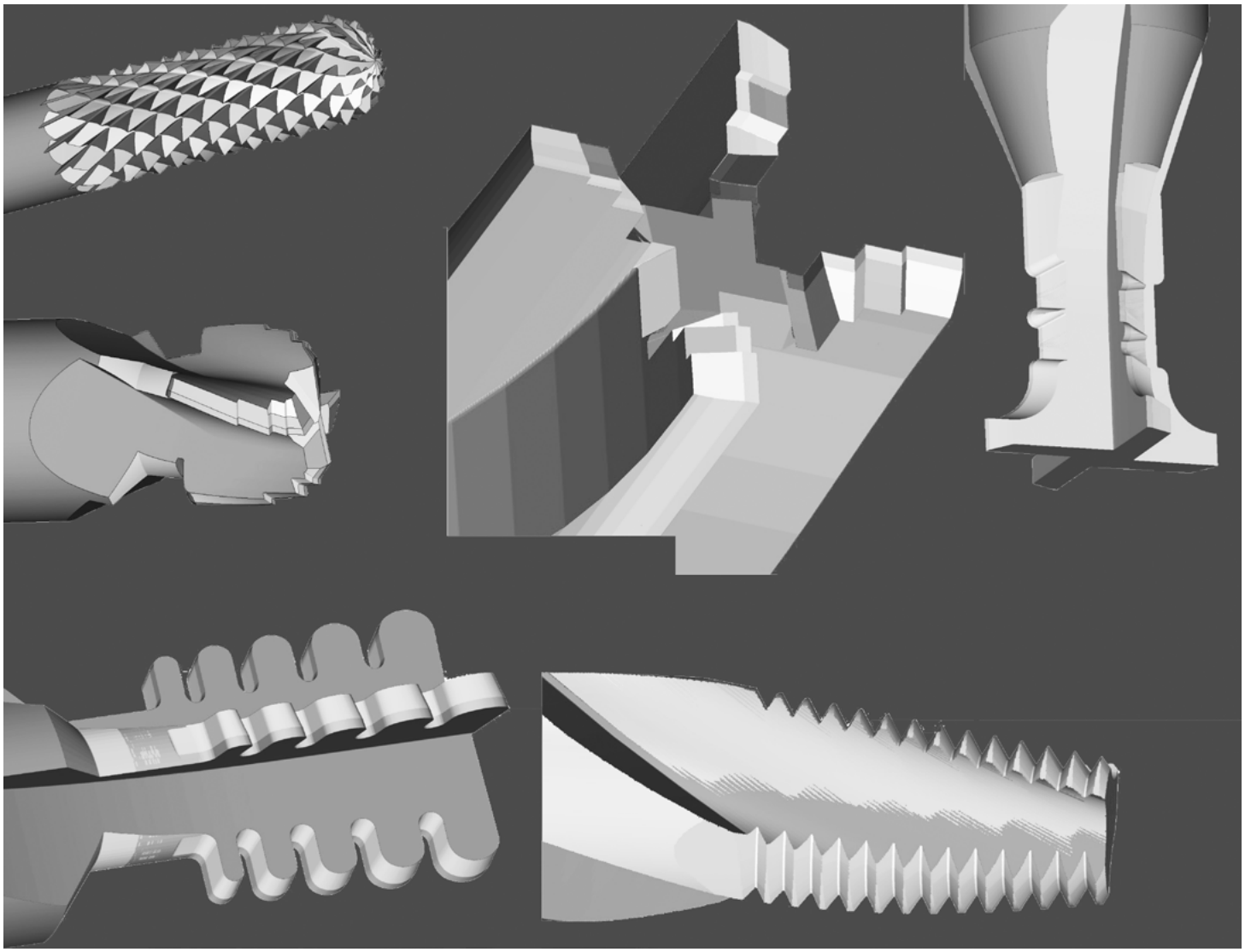
Feed Rate: Chip Load from .0001 per tooth (hardest materials) to .0015 (easiest machinability).

ULTRATOOL®

Products for Aerospace, Medical, Defense, and other specialized industry.

Solid Carbide Specials

Looking for a solid carbide special? If it can be ground, Ultra-Tool can do it. We use the world's most advanced design and grinding software, combined with precision equipment maintained in impeccable condition, all carried out by an experienced team of professional craftsmen. And always manufactured at our factories in Florida or California. Contact our sales desk for more information or to talk to a specialist.



