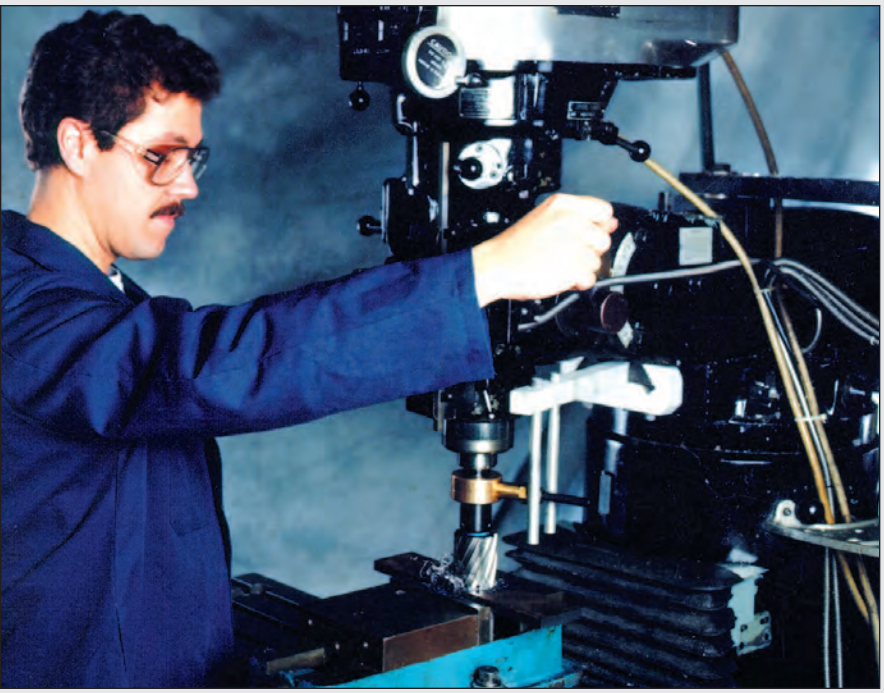


Hougen®

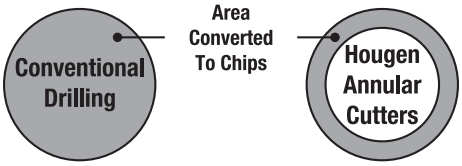
ROTABROACH® INDUSTRIAL PRODUCTS AND ACCESSORIES

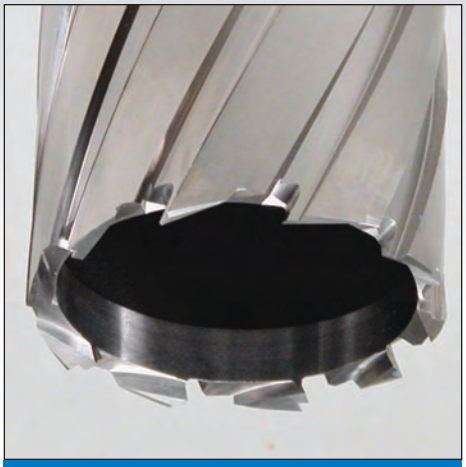
WWW.HOUGEN.COM

TAKE CONTROL OF YOUR TOUGHEST PRODUCTION APPLICATIONS

Rotabroach® - The Energy Saver

Rotabroach® Cutters require far less horsepower than twist drills of comparable size when run at the same feed rate. As a result, cutters can be run at higher feeds with higher metal removal rates while horsepower requirements are not increased. The geometry of Rotabroach® Cutters is such that far less material is converted into chips than when using twist drills.



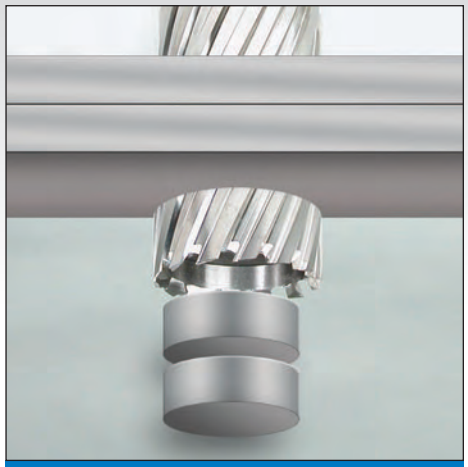


Experience the Hougen-Edge®

Our exclusive and patented tooth geometry - the Hougen-Edge®, is one of the reasons Rotabroach® Cutters require less thrust and improve finish and tool life. The alternating tooth angles equalize forces to keep the cutter path straight, even thru the deepest holes.

