Vol 1

Inch & Metric

High Speed Machining Guide

Roughing & Semi-Finishing

Dia.	RPM		
	30-40 HRC	40-50 HRC	50-60 HRC
1/32″	38,400 - 60,000	32,000 - 50,000	24,600 - 40,000
1 mm	38,400 - 60,000	32,000 - 50,000	24,600 - 40,000
1/16″	26,400 - 42,000	22,000 - 35,000	16,600 - 28,000
2 mm	24,000 - 36,600	20,000 - 30,500	15,000 - 24,400
3/32″	21,600 - 31,200	18,000 - 26,000	13,400 - 20,800
3 mm	19,200 - 28,800	16,000 - 24,000	11,800 - 19,200
1/8″	19,200 - 28.800	16,000 - 24,000	11,800 - 19,200
4 mm	17,100 - 24,200	14200 - 20,000	10,400 - 16,200
3/16″	15,000 - 19,776	12,500 - 16,480	9,000 - 13,184
5 mm	15,000 - 19,800	12,500 - 16,500	9,000 - 13,200
6 mm	12,120 - 16,800	10,100 - 14,000	7,080 - 11,200
1/4″	12,120 - 16,800	10,100 - 14,000	7,080 - 11,200
7 mm	11,800 - 16,400	9,700 - 13,600	6,700 - 10,900
5/16″	11,400 - 15,900	9,200 - 13,250	6,360 - 10,600
8 mm	11,400 - 15,900	9,200 - 13,250	6,400 - 10,600
9 mm	11,000 - 15,200	9,000 - 12,700	6,200 - 10,150
3/8″	10,560 - 14,520	8,800 - 12,100	6,040 - 9,680
10 mm	10,600 - 14,500	8,800 - 12,100	6,000 - 9,700
11 mm	9,500 - 12,500	7,900 - 10,400	5,300 - 8,300
7/16″	9,480 - 12,480	7,900 - 10,400	5,320 - 8,320
12 mm	8,300 - 10,900	6,900 - 9,100	4,500 - 7,300
1/2″	8,280 - 10,920	6,900 - 9,100	4,520 - 7,280

Finishing

Dia.	RPM		
	30-40 HRC	40-50 HRC	50-60 HRC
1/32″	20,000 - 50,000	20,000 - 50,000	20,000 - 50,000
1 mm	20,000 - 50,000	20,000 - 50,000	20,000 - 50,000
1/16″	20,000 - 50,000	20,000 - 50,000	20,000 - 50,000
2 mm	20,000 - 50,000	20,000 - 50,000	20,000 - 50,000
3/32″	20,000 - 50,000	20,000 - 50,000	20,000 - 50,000
3 mm	20,000 - 38,000	20,000 - 50,000	20,000 - 30,500
1/8″	20,000 - 50,000	20,000 - 38,000	20,000 - 30,500
4 mm	20,000 - 32,000	20,000 - 42,000	18,000 - 25,400
3/16″	20,000 - 34,000	20,000 - 26,000	16,000 - 20,300
5 mm	20,000 - 26,000	20,000 - 34,000	16,000 - 20,300
6 mm	15,000 - 18,000	18,000 - 24,400	12,000 - 15,000
1/4″	18,000 - 24,400	15,000 - 18,000	12,000 - 15,000
7 mm	13,500 - 16,000	16,300 - 21,700	10,900 - 13,500
5/16″	14,600 - 19,000	12,000 - 14,000	9,700 - 12,000
8 mm	12,000 - 14,000	14,600 - 19,000	9,700 - 12,000
9 mm	11,000 - 13,000	13,300 - 17,600	8,900 - 11,000
3/8″	12,000 - 16,200	10,000 - 12,000	8,100 - 10,000
10 mm	10,000 - 12,000	12,000 - 16,200	8,100 - 10,000
11 mm	8,700 - 10,400	10,000 - 13,900	6,900 - 8,700
7/16″	10,000 - 13,900	8,700 - 10,400	6,900 - 8,700
12 mm	7,800 - 9,800	9,100 - 12,200	6,100 - 7,600
1/2″	9,100 - 12,200	7,800 - 9,800	6,100 - 7,600

