# OSG PHOENIX®

# PFB Ball End Mill
## PH Machining Guide

## Roughing & Finishing (LDR 4xD)

**For LDR Greater See LDR Notes**

**RPM/Spindle Speed**

| Material | | Carbon/Alloy Steel (30-40 HRC) | | Tool Steel (40-50 HRC) | | Tool Steel (50-60 HRC) | |
|---|---|---|---|---|---|---|---|
| Diameter | | Rough | Finish | Rough | Finish | Rough | Finish |
| Inch | mm | | | | | | |
| - | 6 | 14715 - 17950 | 29100 - 35580 | 13100 - 16330 | 17950 - 35740 | 9865 - 13100 | 16330 - 24420 |
| 0.250 | - | 13900 - 16960 | 27500 - 33615 | 12375 - 15430 | 16960 - 33770 | 9320 - 12380 | 15430 - 23070 |
| - | 8 | 11035 - 13465 | 21830 - 26685 | 9825 - 12250 | 13465 - 26800 | 7400 - 9825 | 12250 - 18315 |
| 0.375 | - | 9270 - 11300 | 18335 - 22410 | 8250 - 10290 | 11310 - 22515 | 6215 - 8250 | 10290 - 15385 |
| - | 10 | 8830 - 10770 | 17465 - 21345 | 7860 - 9800 | 10770 - 21445 | 5920 - 7860 | 9800 - 14650 |
| - | 12 | 7360 - 8975 | 14555 - 17790 | 6550 - 8165 | 8975 - 17870 | 4930 - 6550 | 8165 - 12210 |
| 0.500 | - | 6950 - 8480 | 13750 - 16810 | 6190 - 7715 | 8480 - 16885 | 4660 - 6190 | 7715 - 11535 |
| 0.625 | - | 5560 - 6785 | 11000 - 13445 | 4950 - 6175 | 6785 - 13510 | 3730 - 4950 | 6175 - 9230 |
| - | 16 | 5520 - 6730 | 10915 - 13340 | 4910 - 6125 | 6730 - 13400 | 3700 - 4910 | 6125 - 9160 |
| 0.750 | - | 4635 - 5655 | 9170 - 11200 | 4125 - 5145 | 5655 - 11255 | 3110 - 4125 | 5145 - 7690 |
| - | 20 | 4415 - 5385 | 8735 - 10675 | 3930 - 4900 | 5385 - 10725 | 2960 - 3930 | 4900 - 7325 |
| - | 25 | 3530 - 4310 | 6985 - 8540 | 3145 - 3920 | 4310 - 8575 | 2365 - 3145 | 3920 - 5860 |
| 1.000 | - | 3475 - 4240 | 6875 - 8400 | 3095 - 3860 | 4240 - 8445 | 2330 - 3095 | 3860 - 5770 |
| - | 30 | 2945 - 3590 | 5825 - 7115 | 2620 - 3265 | 3590 - 7150 | 1975 - 2620 | 3265 - 4885 |
| 1.250 | - | 2780 - 3390 | 5500 - 6720 | 2475 - 3090 | 3390 - 6750 | 1865 - 2475 | 3090 - 4615 |
| - | 32 | 2760 - 3360 | 5460 - 6670 | 2455 - 3060 | 3360 - 6700 | 1850 - 2455 | 3060 - 4580 |

