OSG PHOENIX®

PFB Ball End Mill
M S Machining Guide

Roughing & Finishing (LDR 4xD)

For LDR Greater See LDR Notes

RPM/Spindle Speed

Material		Stainless Steel (annealed)		Stainless Steel (hardened)		Titanium Alloys		Heat Resistant Alloys (annealed)		Heat Resistant Alloys (hardened)	
Diameter Inch	mm	Rough	Finish	Rough	Finish	Rough	Finish	Rough	Finish	Rough	Finish
-	6	15485 - 16460	31780 - 32600	12225 - 13040	25260 - 26080	6520 - 7335	12225 - 13040	3095 - 3425	5375 - 5870	2600 - 2850	4480 - 4890
0.250	-	14630 - 15555	30030 - 30800	11550 - 12320	23870 - 24640	6160 - 6930	11550 - 12320	2926 - 3234	5080 - 5545	2465 - 2695	4235 - 4620
-	8	11615 - 12345	23835 - 24450	9170 - 9780	18950 - 19560	4890 - 5500	9170 - 9780	2325 - 2570	4035 - 4400	1955 - 2140	3360 - 3665
0.375	-	9755 - 10370	20020 - 20535	7700 - 8215	15915 - 16430	4110 - 4620	7700 - 8215	1950 - 2155	3390 - 3695	1645 - 1800	2825 - 3080
-	10	9290 - 9880	19070 - 19560	7335 - 7825	15160 - 15645	3915 - 4400	7335 - 7825	1860 - 2055	3230 - 3520	1565 - 1710	2690 - 2935
-	12	7745 - 8230	15890 - 16300	6115 - 6520	12630 - 13040	3260 - 3670	6115 - 6520	1550 - 1710	2690 - 2935	1300 - 1425	2240 - 2445
0.500	-	7315 - 7775	15015 - 15400	5775 - 6160	11935 - 12320	3080 - 3465	5775 - 6160	1465 - 1615	2540 - 2775	1235 - 1350	2120 - 2310
0.625	-	5855 - 6220	12015 - 12320	4620 - 4930	9550 - 9855	2465 - 2775	4620 - 4930	1170 - 1295	2035 - 2220	985 - 1080	1695 - 1850
-	16	5800 - 6175	11920 - 12225	4585 - 4890	9475 - 9780	2445 - 2750	4585 - 4890	1160 - 1285	2015 - 2200	980 - 1070	1680 - 1835
0.750	-	4880 - 5185	10010 - 10265	3850 - 4110	7960 - 8215	2055- 2310	3850 - 4110	975 - 1080	1695 - 1850	820 - 900	1410 - 1540
-	20	4645 - 4940	9535 - 9780	3670 - 3915	7580 - 7825	1655 - 2200	3665 - 3915	930 - 1030	1615 - 1760	785 - 855	1345 - 1470
-	25	3715 - 3950	7630 - 7825	2935 - 3130	6065 - 6260	1565 - 1760	2935 - 3130	745 - 820	1290 - 1410	625 - 685	1075 - 1175
1.000	-	3660 - 3890	7510 - 7700	2890 - 3080	5970 - 6160	1546 - 1735	2890 - 3080	730 - 810	1270 - 1385	615 - 675	1060 - 1155
-	30	3100 - 3295	6356 - 6520	2445 - 2610	5050 - 5215	1300 - 1470	2445 - 2610	620 - 685	1075 - 1175	520 - 570	895 - 980
1.250	-	2925 - 3110	6000 - 6160	2310 - 2465	4775 - 4930	1230 - 1385	2310 - 2464	585 - 650	1015 - 1110	495 - 540	850 - 925
-	32	2900 - 3085	5960 - 6110	2290 - 2445	4735 - 4890	1220 - 1375	2290 - 2445	580 - 640	1000 - 1100	490 - 535	840 - 915

