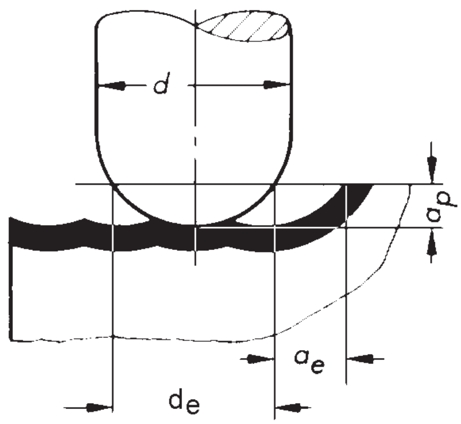
Technical Data

Formulas:



Legend:

- **p** = 3.1416
- a_e = Width of cut
- a_p = Depth of cut
- **d** = Diameter of milling cutter, in inches
- d_e = Effective diameter
- f_z = Feed, inches per tooth
- **h** = Scallop height
- **ipm** = Feed, inches per minute
- **ipr** = Inches per revolution
- **mrr** = Metal removal rate in cubic inches
- **rpm** = Revolutions per minute
- **s** = Stepover value between two cutting passes, in inches
- **sfm** = Surface feet per minute
- **z** = Number of effective teeth

To calculate effective diameter of ball nose tool

$$d_e = 2 * \sqrt{\left(\frac{d}{2}\right)^2 - \left(\frac{d}{2} - a_p\right)^2}$$

To calculate sfm when rpm is known

$$sfm = .262 * d * rpm$$

To calculate rpm when sfm is known

$$rpm = \frac{sfm * 3.82}{d}$$

To calculate scallop height (cusp height)

$$h = \frac{d}{2} - \sqrt{\left(\frac{d}{2}\right)^2 - \left(\frac{s}{2}\right)^2}$$

To calculate inches per minute (table feed)

$$ipm = f_z * z * rpm$$

To calculate inches per revolution

$$ipr = \frac{ipm}{rpm}$$

To calculate f_z when ipm, rpm & z are known

$$f_z = \frac{ipm}{z * rpm}$$

To calculate f_z when ipr & z are known

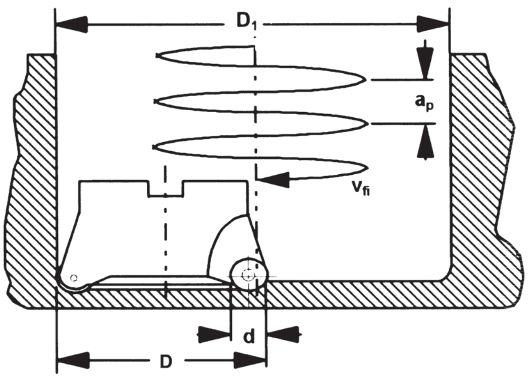
$$f_z = \frac{ipr}{z}$$

To calculate metal removal rate

$$mrr = a_p * a_e * ipm$$

Technical Data

Circular and Helical Interpolation:



Circular and Helical Interpolation is an application where the cutter rotates on its own axis together in an orbiting motion around the workpiece (either internally or externally), while at the same time plunging to the required depth of cut. In order to accomplish this application, a machine with three-axis control capabilities is required.

Calculating feed rate: Unlike linear milling applications (face milling) where the tools cutting edge and centerline is identical, circular and helical interpolation feed rate is based only on the tools centerline (Vfi). The following formulas should be used to obtain the optimal running conditions.

Definitions

D	=	cutter diameter
d	=	insert diameter
D1	=	workpiece bore diameter
ap	=	depth of cut
fz	=	feed per tooth
fzkor	=	correction feed per tooth
Vfi	=	feed rate at cutters centerline
T	=	number of cutting teeth
rpm	=	revolutions per minute

Milling Cutter Diameter Selection Calculation:

Note: all values should be in inch

Minimum Cutter Diameter: $D_{min} = \frac{D_1}{2}$

Optimum / maximum Cutter Diameter: $D_{opt/max} = \frac{D1 + d}{2} - 1$

Calculating Feed Rate:

Note: all values should be in inch

Feed Rate Correction for Drill Milling with Round Inserts: $f_{zkor} = fz \times \frac{d}{ap} \times \frac{1}{135} \text{ inv cos* } \left(1 - \frac{1.5 \times ap}{d}\right)$

Depth of Cut (ap):
max. ap ≤ 0.5 x d **opt.** ap = 0.25 x d ***** inv cos = $\cos^{-1}$