More cutting edges at work during each revolution smooths out finishes and reduces chip loads per tooth as compared to twist drills. From three to 12 teeth per cutter, depending upon diameter, helps tools last longer, even at higher feed rates.

Made in U.S.A.



Stack-Cut Geometry

Rotabroach® Annular Cutters with a Stack-Cut tooth geometry must be used whenever two or more plates are being drilled simultaneously. With our exclusive end tooth design, stacked materials can typically be drilled in a single pass.

It should be noted that these modified cutters must be used when stack cutting. Non-modified Cutters cannot successfully cut through stacked material.

Stack-Cut and Flat Bottom Grooving tooth Geometry is available upon request on the cutters included in this catalog.

Hougen's Technical Service Department should be contacted whenever special tooth geometry and applications will be necessary.

Applications involving turning, milling or drilling operations - for CNC systems or manual machines, even high production transfer equipment. In virtually every thru hole application, Rotabroach® Industrial Cutters outperform conventional tooling. They even do the jobs impossible for conventional tooling, such as oblique entry holes, holes started on curved surfaces, arcs of holes, and face grooves. Some typical applications of Rotabroach® Cutters with nontypical results for conventional tools include...

- A manufacturer of construction equipment needed to produce a 4-1/8" dia. hole thru 2-3/4" thick mild steel. Previously took 15 minutes and three passes to complete one hole. With Rotabroach®, under one minute in one pass with a feed rate of 5 IPM.
- A producer of heat exchangers used conventional tools for a 2.015" hole thru 2-3/4" thick pressure vessel walls - it took 19 minutes. Rotabroach® tools require just over one minute per hole, with over 600 lineal inches of holes produced per tool, per sharpening.
- A custom bicycle manufacturer uses Rotabroach® Cutters to radius the ends of frame tubing to make a miter fit. End mills were used but slow feed rates, large burrs, distortion, and short tool life gobbled up time. With Rotabroach®, the radius is now drilled with a 50% or more time savings, plus less time taken to deburr.
- A company producing weight lifting benches and racks uses Rotabroach® Cutters to produce 1-1/8" dia. holes thru 0.120" thick tube walls in 15 seconds per hole. They're using a 1 HP motor to drive the spindle, a motor rated by its manufacturer to drill 1/2" maximum using twist drills.
- A manufacturer of coal handling equipment for power plants drills 3-1/2" holes thru 1-1/4" thick weldments. Twist drills distorted the material while taking nearly six minutes per hole. The Rotabroach® advantage: a savings of approximately 5-1/2 minutes per hole and no deformation.
- A fabricator of nuclear components uses Rotabroach® tools to put 2-3/4" holes thru 8-1/2" of 625 Inconel. A double savings of time (over six hours per hole saved) and money as value of the solid slug increased by $150 per hole.
- Rotabroach® tools also face groove - fast - as a manufacturer of high horsepower compressors discovered. Using 1/8" dia. end mills (one for roughing, one for finishing) and CNC machining centers with a circular interpolation program, the sealing V-groove took two hours and many broken tools to complete. For this application, Hougen engineers developed a special tooth geometry Rotabroach® Cutter that completes the 7/16" deep groove in just 16 seconds. Rotabroach® Cutters are used in all types of industries - • Construction • Fabrication • Aerospace • Automotive • Petroleum • Food processing equipment • Valves, piping, and pumps. - All saving time, and dollars with the Rotabroach® Advantage.

ROTABROACH® HEAVY-DUTY INDUSTRIAL CUTTERS

- **M2 H.S.S. Series**
  "53,000-Series" - 3" D.O.C.
  "54,000-Series" - 4" D.O.C.
  "56,000-Series" - 6" D.O.C.
- **M2 H.S.S. Series with TiN Coating**
  "33,000-Series" - 3" D.O.C.
  "34,000-Series" - 4" D.O.C.
  "36,000-Series" - 6" D.O.C.

Heavy Duty Construction
Rotabroach® Industrial Cutters are "tougher" tools which allow heavier feeds with increased speeds and deeper holes.