**Chip Load/Inch Per Tooth**

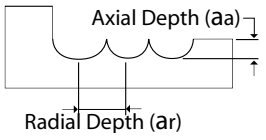
| Material | | Carbon/Alloy Steel (30-40 HRC) | | Tool Steel (40-50 HRC) | | Tool Steel (50-60 HRC) | |
|---|---|---|---|---|---|---|---|
| Diameter | | Rough | Finish | Rough | Finish | Rough | Finish |
| Inch | mm | | | | | | |
| - | 6 | 0.0045 - 0.0055 | 0.0040 - 0.0050 | 0.0040 - 0.0050 | 0.0040 - 0.0045 | 0.0040 - 0.0045 | 0.0035 - 0.0040 |
| 0.250 | - | 0.0045 - 0.0055 | 0.0040 - 0.0050 | 0.0040 - 0.0050 | 0.0040 - 0.0045 | 0.0040 - 0.0045 | 0.0035 - 0.0040 |
| - | 8 | 0.0063 - 0.0070 | 0.0052 - 0.0067 | 0.0052 - 0.0067 | 0.0052 - 0.0063 | 0.0052 - 0.0063 | 0.0047 - 0.0055 |
| 0.375 | - | 0.0070 - 0.0080 | 0.0063 - 0.0079 | 0.0062 - 0.0077 | 0.0054 - 0.0065 | 0.0060 - 0.0072 | 0.0050 - 0.0060 |
| - | 10 | 0.0070 - 0.0080 | 0.0063 - 0.0079 | 0.0062 - 0.0077 | 0.0054 - 0.0065 | 0.0060 - 0.0072 | 0.0050 - 0.0060 |
| - | 12 | 0.0087 - 0.0100 | 0.0080 - 0.0094 | 0.0080 - 0.0092 | 0.0070 - 0.0090 | 0.0078 - 0.0090 | 0.0062 - 0.0081 |
| 0.500 | - | 0.0087 - 0.0100 | 0.0080 - 0.0094 | 0.0080 - 0.0092 | 0.0070 - 0.0090 | 0.0078 - 0.0090 | 0.0062 - 0.0081 |
| 0.625 | - | 0.0097 - 0.0110 | 0.0090 - 0.0106 | 0.0096 - 0.0105 | 0.0092 - 0.0101 | 0.0094 - 0.0102 | 0.0090 - 0.0098 |
| - | 16 | 0.0097 - 0.0110 | 0.0090 - 0.0106 | 0.0096 - 0.0105 | 0.0092 - 0.0101 | 0.0094 - 0.0102 | 0.0090 - 0.0098 |
| 0.750 | - | 0.0108 - 0.0120 | 0.0100 - 0.0116 | 0.0107 - 0.0112 | 0.0103 - 0.0108 | 0.0099 - 0.0109 | 0.0095 - 0.0105 |
| - | 20 | 0.0108 - 0.0120 | 0.0100 - 0.0116 | 0.0107 - 0.0112 | 0.0103 - 0.0108 | 0.0099 - 0.0109 | 0.0095 - 0.0105 |
| - | 25 | 0.0118 - 0.0130 | 0.0110 - 0.0126 | 0.0110 - 0.0120 | 0.0106 - 0.0116 | 0.0100 - 0.0110 | 0.0096 - 0.0106 |
| 1.000 | - | 0.0118 - 0.0130 | 0.0110 - 0.0126 | 0.0110 - 0.0120 | 0.0106 - 0.0116 | 0.0100 - 0.0110 | 0.0096 - 0.0106 |
| - | 30 | 0.0125 - 0.0138 | 0.0118 - 0.0134 | 0.0118 - 0.0130 | 0.0114 - 0.0122 | 0.0110 - 0.0118 | 0.0106 - 0.0114 |
| 1.250 | - | 0.0130 - 0.0145 | 0.0125 - 0.0145 | 0.0125 - 0.0135 | 0.0120 - 0.0130 | 0.0115 - 0.0125 | 0.0110 - 0.0120 |
| - | 32 | 0.0130 - 0.0145 | 0.0125 - 0.0145 | 0.0125 - 0.0135 | 0.0120 - 0.0130 | 0.0115 - 0.0125 | 0.0110 - 0.0120 |

**Axial and Radial Depths**

| Material Hardness | Carbon/Alloy Steel (30-40 HRC) | Tool Steel (40-50 HRC) | Tool Steel (50-60 HRC) | Tool Steel (Over 60 HRC) |
|---|---|---|---|---|
| Axial Depth (aa) | 10% of tool Dia. Max. | 7% of tool Dia. Max. | 5% of tool Dia. Max. | 4% of tool Dia. Max. |
| Radial Depth (ar) | 40% of tool Dia. Max. | 35% 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% |

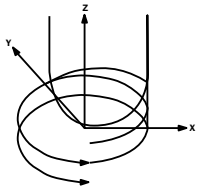



Carbide shank recommended for LDR 6xD and above.

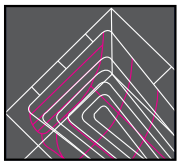
# High Speed Machining Guide

## Machining Tips

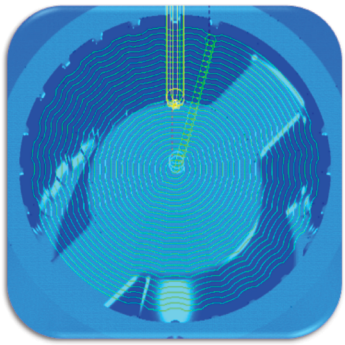
- Use Z-Level climb cutting for roughing operations.
- Use Helical for material engagement whenever possible. Use 3° ramp angle and 0.8xDiameter of cutter for the tool path arc.
- Add radiuses larger than cutter to corner of tool path for smooth operation.
- LDR should always be as short as possible.
- 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)

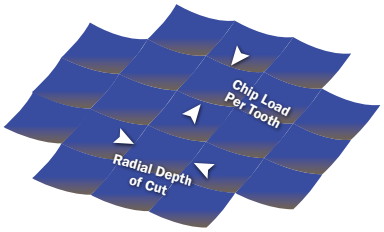
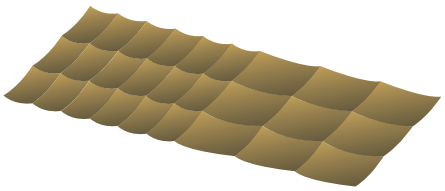



**Fig. 1 (Above):** Chip load and radial depth of cut must be equal to achieve best surface finish as shown.

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



**Radial DOC (Step Over) Calculation**

h= Cusp Height
r = Cutter Radius

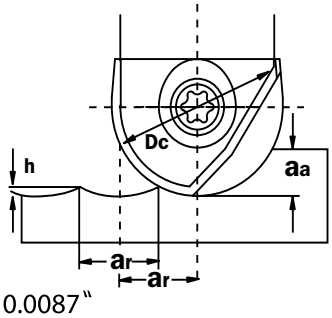
$$Ar = \sqrt{hx8xr}$$

**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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