Chip Load/Inch Per Tooth

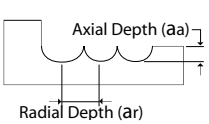
Material		Stainless Steel (annealed)		Stainless Steel (hardened)		Titanium Alloys		Heat Resistant Alloys (annealed)		Heat Resistant Alloys (hardened)	
Diameter Inch	mm	Rough	Finish	Rough	Finish	Rough	Finish	Rough	Finish	Rough	Finish
-	6	0.0035 - 0.0045	0.0030 - 0.0040	0.0030 - 0.0035	0.0020 - 0.0030	0.0030 - 0.0037	0.0020 - 0.0035	0.0020 - 0.0030	0.0015 - 0.0025	0.0015 - 0.0020	0.0010 - 0.0015
0.250	-	0.0035 - 0.0045	0.0030 - 0.0040	0.0030 - 0.0035	0.0020 - 0.0030	0.0030 - 0.0037	0.0020 - 0.0035	0.0020 - 0.0030	0.0015 - 0.0025	0.0015 - 0.0020	0.0010 - 0.0015
-	8	0.0050 - 0.0060	0.0040 - 0.0055	0.0040 - 0.0045	0.0030 - 0.0040	0.0040 - 0.0050	0.0030 - 0.0045	0.0030 - 0.0040	0.0020 - 0.0035	0.0020 - 0.0030	0.0015 - 0.0025
0.375	-	0.0070 - 0.0080	0.0060 - 0.0075	0.0055 - 0.0065	0.0050 - 0.0060	0.0050 - 0.0060	0.0040 - 0.0055	0.0040 - 0.0050	0.0030 - 0.0045	0.0030 - 0.0045	0.0020 - 0.0040
-	10	0.0070 - 0.0080	0.0060 - 0.0075	0.0055 - 0.0065	0.0050 - 0.0060	0.0050 - 0.0060	0.0040 - 0.0055	0.0040 - 0.0050	0.0030 - 0.0045	0.0030 - 0.0045	0.0020 - 0.0040
-	12	0.0080 - 0.0090	0.0070 - 0.0085	0.0065 - 0.0070	0.0055 - 0.0065	0.0060 - 0.0065	0.0050 - 0.0060	0.0050 - 0.0060	0.0040 - 0.0055	0.0045 - 0.0050	0.0035 - 0.0045
0.500	-	0.0080 - 0.0090	0.0070 - 0.0085	0.0065 - 0.0070	0.0055 - 0.0065	0.0060 - 0.0065	0.0050 - 0.0060	0.0050 - 0.0060	0.0040 - 0.0055	0.0045 - 0.0050	0.0035 - 0.0045
0.625	-	0.0090 - 0.0100	0.0080 - 0.0095	0.0070 - 0.0080	0.0060 - 0.0075	0.0065 - 0.0070	0.0055 - 0.0065	0.0060 - 0.0070	0.0050 - 0.0065	0.0050 - 0.0060	0.0040 - 0.0055
-	16	0.0090 - 0.0100	0.0080 - 0.0095	0.0070 - 0.0080	0.0060 - 0.0075	0.0065 - 0.0070	0.0055 - 0.0065	0.0060 - 0.0070	0.0050 - 0.0065	0.0050 - 0.0060	0.0040 - 0.0055
0.750		0.0100 - 0.0110	0.0090 - 0.0105	0.0080 - 0.0090	0.0070 - 0.0085	0.0070 - 0.0080	0.0060 - 0.0075	0.0080 - 0.0090	0.0070 - 0.0085	0.0070 - 0.0080	0.0060 - 0.0075
	20	0.0100 - 0.0110	0.0090 - 0.0105	0.0080 - 0.0090	0.0070 - 0.0085	0.0070 - 0.0080	0.0060 - 0.0075	0.0080 - 0.0090	0.0070 - 0.0085	0.0070 - 0.0080	0.0060 - 0.0075
-	25	0.0110 - 0.0115	0.0100 - 0.0110	0.0090 - 0.0095	0.0080 - 0.0090	0.0080 - 0.0090	0.0070 - 0.0085	0.0090 - 0.0095	0.0080 - 0.0090	0.0080 - 0.0085	0.0070 - 0.0080
1.000	-	0.0110 - 0.0115	0.0100 - 0.0110	0.0090 - 0.0095	0.0080 - 0.0090	0.0080 - 0.0090	0.0070 - 0.0085	0.0090 - 0.0095	0.0080 - 0.0090	0.0080 - 0.0085	0.0070 - 0.0080
-	30	0.0115 - 0.0120	0.0105 - 0.0115	0.0095 - 0.0100	0.0085 - 0.0095	0.0090 - 0.0100	0.0080 - 0.0095	0.0095 - 0.0100	0.0085 - 0.0095	0.0085 - 0.0090	0.0075 - 0.0085
1.250	-	0.0120 - 0.0125	0.0110 - 0.0120	0.0100 - 0.0105	0.0090 - 0.0100	0.0095 - 0.0105	0.0085 - 0.0100	0.0100 - 0.0105	0.0090 - 0.0100	0.0090 - 0.0095	0.0080 - 0.0090
-	32	0.0120 - 0.0125	0.0110 - 0.0120	0.0100 - 0.0105	0.0090 - 0.0100	0.0095 - 0.0105	0.0085 - 0.0100	0.0100 - 0.0105	0.0090 - 0.0100	0.0090 - 0.0095	0.0080 - 0.0090

Axial and Radial Depths

Material Hardness	Stainless Steel (annealed)	Stainless Steel (hardened)	Titanium Alloys	Heat Resistant Alloys (annealed)	Heat Resistant Alloys (hardened)
Axial Depth (aa)	10% of tool Dia. Max.	8% of tool Dia. Max.	10% of tool Dia. Max.	10% of tool Dia. Max.	8% of tool Dia. Max.
Radial Depth (ar)	30% of Tool Dia. Max.	25% of tool Dia. Max.	30% of tool Dia. Max.	30% of tool Dia. Max.	25% of tool Dia. Max.