Large Diameter & Deep Holes
Large diameters and special depths are available on request. Cutters are designed for use on conventional machine tools and machining centers and will lower your cost per hole in production applications. Set-ups require internal lubrication through the spindle or coolant inducer tool holder.

Difficult-To-Machine Materials
Rotabroach® Cutters will produce holes in many high-strength, exotic metals that are either difficult or impossible to machine by conventional tools... and the alternating tooth design of Hougen-Edge geometry provides smoother cutting action.

TiN Coated For Extra Wear
Titanium Nitride coated M2 High Speed Steel Rotabroach® Cutters are for 15 to 25% higher speeds, friction reduction, greater endurance, deep holes, and harder materials. The TiN coating reduces friction and operates at cooler temperatures while presenting a harder cutting edge.

Custom Sizes and Metric Cutters
Made of premium materials available upon request.

How to Order
The chart on the right reflects part no's. for the "53,000-Series" Cutters. To order a different series, replace the first two digits of the part no. with the first two digits of the series number. For example: a "34,000-Series" Cutter in a 3/4" diameter would part no. 34074.

PILOTS

Part No.	Pilot Length	Cutter Series	Shank Diameter
21802	3"	"53,000"	1-1/4" Weldon
21805	3"	"53,000"	3/4" Weldon
21806	4"	"54,000"	1-1/4" Weldon
21807	4"	"54,000"	3/4" Weldon
21808	6"	"56,000"	1-1/4" Weldon

Pilots can not be used without cutter modification.

Cutter Dia. Inches	Decimal Equivalent	No. of Teeth	Part No. (3" D.O.C.)
3/4" Diameter Weldon Shank			
3/4	.7500	4	53074
13/16	.8125	4	53081
7/8	.8750	5	53088
15/16	.9375	5	53095
1	1.0000	6	53102
***1-1/64**	**1.0156**	**6**	**53104**
1-1/16	1.0625	6	53109
1-1/8	1.1250	6	53117
1-3/16	1.1875	6	53124
1-1/4	1.2500	6	53131
1-5/16	1.3125	6	53138
1-3/8	1.3750	6	53145
1-7/16	1.4375	6	53153
1-1/4" Diameter Weldon Shank			
1-1/2	1.5000	6	53160
***1-33/64**	**1.5156**	**8**	**53161**
1-9/16	1.5625	8	53167
1-5/8	1.6250	8	53174
1-11/16	1.6875	8	53181
1-3/4	1.7500	8	53188
1-13/16	1.8125	8	53196
1-7/8	1.8750	8	53203
1-15/16	1.9375	10	53210
2	2.0000	10	53217
***2-1/64**	**2.0156**	**10**	**53219**
2-1/32	2.0313	10	53221
2-1/16	2.0625	10	53224
2-1/8	2.1250	10	53231
2-3/16	2.1875	10	53239
2-1/4	2.2500	10	53246
2-5/16	2.3125	10	53253
2-3/8	2.3750	10	53260
2-7/16	2.4375	12	53267
2-1/2	2.5000	12	53274
***2-33/64**	**2.5156**	**12**	**53276**
2-17/32	2.5313	12	53278
2-9/16	2.5625	12	53282
2-5/8	2.6250	12	53289
2-11/16	2.6875	12	53296
2-3/4	2.7500	12	53303
2-13/16	2.8125	12	53310
2-7/8	2.8750	12	53318
2-15/16	2.9375	12	53325
3	3.000	12	53332
***3-1/64**	**3.0156**	**12**	**53334**
3-1/16	3.0625	12	53339
1-1/2" Diameter Weldon Shank			
3-1/8	3.1250	12	53345
3-1/4	3.2500	12	53356
3-3/8	3.3750	12	53367
3-1/2	3.5000	12	53378
3-5/8	3.6250	12	53390
3-3/4	3.7500	12	53401
3-7/8	3.8750	12	53412
4	4.0000	12	53423

* Tube Sheet Cutter diameters listed in bold.
Please refer to the Industrial Rotabroach® Price List (#02819) for stocking status of all cutters.

ROTABROACH® INDUSTRIAL CUTTERS

- **M2 H.S.S. Series**
  "42,000-Series" - 2" D.O.C.
  "43,000-Series" - 3" D.O.C.
- **M2 H.S.S. Series with TiN Coating**
  "22,000-Series" - 2" D.O.C.
  "23,000-Series" - 3" D.O.C.