Chip Load Per Tooth

Dia.	IPT					
	30 - 40 HRC		40 -50 HRC		50 - 60 HRC	
	Rough & Semi	Finishing	Rough & Semi	Finishing	Rough & Semi	Finishing
1/32″	0.0006 - 0.0010	0.0006 - 0.0009	0.0005 - 0.0008	0.0006 - 0.0007	0.0004 - 0.0007	0.0004 - 0.0006
1 mm	0.0008 - 0.0009	0.0006 - 0.0009	0.0007 - 0.0009	0.0006 - 0.0008	0.0006 - 0.0007	0.0005 - 0.0007
1/16″	0.0012 - 0.0015	0.0010 - 0.0016	0.0010 - 0.0015	0.0010 - 0.0014	0.0008 - 0.0012	0.0007 - 0.0010
2 mm	0.0015 - 0.0019	0.0013 - 0.0018	0.0013 - 0.0017	0.0012 - 0.0016	0.0011 - 0.0015	0.0010 - 0.0014
3/32″	0.0020 - 0.0025	0.0014 - 0.0024	0.0015 - 0.0020	0.0014 - 0.0022	0.0010 - 0.0014	0.0012 - 0.0020
3 mm	0.0023 - 0.0028	0.0019 - 0.0027	0.0012 - 0.0026	0.0018 - 0.0024	0.0017 - 0.0022	0.0015 - 0.0021
1/8″	0.0025 - 0.0030	0.0019 - 0.0028	0.0020 - 0.0027	0.0019 - 0.0026	0.0015 - 0.0020	0.0017 - 0.0022
4 mm	0.0030 - 0.0037	0.0026 - 0.0036	0.0027 - 0.0345	0.0025 - 0.0032	0.0023 - 0.0030	0.0020 - 0.0028
3/16″	0.0035 - 0.0042	0.0032 - 0.0043	0.0032 - 0.0041	0.0030 - 0.0040	0.0030 - 0.0039	0.0023 - 0.0031
5 mm	0.0038 - 0.0047	0.0032 - 0.0044	0.0033 - 0.0043	0.0031 - 0.0040	0.0028 - 0.0037	0.0026 - 0.0035
6 mm	0.0045 - 0.0056	0.0039 - 0.0053	0.0040 - 0.0052	0.0037 - 0.0048	0.0034 - 0.0045	0.0031 - 0.0042
1/4″	0.0050 - 0.0060	0.0040 - 0.0053	0.0050 - 0.0057	0.0040 - 0.0051	0.0040 - 0.0050	0.0038 - 0.0048
7 mm	0.0053 - 0.0065	0.0045 - 0.0062	0.0047 - 0.0060	0.0043 - 0.0056	0.0039 - 0.0052	0.0036 - 0.0049
5/16″	0.0063 - 0.0070	0.0053 - 0.0068	0.0053 - 0.0066	0.0052 - 0.0063	0.0051 - 0.0062	0.0046 - 0.0054
8 mm	0.0060 - 0.0075	0.0051 - 0.0071	0.0053 - 0.0069	0.0049 - 0.0064	0.0045 - 0.0060	0.0041 - 0.0055
9 mm	0.0068 - 0.0084	0.0058 - 0.0080	0.0060 - 0.0078	0.0055 - 0.0072	0.0051 - 0.0067	0.0046 - 0.0062
3/8″	0.0070 - 0.0080	0.0062 - 0.0079	0.0062 - 0.0077	0.0054 - 0.0065	0.0060 - 0.0072	0.0050 - 0.0061
10 mm	0.0075 - 0.0093	0.0064 - 0.0089	0.0067 - 0.0086	0.0061 - 0.0080	0.0056 - 0.0074	0.0051 - 0.0069
11 mm	0.0083 - 0.0103	0.0071 - 0.0098	0.0073 - 0.0095	0.0068 - 0.0088	0.0062 - 0.0082	0.0056 - 0.0076
7/16″	0.0080 - 0.0087	0.0068 - 0.0086	0.0068 - 0.0084	0.0060 - 0.0078	0.0066 - 0.0080	0.0053 - 0.0070
12 mm	0.0090 - 0.0112	0.0077 - 0.0107	0.0080 - 0.0103	0.0074 - 0.0096	0.0068 - 0.0089	0.0061 - 0.0083
1/2″	0.0087 - 0.0100	0.0080 - 0.0094	0.0080 - 0.0092	0.0070 - 0.0090	0.0078 - 0.0090	0.0062 - 0.0081

