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 inches per revolution

\[ ipr = \frac{ipm}{rpm} \]

To calculate sfm when rpm is known

\[ sfm = 0.262 \times d \times rpm \]

To calculate \( f_z \) when \( ipm \), rpm & \( z \) are known

\[ f_z = \frac{ipm}{z \times rpm} \]

To calculate rpm when sfm is known

\[ rpm = \frac{sfm \times 3.82}{d} \]

To calculate \( f_z \) when \( ipr \) & \( z \) are known

\[ f_z = \frac{ipr}{z} \]

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 metal removal rate

\[ mrr = a_p \times a_e \times ipm \]

To calculate inches per minute (table feed)

\[ ipm = f_z \times z \times rpm \]
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.

### Milling Cutter Diameter Selection Calculation:

**Note:** all values should be in inch

Minimum Cutter Diameter: \[
D_{\text{min}} = \frac{D_1}{2}
\]

Optimum / maximum Cutter Diameter: \[
D_{\text{opt/max}} = \frac{D_1 + d}{2} - 0.1
\]

### Calculating Feed Rate:

**Note:** all values should be in inch

Feed Rate Correction for Drill Milling with Round Inserts:

\[
 f_{zkor} = f_z x \frac{d}{a_p} x \frac{1}{135} \text{ inv cos}^* \left( 1 - \frac{1.5 x a_p}{d} \right)
\]

Depth of Cut \((a_p)\):

\[
\text{max. } a_p \leq 0.5 x d \quad \text{opt. } a_p = 0.25 x d \quad * \text{ inv cos} = \cos^{-1}
\]

Feed Rate at Centerline of Tool when Drill Milling \((V_{fi})\)

\[
V_{fi} = \left( 1 - \frac{D}{D_1} \right) x \text{ rpm} x f_{zkor} x T
\]

or approximately:

\[
V_{fi} = 0.008 x \text{ rpm} x f_{zkor} x T
\]

### Example:

**Cutter Data:**

Cutter description: TR360 Face Mill
Diameter \((D)\): 4”
Insert Diameter: 0.6299 (16mm)
Insert grade: TN5515
No. of teeth \((T)\): 8

**Recommended Machining Conditions:**

Surface feet/minute (sfm): 533
Spindle speed (rpm): 509
Feed per tooth \((f_z)\): 0.008”
Depth of Cut \((a_p)\): 0.157” (opt. \(a_p = 0.25 x 0.6299\))

\[
f_{zkor} = 0.008 x 0.6299 x 0.157 x \text{ inv cos} \left( 1 - \frac{1.5 x 0.157}{0.6299} \right) = 0.0122
\]

\[
V_{fi} = \left( 1 - \frac{4}{8} \right) x 0.509 x 0.122 x 8 + 24.798 \quad \text{or} \quad 25 \text{ ipm}
\]

**Machining Programming:**

In order to maintain the recommended 0.008” feed per tooth \((f_z)\) for this insert size and application, the machine tool should be programmed for a feed of 25” per minute (ipm).
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 tool cutting edge and centerline is identical, circular and helical interpolation feed rate is based only on the tool’s centerline (Vfi). The following formulas should be used to obtain the optimal running conditions.

**Definitions**

- \( D \): cutter diameter
- \( d \): insert diameter
- \( D_1 \): workpiece bore diameter
- \( a_p \): depth of cut
- \( f_z \): feed per tooth
- \( f_z kor \): correction feed per tooth
- \( V_fi \): feed rate at cutters centerline
- \( T \): number of cutting teeth
- \( rpm \): revolutions per minute

**Example:**

Cutter Data:

<table>
<thead>
<tr>
<th>Cutter Description</th>
<th>TXP90 Face Mill</th>
<th>TXP90 End Mill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (D)</td>
<td>4”</td>
<td>1.5”</td>
</tr>
<tr>
<td>Insert number</td>
<td>222.79.400</td>
<td>222.79.400</td>
</tr>
<tr>
<td>Insert grade</td>
<td>TN7525</td>
<td>TN7525</td>
</tr>
<tr>
<td>No. of teeth (T)</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>

ID: Face Mill  \( V_f = 0.008 \times 10 \times 358 = 28.6 \text{ipm} \)

OD: End Mill  \( V_f = 0.004 \times 4 \times 1082 = 17.3 \text{ipm} \)

**Machining Programming:**

Based on the above OD and ID milling calculations, you must program the machine at the appropriate feed rate (Vfi) for each tool’s centerline.
Cutting Ratios and Undeformed Chip Thickness in Milling

Valid for $a_e < 0.3 \, d_1$

$$f_z = h_m \cdot \sqrt{\frac{d_1}{a_e}} \quad h_m = f_z \cdot \sqrt{\frac{a_e}{d_1}}$$

At least 2 cutting edges in the working area of the feed motion angle $\phi$

Valid for $a_p < 0.3 \, d_1$

$$v_r = v_c \cdot z \cdot n$$

$\min. \text{cutter diameter } d_1 = 1.25 \cdot a_e$

$\max. \text{width of cut } a_e = 0.8 \cdot d_1$

Valid for $a_p < 0.3$

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

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

$$f_z = h \cdot \sin \chi_f$$

$$h = f_z \cdot \sin \chi_f$$
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

$$a_e \leq \frac{D}{4} : h_m = \sqrt{\frac{a_e}{D}} \cdot f_z \cdot \sin \chi_r$$

$$h_m = f_z \cdot \sin \chi_r$$