For Lighter Workloads

Designed for use in smaller, lower horsepower machines, these economical tools are equipped with either a .188" or .218" wall thickness to limit workloads, yet still provide high feed rates and speeds.

How to Order

To order "22,000-Series" or "23,000-Series" cutters, replace the first two digits of the part no. with the first two digits of the series number. For example: a "22,000-Series" Cutter in a 3/4" diameter would part no. 22024.

PILOTS

Part No.	Pilot Length	Cutter Series	Shank Diameter
21800	2"	"42,000"	3/4" Weldon
21801	2"	"42,000"	1-1/4" Weldon
21805	3"	"43,000"	1-1/4" Weldon

Cutter Dia. Inches	Decimal Equivalent	No. of Teeth	Part No. (M2 H.S.S.)
3/4" Weldon Shank - 2" D.O.C.			
3/4	.7500	4	42024
13/16	.8125	4	42026
7/8	.8750	5	42028
15/16	.9375	5	42030
1	1.0000	6	42032
1-1/16	1.0625	6	42034
1-1/8	1.1250	6	42036
1-3/16	1.1875	6	42038
1-1/4	1.2500	6	42040
1-5/16	1.3125	6	42042
1-3/8	1.3750	6	42044
1-7/16	1.4375	6	42046
1-1/4" Weldon Shank - 2" D.O.C.			
1-1/2	1.5000	6	42048
1-9/16	1.5625	8	42050
1-5/8	1.6250	8	42052
1-11/16	1.6875	8	42054
1-3/4	1.7500	8	42056
1-13/16	1.8125	8	42058
1-7/8	1.8750	8	42060
1-15/16	1.9375	10	42062
2	2.0000	10	42064
1-1/4" Weldon Shank - 3" D.O.C.			
2-1/16	2.0625	10	43066
2-1/8	2.1250	10	43068
2-3/16	2.1875	10	43070
2-1/4	2.2500	10	43072
2-5/16	2.3125	10	43074
2-3/8	2.3750	10	43076
2-7/16	2.4375	10	43078
2-1/2	2.5000	10	43080
2-9/16	2.5625	10	43082
2-5/8	2.6250	10	43084
2-11/16	2.6875	10	43086
2-3/4	2.7500	10	43088
2-13/16	2.8125	10	43090
2-7/8	2.8750	10	43092
2-15/16	2.9375	10	43094
3	3.0000	10	43096
3-1/16	3.0625	10	43098

Grind Downs

Hougen® Annular Cutters can be made available in non-standard diameters by grinding down the O.D. to the requested size. The chart below lists the grind down range available for each cutter series and nominal diameter range. Please refer to the Industrial Price List for details on how to price grind downs.

Grind Down Limits

Official Grind Down Limits		
Dia. Range	Minimum (Inches)	Maximum (Inches)
RotaCut™ ("11,000-Series")		
1/4", 9/32", 6mm, 7mm	No Grind Down	
5/16" - 17/32"	.0015	.0070
8mm - 14mm	.0015	.0070
9/16" - 1-1/2"	.0020	.0100
15mm - 25mm	.0020	.0100
"12,000-Series"		
7/16", 1/2", 12mm, 13mm	.0020	.0100
9/16" - 1-5/16"	.0020	.0150
14mm - 34mm	.0020	.0150
1-3/8" - 2-3/8"	.0020	.0200
35mm - 51mm	.0020	.0200
"42,000-Series"		
3/4" - 13/16"	.0020	.0150
7/8" - 2"	.0020	.0200
"43,000-Series"		
2-1/16" - 3-1/16"	.0020	.0200
"53/54/56,000-Series"		
3/4", 13/16" 20mm	.0020	.0150
7/8" - 4"	.0020	.0313