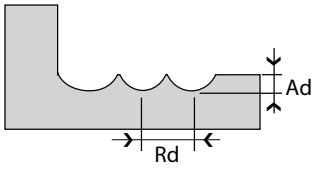
Metric Formulas

- $\text{RPM} = \dfrac{1000 \cdot \frac{m}{min}}{\pi \cdot \text{Ø}}$
- $\text{Speed}\left[\frac{m}{min}\right] = \dfrac{\pi \cdot \text{Ø} \cdot \text{RPM}}{1000}$
- $\text{Table Feed}\left[\frac{mm}{min}\right] = \text{RPM} \cdot \frac{mm}{tooth} \cdot \#\text{flutes}$
- $\text{Chipload}\left[\frac{mm}{tooth}\right] = \dfrac{\text{table feed}}{\text{RPM} \cdot \#\text{ flutes}}$
- $\text{Effective Ø} = 2 \cdot \sqrt{r^2 - (r\text{-}Ap)^2}$

Inch Formulas

- $\text{RPM} = \dfrac{1000 \times m/min}{\pi \cdot 0}$
- IPM = RPM x # Flutes x Chip Load
- $\text{Chip Load} = \dfrac{\text{IPM}}{(\text{RPM} \times \#\text{ Flutes})}$
- $\text{SFM} = \dfrac{\text{Effective Diam.} \times \text{RPM}}{3.82}$
- $\text{E.D.} = 2 \times \sqrt{(R^2 - (R - Ad)^2)}$

Axial & Radial Depths



Radial Depths

- Radial depths can be up to 35% of the cutter diameter for roughing and semi-finishing operations.
- Radial depths of cut for finishing are determined by the surface finish requirements unique to each application.

Axial Depths

30-40 HRC
Axial depth = 10% of tool Ø

40-50 HRC
Axial depth = 7% of tool Ø

50-60 HRC
Axial depth = 5% of tool Ø

Machining Tips

- Use Helical Engagement in materials above 40 HRC.
- Ensure cusp left for next operation is manageable.
- Use two fluted end mills in all roughing operations.
- Balanced holders and tools are critical when operating at 8000 RPM and above.
- Ensure runout of cutting tool is less than 0.0003" to get the best tool life.
- Length to diameter ratio should be as short as possible.
- Use Z-Level climb cutting for roughing operations.
- Use air for all applications except those involving sticky materials such as stainless.

OSG RECOMMENDED:

EXOCARB® WXS®

EXOCARB® WXS® end mills are the new industry standard for hard milling. Everything about WXS® is designed for rigidity and performance in hardened steel 50 HRC and greater.

Substrates, geometry, and proprietary WXS® coating are all specifically tailored for hardened steels like D2, A2, S7, H13 and CPM.

EXOCARB® WXL®

EXOCARB® WXL® end mills are the new industry standard for hard milling. Everything about WXL® is designed for rigidity and performance in wide variety of materials and a wide variety of milling applications.

Substrates, geometry, and proprietary WXL® coating are all specifically tailored for nonferrous materials, mild steels, and steels up to 50 HRC.

EXOPRO® PHX

The EXOPRO® PHX end mill series is designed exclusively for mold makers, to help them realize greater cost savings and shorter delivery times with their existing equipment. New spiral gash geometry is combined with radial chip thinning principles to create end mills capable of taking deeper depths of cut with length to diameter ratio's previously thought impractical.

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