Feed Rate at Centerline of Tool when Drill Milling (Vfi) $V_{fi} = \left(1 - \frac{D}{D1}\right) \times rpm \times f_{zkor} \times T$

or approximately: $V_{fi} = .008 \times rpm \times f_{zkor} \times T$

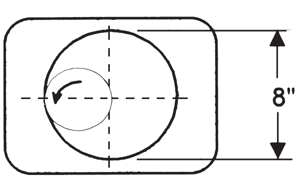
Example:

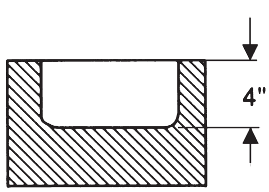
Cutter Data:

Cutter description:..... **TR360 Face Mill**
Diameter (D):............. 4”
Insert Diameter: .... .6299 (16mm)
Insert grade: TN5515
No. of teeth (T):......... 8

Recommended Machining Conditions:

Surface feet/minute (sfm):...... 533
Spindle speed (rpm): 509
Feed per tooth (fz):................. .008”
Depth of Cut (ap):................... .157” (opt. ap = .25 x .6299)





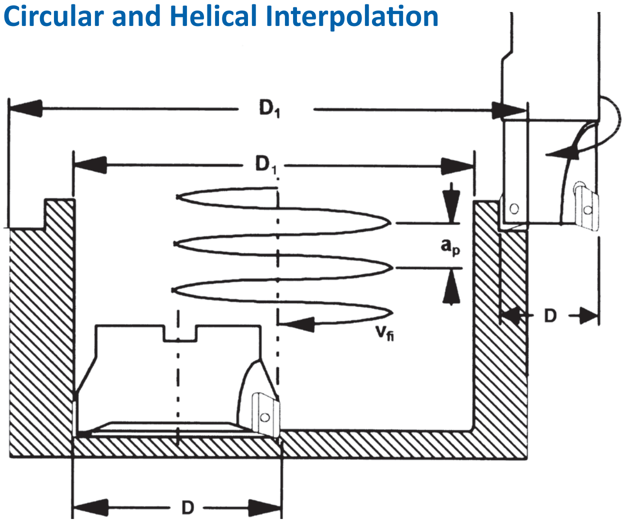
$f_{zkor} = .008 \times \frac{.6299}{.157} \times \text{ inv cos } \left(1 - \frac{1.5 \times .157}{.6299}\right) = 0.0122$

$V_{fi} = \left(1 - \frac{4}{8}\right) \times .509 \times 0.122 \times 8 + 24.798 \text{ or } 25 \text{ ipm}$

Machining Programming:
In order to maintain the recommended .008” feed per tooth (fz) for this insert size and application, the machine tool should be programmed for a feed of 25” per minute (ipm).

Technical Data

Circular and Helical Interpolation



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Milling Cutter Diameter Selection Calculation

Note: all values should be in inch

Minimum Cutter Diameter: $D_{min} = \frac{D_1}{2}$

Optimum / Maximum cutter Diameter: $D_{opt/max} = \frac{D1 + d}{2} - 1$

Calculating Feed Rate:

Note: all values should be in inch

Feed Rate at the Cutting Edge (Vf) Inches per Minute: $V_f = f_z \times rpm \times T$

Feed Rate at Centerline of Tool when Drill Milling (Vfi):

Internal Milling Applications:

$$V_{fi} = \frac{V_f \times (D_1 - D)}{D_1}$$

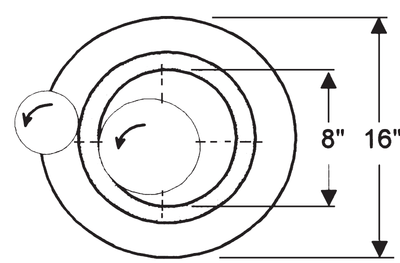
External Milling Applications:

$$V_{fi} = \frac{V_f \times (D_1 - D)}{D_1}$$

Example:

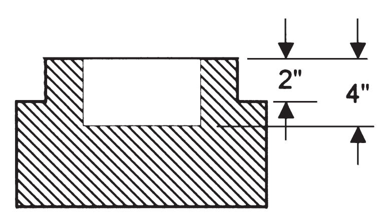
Cutter Data:

Cutter description:	**TXP90 Face Mill**	**TXP90 End Mill**
Diameter (D):	4”	1.5”
Insert number:	222.79.**400**	222.79.**400**
Insert grade:	TN7525	TN7525
No. of teeth (T):	8	4



ID: Face Mill **Vf = .008 x 10 x 358 = 28.6ipm**

OD: End Mill **Vf = .004 x 4 x 1082 = 17.3ipm**



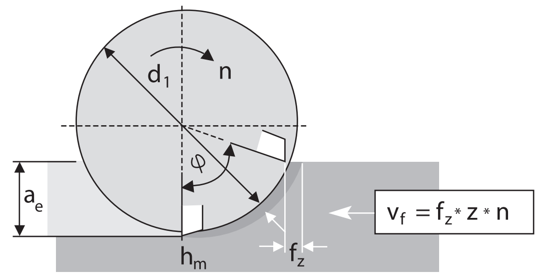
Machining Programming:

Based on the above OD and ID milling calculations, you must program the machine at the appropriate feed rate (Vfi) for each tools centerline.