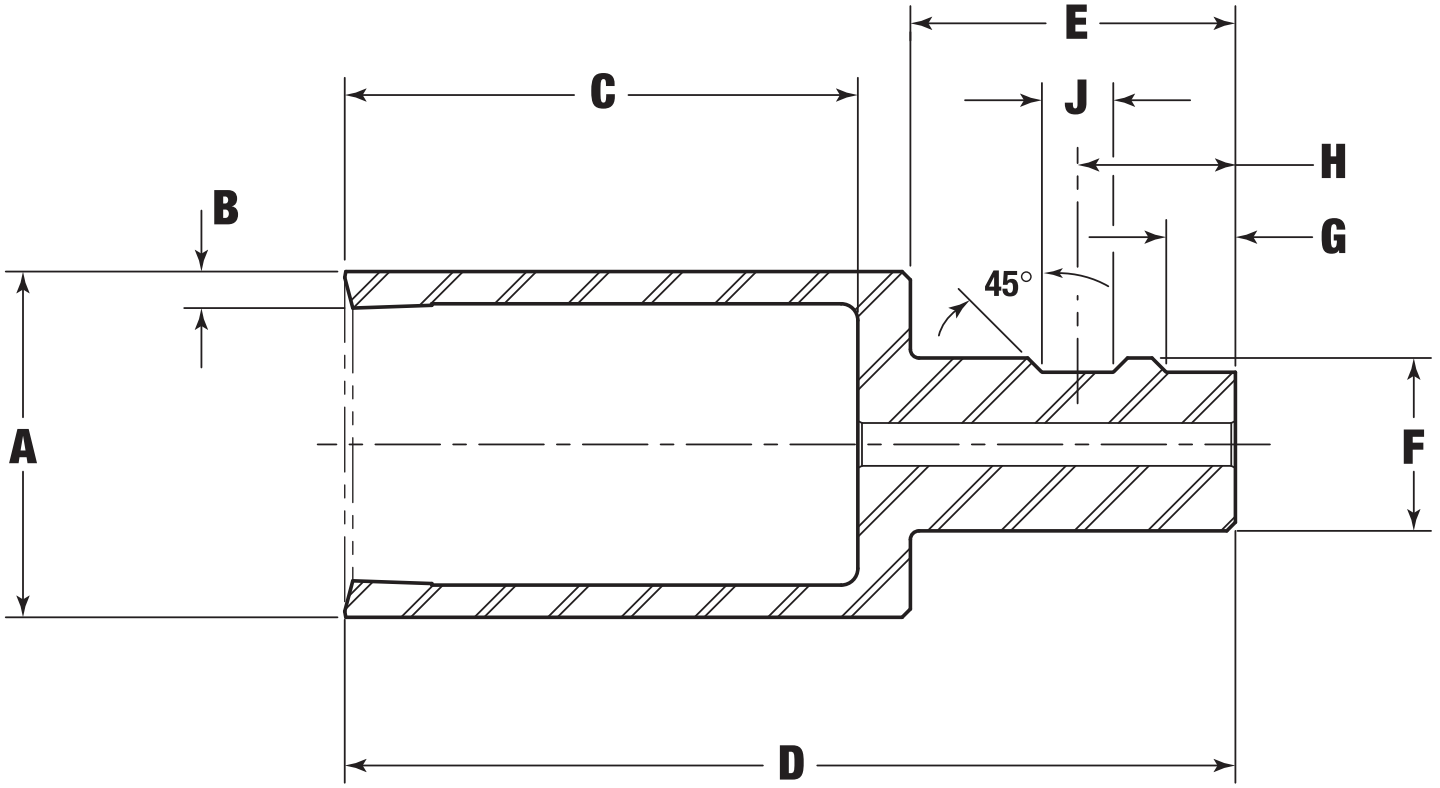
RotaMagic™ Concentrated Cutting Fluid is water soluble and yields a 10:1 ratio when mixed with water. (Biodegradable)

Slick-Stik™ is softer than other stick lubricants for easy application, superior adhesion to the tool, assuring thorough coverage. Use with ferrous or non-ferrous materials.

ROTAMAGIC CUTTING FLUID & SLICK-STIK™ LUBRICANT

Part No.	Description
11741-12	(12) 1 Pint Bottles - makes 1 pint each, 12 pints total
11742-4	(4) 1 Gallon Bottles - makes 11 gallons each, 44 gallons total
11743	(1) 5 Gallon Pail - makes 55 gallons total
11745-6	(6) 16 oz. Slick-Stik Lubricant
11746-12	(12) 1.68 oz. Slick-Stik Lubricant
11746-24	(24) 1.68 oz. Slick-Stik Lubricant in display box