ULTRATOOL® Decimal Equivalent Chart

	80	.0135		1/8	.1250		19/64	.2969		47/64	.7344	
	79	.0145			30	.1285		N	.3020		.7480	19.0mm
1/64		.0156			29	.1360	5/16		.3125	3/4	.7500	
	78	.0160				.1378	3.5mm		.3150	8.0mm	49/64	.7656
	77	.0180			28	.1405		O	.3160			.7677	19.5mm
		.0197	0.5mm	9/64		.1406		P	.3230		25/32	.7812	
	76	.0200			27	.1440	21/64		.3281			.7874	20.0mm
	75	.0210			26	.1470		Q	.3320		51/64	.7969	
	74	.0225			25	.1495			.3346	8.5mm		.8071	20.5mm
	73	.0240			24	.1520		R	.3390		13/16	.8125	
	72	.0250			23	.1540	11/32		.3438			.8268	21.0mm
	71	.0260		5/32		.1562		S	.3480		53/64	.8281	
	70	.0280			22	.1570			.3543	9.0mm	27/32	.8438	
	69	.0292				.1575	4.0mm	T	.3580			.8465	21.5mm
	68	.0310			21	.1590	23/64		.3594		55/64	.8594	
1/32		.0312			20	.1610		U	.3680			.8661	22.0mm
	67	.0320			19	.1660			.3740	9.5mm	7/8	.8750	
	66	.0330			18	.1695	3/8		.3750			.8858	22.5mm
	65	.0350		11/64		.1719		V	.3770		57/64	.8906	
	64	.0360			17	.1730		W	.3860			.9055	23.0mm
	63	.0370			16	.1770	25/64		.3906		29/32	.9062	
	62	.0380				.1772	4.5mm		.3937	10.0mm	59/64	.9219	
	61	.0390			15	.1800		X	.3970			.9252	23.5mm
		.0394	1.0mm		14	.1820		Y	.4040		15/16	.9375	
	60	.0400			13	.1850	13/32		.4062			.9449	24.0mm
	59	.0410		3/16		.1875		Z	.4130		61/64	.9531	
	58	.0420			12	.1890			.4134	10.5mm		.9646	24.5mm
	57	.0430			11	.1910	27/64		.4219		31/32	.9688	
	56	.0465			10	.1935			.4331	11.0mm		.9843	25.0mm
3/64		.0469			9	.1960	7/16		.4375		63/64	.9844	
	55	.0520				.1969	5.0mm		.4528	11.5mm	1”	1.000	25.4mm
	54	.0550			8	.1990	29/64		.4531				
		.0591	1.5mm		7	.2010	15/32		.4688				
	53	.0595		13/64		.2031			.4724	12.0mm			
1/16		.0625			6	.2040	31/64		.4844				
	52	.0635			5	.2055			.4921	12.5mm			
	51	.0670			4	.2090	1/2		.5000				
	50	.0700			3	.2130			.5118	13.0mm			
	49	.0730				.2165	5.5mm	33/64		.5156			
	48	.0760		7/32		.2188	17/32		.5312				
5/64		.0781			2	.2210			.5315	13.5mm			
	47	.0785			1	.2280	35/64		.5469				
		.0787	2.0mm		A	.2340			.5512	14.0mm			
	46	.0810		15/64		.2344	9/16		.5625				
	45	.0820				.2362	6.0mm		.5709	14.5mm			
	44	.0860			B	.2380	37/64		.5781				
	43	.0890			C	.2420			.5906	15.0mm			
	42	.0935			D	.2460	19/32		.5938				
3/32		.0938			E	.2500	39/64		.6094				
	41	.0960		1/4		.2500			.6102	15.5mm			
	40	.0980				.2559	6.5mm	5/8		.6250			
		.0984	2.5mm		F	.2570			.6299	16.0mm			
	39	.0995			G	.2610	41/64		.6406				
	38	.1015		17/64		.2656			.6496	16.5mm			
	37	.1040			H	.2660	21/32		.6562				
	36	.1065			I	.2720			.6693	17.0mm			
7/64		.1094				.2756	7.0mm	43/64		.6719			
	35	.1100			J	.2770	11/16		.6875				
	34	.1110			K	.2810			.6890	17.5mm			
	33	.1130		9/32		.2812	45/64		.7031				
	32	.1160			L	.2900			.7087	18.0mm			
		.1181	3.0mm		M	.2950	23/32		.7188				
	31	.1200				.2953	7.5mm		.7283	18.5mm			

Conversion Formulas

inches to millimeters:
multiply by 25.4

millimeters to inches:
multiply by .03937

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