Length-to-Diameter Compensions

Overhang Length	Cutting Speed	Aa	Ar
LDR Under 4xD	100%	100%	100%
LDR 4xD to 6xD	60% - 80%	60% - 80%	60% - 80%
LDR 6xD to 10xD	40% - 60%	40% - 60%	40% - 60%

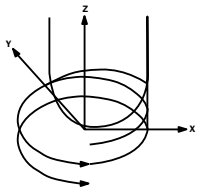


Carbide shank recommended for LDR 6xD and above.

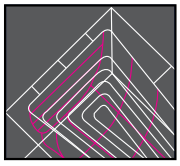
High Speed Machining Guide

Machining Tips

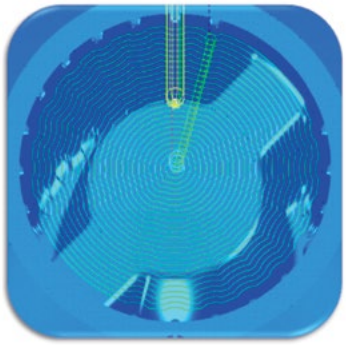
- Use Z-Level climb cutting for roughing operations.
- Use Helical for material engagement whenever possible. Use 3° ramp angle and 0.8xDiameter of cutter for the tool path arc.
- Add radiuses larger than cutter to corner of tool path for smooth operation.
- LDR should always be as short as possible.
- LDR of 4xD or less use chart on reverse side with high speed steel body.
- LDR of 6xD to 10xD use chart on reverse side with carbide body.
- **Machining is very difficult over 10xD.**
- Leave extra stock for semi-finishing to prevent gouging of surface when using long reach tools.
- Use air or oil mist for all applications except those involving gummy or sticky materials such as stainless, which machines well with water based coolant.



Helical Interpolation



Corner Rounding on Tool Path



Z-Level Machining with Climb Cutting is Highly Recommended

Diagnosing Problems

Insert Chipping - early during use means chip load too high, please reduce feed rate in increments of 20% until problem is resolved or shorten the length of the tool.

Insert Burning - of coating or glowing at the tip means RPM is too high. Reduce RPM by 20% increments until problem is resolved along with feed rate until excessive heat is subdued.

Chatter - excessive tool length is a primary cause. After reducing tool length if possible, lower RPM and feed rate until chatter is minimized.

Formulas

RPM = (3.82 x SFM) / Tool Diameter
SFM = 0.262 x RPM x Tool Diameter
IPM = RPM x # Flutes x Chip Load
Chip Load = IPM / (RPM x # Flutes)

Stock Left for Semi-Finishing

Medium parts 6" square to 24"

- No heat treat: leave 0.010" to 0.015" stock.
- Heat treat: leave 0.015" to 0.030" stock, depending on geometry.

Finishing Tips for Surface Finishes

Ar = CL (Radial DOC = Chip Load)

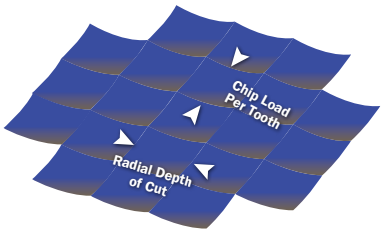


Fig. 1 (Above): Chip load and radial depth of cut must be equal to achieve best surface finish as shown.

Fig. 2 (Below): Shows non-symmetrical finish resulting from not using Ar = CL.

Radial DOC (Step Over) Calculation

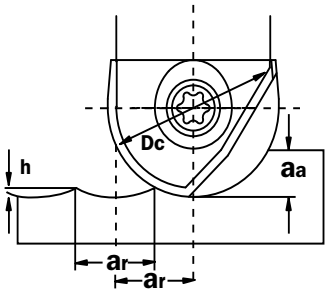
h= Cusp Height
r = Cutter Radius

$$Ar = \sqrt{hx8xr}$$

Radial DOC (Step Over) Example

50 RMS finish with $^{3}/_{8}$" Dia. BEM

h= 0.000050 (Cusp Height)
r = 0.1875"



$$Ar = \sqrt{0.000050 \times 8 \times 0.1875} = 0.0087"$$

Tool Dia.		Radial Depth or Step Over		Surface Finish (h)	
Inch	mm	Inch	mm	Inch	mm
0.250	6	0.0071	0.180	0.000050	0.00127
0.275	7	0.0074	0.188	0.000050	0.00127
0.312	8	0.0079	0.201	0.000050	0.00127
0.375	10	0.0087	0.225	0.000050	0.00127
0.500	12	0.0100	0.247	0.000050	0.00127
0.625	16	0.0112	0.285	0.000050	0.00127
0.750	20	0.0122	0.319	0.000050	0.00127
1.000	25	0.0141	0.356	0.000050	0.00127
1.187	30	0.0154	0.390	0.000050	0.00127
1.250	32	0.0158	0.402	0.000050	0.00127

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