ROTABROACH® CUTTER DIMENSIONS



Cutter Series	Depth of Cut	A +.000 -.001	B	C	D	E	F +.0000 -.0005	G ±.031	H ±.015	J +.002 -.000
(Part No.)	(D.O.C.)	Outer Dia.	Wall Thickness	Inside Depth	Overall Length	Shank Length	Shank Dia.	1st Flat	Screw C/L	2nd Flat Width
"22,000" "42,000"	2"	3/4" - 1-1/16"	.196	2.37	4.72	2.10	3/4" Weldon	----	1.015	.455
		1-1/8" - 1-7/16"	.188							
		1-1/2" - 2"			4.97	2.35	1-1/4" Weldon	.50	1.141	.515
"23,000" "43,000"	3"	2-1/16" - 3-1/16"	.218	3.42	6.02					
"33,000" "53,000"	3"	3/4" - 1-7/16"	(.264)*	3.67	6.15	2.10	3/4" Weldon	----	1.015	.455
		1-1/2" - 3-1/16"	.264	3.71	6.44	2.35	1-1/4" Weldon	.50	1.141	.515
		3-1/8" - 4"			6.85	2.76	1-1/2" Weldon	.56	1.187	
"34,000" "54,000"	4"	3/4" - 1-7/16"	(.264)*	4.67	7.15	2.10	3/4" Weldon	----	1.015	.455
		1-1/2" - 3-1/16"	.264	4.71	7.44	2.35	1-1/4" Weldon	.50	1.141	.515
		3-1/8" - 4"			7.85	2.76	1-1/2" Weldon	.56	1.187	
"36,000" "56,000"	6"	3/4" - 1-7/16"	(.264)*	6.67	9.15	2.10	3/4" Weldon	----	1.015	.455
		1-1/2" - 3-1/16"	.264	6.71	9.44	2.35	1-1/4" Weldon	.50	1.141	.515
		3-1/8" - 4"			9.85	2.76	1-1/2" Weldon	.56	1.187	

* Nominal Tooth Width varies with the following parameters:
- Cutter diameters manufactured as grind downs must also take into account wall thickness reduction as a result.
- 3/4" diameter "53, 54 & 56,000-Series" feature a nominal wall thickness of .207"
- 13/16" diameter "53, 54 & 56,000-Series" feature a nominal wall thickness of .238"

ROTABROACH® DATA FOR MACHINING CENTERS

The following charts contain information required for calculating speeds and feeds for use of Rotabroach® Industrial Cutters in Machining Centers. A Rotabroach® Speeds & Feeds Calculator is also available on the Hougen® website for free download to your computer. Please note that the suggested speeds and feeds are to be used as starting points. Adjustments may be required depending on application and workpiece conditions.

Material Cutting Speed: Surface Feet per Minute (SFM)

Type of Material		Brinell Hardness	Cutting Speed (sfm)	Tool Material
Aluminum	• Wrought & Cast	30-150	500-1000	M2
	• Die cast 360.0, 380.0	40-125	450-600	M2
	383.0, 413.0	40-125	450-600	M2
	390.0, 392.0	40-125	75-100	M2
Brass & Bronze		----	300-600	M2
Cast Iron	• Soft	120-150	75-125	M2
	• Medium	160-220	50-100	M2/M42
	• Chilled	230-300	30-50	M42
Malleable Iron	• Ferritic	110-160	100-130	M2
	• Pearlitic	160-220	75-100	M2
	• Tempered Matensite	200-320	30-60	M42
Magnesium		50-90	400-800	M2
Nickel Alloys	• 200-230	80-170	60-80	M2
	• Monel 400-404	115-240	35-50	M2
	• Monel K500, 502	150-330	20-40	M42
Steel Free Machining	• Resulphurized/Leaded	----	105-300	M2
Carbon Steel	• 10xx, 12xx, xx10, xx20	125-160	90-110	M2
Steel Alloys Soft	• 10xx, 12xx, xx10, xx20 • 41xx, 51xx, xx30, xx40 • 52xx, 93xx, xx50, x100	170-210	65-90	M2
Steel Alloys Medium	• 10xx, 12xx, xx10, xx20 • 41xx, 51xx, xx30, xx40 • 52xx, 93xx, xx50, x100	220-250	55-75	M2
Steel Alloys Hard		260-300	35-50	M2/M42
		325-400	30-40	M42/M42 Coated
Tool Steel	• T15, M42, D2 • M2, A2 • S6, H13	210-250	35-60	M2/M42
Forgings		----	40-50	M2
Armor Plate		200-250	40-55	M2/M42
		250-300	30-45	M42/M42 Coated
Stainless Steel Ferritic	• 430/405 • 430F	135-185	90-125	M2
Stainless Steel Austenitic	• Lower BHN	135-185	55-75	M2
	• Higher BHN • 309/316 • 301/304 • 303/203EZ	225-275	40-70	M2
Stainless Steel Nitonic (Low Alloy)		275-325	25-35	M42
Stainless Steel Martensitic	By Hardness Range • 501 • 416/440F	135-185	70-125	M2
		185-240	45-110	M2
		275-325	35-55	M42
		375-425	30-55	M42 Coated
Stainless Steel Precipitation Hardening	By Hardness Range • 17-4 PH	150-200	45-55	M2
		275-325	40-50	M42
		325-375	35-45	M42 Coated
Inconel	• 600/Hastelloy B, C, X, S	140-220	12-18	M2/M42
		240-310	10-15	M42
Inconel	• 718/Waspelloy	200-300	10-15	M2/M42
		300-400	7-12	M42/M42 Coated
Inconel	• 700/Rene 41	225-300	10-15	M2/M42
		300-400	7-12	M42/M42 Coated