Technical Data

Cutting Ratios and Undeformed Chip Thickness in Milling

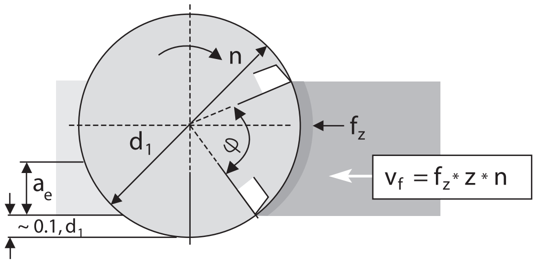
Valid for $a_e < 0.3\ d_1$



$$f_z = h_m * \sqrt{\frac{d_1}{a_e}} \qquad h_m = f_z * \sqrt{\frac{a_e}{d_1}}$$

At least 2 cutting edges in the working area of the feed motion angle φ

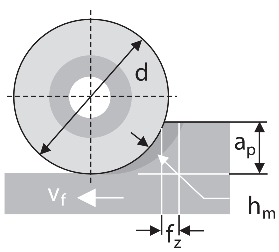
Valid for $a_p < 0.3\ d_1$



min. cutter diameter $d_1 \simeq 1.25 * a_e$

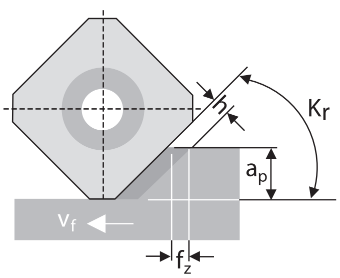
max. width of cut $a_e \simeq 0.8 * d_1$

Valid for $a_p < 0.3$



$$f_z = h_m * \sqrt{\frac{d}{a_p}}$$

$$h_m = f_z * \sqrt{\frac{a_p}{d}}$$

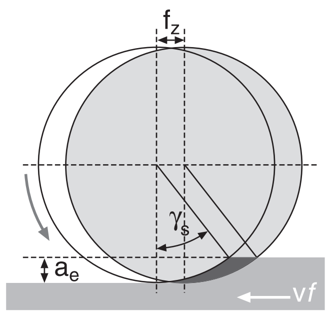


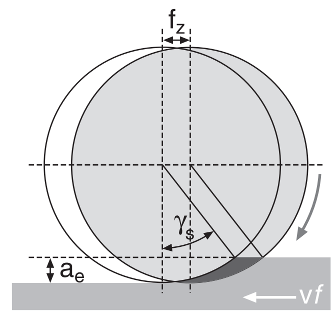
$f_z = h : \sin \chi_r$

$h = f_z * \sin \chi_r$

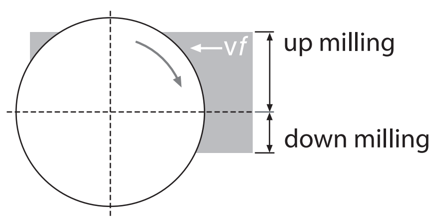
Technical Data

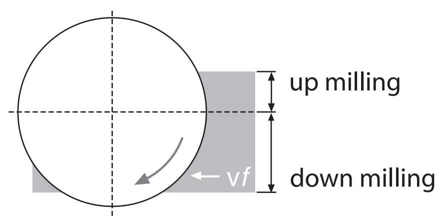
Up Milling / Down Milling with Square Shoulder and Side Face Mills



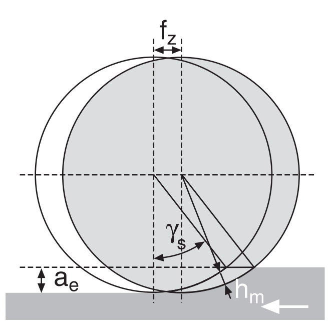


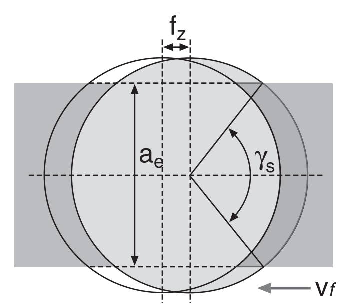
Up Milling / Down Milling with Face Mills





Average Chip Thickness h_m





Approximate Formula

$$a_e \le \frac{D}{4} : h_m \approx \sqrt{\frac{a_e}{D}} * f_z * \sin \chi_r$$

$$h_m \approx f_z * \sin \chi_r$$