Feed Per Tooth (FPT)

Material or Application Type	Feed per Tooth (Inches)
• Thin-Walled Workpieces • Curved Entry Surfaces • Semi-Circle • Fragile Setups	.001/.002 (.003 for work-hardening material)
• Soft/Gummy Materials	.004/.005
• Average Applications	.003/.004
• Deep Holes	.004/.005

Material Tensile Strength (Kc)

Material Type	BHN Hardness	Tensile Strength (Kc)
Free Machining & Low Carbon Steel	----	239,200
Carbon Steel	----	254,000
	125-160	283,000
Alloy Steel (soft)	----	297,000
	170-210	312,300
Alloy Steel (med. hard)	----	326,000
	220-250	341,000
Tool Steel (hot & cold worked)	210-250	355,000
Alloy Steel (hard)	260-300	370,000
Stainless Steel	----	370,000
Cast Iron	180 max	167,000
	180-250	196,000
	250-300	255,000
Aluminum	----	106,000

Hardness Conversion Chart

Rockwell Hardness "C" Scale	Brinell Hardness
20	226
25	253
28	271
30	286
32	301
34	319
36	336
38	353
40	371
43	400

Our Technical Support Department can help with all your special cutter needs and applications.

800-426-7818

ROTABROACH® DATA FOR MACHINING CENTERS

Conversion Chart: SFM to RPM

Cutter Dia. (Inches)	Surface Feet per Minute									
	10	20	30	40	50	60	70	80	90	100
	Revolutions per Minute (RPM)									
.7500	51	102	153	204	255	306	357	407	458	509
.8750	44	87	131	175	218	262	306	349	393	437
1.0000	38	76	115	153	191	229	267	306	344	382
1.1250	34	68	102	136	170	204	238	272	306	340
1.2500	31	61	92	122	153	183	214	244	275	306
1.3750	28	56	83	111	139	167	194	222	250	278
1.5000	25	51	76	102	127	153	178	204	229	255
1.6250	24	47	71	94	118	141	165	188	212	235
1.7500	22	44	65	87	109	131	153	175	196	218
1.8750	20	41	61	81	102	122	143	163	183	204
2.0000	19	38	57	76	95	115	134	153	172	191
2.1250	18	36	54	72	90	108	126	144	162	180
2.2500	17	34	51	68	85	102	119	136	153	170
2.3750	16	32	48	64	80	96	113	129	145	161
2.5000	15	31	46	61	76	92	107	122	138	153
2.6250	15	29	44	58	73	87	102	116	131	146
2.7500	14	28	42	56	69	83	97	111	125	139
2.8750	13	27	40	53	66	80	93	106	120	133
3.0000	13	25	38	51	64	76	89	102	115	127
3.1250	12	24	37	49	61	73	86	98	110	122
3.2500	12	24	35	47	59	71	82	94	106	118
3.3750	11	23	34	45	57	68	79	91	102	113
3.5000	11	22	33	44	55	64	76	87	98	109
3.6250	11	21	32	42	53	63	74	84	95	105
3.7500	10	20	31	41	51	61	71	81	92	102
3.8750	10	20	30	39	49	59	69	79	89	99
4.0000	10	19	29	38	48	57	67	76	86	95

To compute RPM's for cutting speeds other than those shown, either select two speeds from the table that add up to the speed desired and then add their RPM's, or select a factor which, when multiplied by one of the speeds in the table, gives the desired speed and multiply its RPM by the same factor.
Examples: To find the RPM for a 1" diameter cutter run at 150 SFM --
1) Add RPM's for 100 SFM (382) and 50 SFM (191) = 573 rpm
2) Or multiply the RPM for 50 SFM (191) by a factor of 3 = 573 rpm

Formulas for Calculating Speeds & Feeds

Visit www.hougen.com to use and download the speeds & feeds calculator!

Area Factor = IN^2
$IN^2 = \pi \times (D \times WT - WT^2)$

Feed Per Tooth = FPT
(see chart on page 6)

Horsepower = HP
$HP = IN^2 \times IPM \times K$

Inches per Minute = IPM
IPM = FPT x NT x RPM

K (how difficult the material is to machine)
Steel (K = 1)
Cast Iron (K = .5)
Aluminum (K = .25)

Outer Diameter = D

Material Tensile Strength = Kc
(see chart on page 6)

Thrust = T
T = .7 x WT x FPT x NT x Kc

Wall Thickness = WT
.188, .196, .218, .264

No. of Teeth = NT
(see chart on pages 3 and 4)

Surface Feet per Minute = SFM
SFM = [π x D ÷ 12] x RPM

Revolutions per Minute = RPM
RPM = SFM ÷ [π ÷ 12] x OD

Area Factors (IN^2)

Cutter Dia. (Inches)	Decimal Equivalent	Cutter Series	
		"53,000"	"42,000" "43,000"
3/4	.7500	.353	.341
13/16	.8125	.430	.380
7/8	.8750	----	.418
15/16	.9375	----	.457
1	1.0000	----	.495
*** 1-1/64**	**1.0156**	**----**	**----**
1-1/16	1.0625	----	.534
1-1/8	1.1250	.714	.553
1-3/16	1.1875	.766	.590
1-1/4	1.2500	.818	.627
1-5/16	1.3125	.870	.664
1-3/8	1.3750	.921	.701
1-7/16	1.4375	.973	.738
1-1/2	1.5000	1.025	.775
*** 1-33/64**	**1.5156**	**1.038**	**----**
1-9/16	1.5625	1.077	.812
1-5/8	1.6250	1.129	.849
1-11/16	1.6875	1.181	.886
1-3/4	1.7500	1.232	.923
1-13/16	1.8125	1.284	.959
1-7/8	1.8750	1.336	.996
1-15/16	1.9375	1.388	1.033
2	2.0000	1.440	1.070
*** 2-1/64**	**2.0156**	**1.453**	**----**
2-1/32	2.0313	1.466	----
2-1/16	2.0625	1.492	1.263
2-1/8	2.1250	1.543	1.306
2-3/16	2.1875	1.595	1.349
2-1/4	2.2500	1.647	1.392
2-5/16	2.3125	1.699	1.434
2-3/8	2.3750	1.751	1.477
2-7/16	2.4375	1.803	1.520
2-1/2	2.5000	1.854	1.563
*** 2-33/64**	**2.5156**	**1.867**	**----**
2-17/32	2.5313	1.880	----
2-9/16	2.5625	1.906	1.606
2-5/8	2.6250	1.958	1.648
2-11/16	2.6875	2.010	1.691
2-3/4	2.7500	2.062	1.734
2-13/16	2.8125	2.114	1.777
2-7/8	2.8750	2.166	1.820
2-15/16	2.9375	2.217	1.862
3	3.0000	2.269	1.905
*** 3-1/64**	**3.0156**	**2.282**	**----**
3-1/16	3.0625	2.321	1.948
3-1/8	3.1250	2.373	----
3-1/4	3.2500	2.477	----
3-3/8	3.3750	2.580	----
3-1/2	3.5000	2.684	----
3-5/8	3.6250	2.788	----
3-3/4	3.7500	2.891	----
3-7/8	3.8750	2.995	----
4	4.0000	3.099	----

(see chart on page 5)

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