Tooling Selection for Advanced Roughing (Dynamic Milling)
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Agenda

• What is Advanced Roughing
• What are the advantages
• What types of tools are required for this strategy
• How do I find the “right” tool for my application
Advanced Roughing

• Characteristics:
  – Low Width of cut (Ae) to Cutter diameter (Dc) Ratio
    – Small arc of contact
    – High speeds with relatively low thermal loads on the cutter
    – Small average chip thickness requires a compensation in feedrate
  – Large depth of cut (Ap) possible because of light radial load
  – Similar machining strategies:
    – Trochoidal milling
    – Peel milling
    – Side milling
    – Push-pull
Arc of Contact

Big arc of contact

Small arc of contact

Big A.O.C

= Lower Cutting Speed
Angle of Engagement

Where:
- \( R \) = Radius of tool
- \( a_e \) = radial depth of cut
- \( \alpha = \arccos \left( \frac{R-a_e}{R} \right) \)

<table>
<thead>
<tr>
<th>% ae</th>
<th>( \alpha )</th>
</tr>
</thead>
<tbody>
<tr>
<td>3%</td>
<td>20°</td>
</tr>
<tr>
<td>5%</td>
<td>25°</td>
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<tr>
<td>8%</td>
<td>33°</td>
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<td>10%</td>
<td>37°</td>
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<td>30%</td>
<td>66°</td>
</tr>
<tr>
<td>40%</td>
<td>78°</td>
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Arc of Contact

- Arc of Contact increases as the tool enters a corner.
- If compensation in feedrate or $a_e$ is not made, the tool will most likely become overloaded.
  - Chatter
  - Poor surface finish
  - Tool breakage
  - Increased build-up
  - Undercut corners

Linear milling:

\[ a_e = \text{programmed } a_e \]
Toolpath Examples

Feedrate and Stepover change to accommodate increased Arc of Contact

Transition from offset sidemilling toolpath to trochoidal milling
Toolpath Examples
Advanced Roughing Advantages

• Advanced Roughing toolpaths can provide huge cycle time reductions
  – High Ap ability leads to higher MRR
  – 40%-70% cycle time reductions possible, depending on part geometry and tool selection

• Increased Tool Life
  – Double or triple increases in tool life are often achieved

• Simplified programming / processing
  – Use smaller endmills to cover a wider variety of parts
Tooling Basics for Advanced Roughing

- **Best Tools:**
  - Many flutes
    - 3-4 flutes for aluminum and non-ferrous materials
      - Niagara AN340
    - 4+ flutes for steels, stainless steels
      - Niagara STR540
    - 6+ flutes for hardened steels, super alloys, Titaniums
      - Niagara S638
Tooling Basics for Advanced Roughing

- **Best Tools:**
  - High Ap
    - Depths of cut up to 3XD are easily achieved in stable setups and good toolholders
    - Select tools with larger core diameters or with dual cores to maximize rigidity
    - High helix angles provide smoother cutting action but also produce more axial force on the tool
Tooling Basics for Advanced Roughing

• Best Tools:
  – Chip Control
    – Chip splitters or corn cob style tools
Tooling Basics for Advanced Roughing
Tooling Basics for Advanced Roughing

- **Best Tools:**
  - **Size**
    - Tool diameters depend on feature size
    - Most common sizes:
      - 1/2” – 5/8”
    - Size dependent on the feature or area being machined
    - Helical mills and other indexable tools can be used, but do not provide the magnitude of benefits that are achieved with solid carbide tools
What Tool is Right for My Application?

It is in your moments of decision that your destiny is shaped.
Tony Robbins

• Main Considerations
  – Component Material
  – Feature Characteristics
  – Machine Considerations
  – Fixture Considerations
  – Toolholding Considerations
Material Considerations

• Advanced Roughing is a good option for most materials, but some require specialized tools to optimize MRR
  – Aluminum
    – Up to 40% stepover
    – Fewer flutes and more open geometry
  – Steels
    – Up to 20% stepover
    – More flutes in the cutter, 5 – 6 depending on stepover
  – Titaniums / Superalloys
    – Up to 12% stepover
    – More flutes in the cutter, 7 – 9 depending on stepover and Dc
  – Stainless Steels
    – Up to 20% stepover
    – 5 – 7 flutes depending on stepover
Feature Considerations

- Not all features are created equal for Advanced Roughing
  - Watch for multi-level 3d shaped features
  - Maximize MRR by utilizing the most flute length possible
  - After the initial deepest Ap, tool path should “step up” to subsequent paths
    - Less Ap = Less MRR
    - Leaves large cusp for finishing operations on 3d features
  - Best features involve straight walls with large wall corner radii
Machine Considerations

• All Machines are not created equal
• Tools are highly dependent on the capability of the machine
  – For slower or older machines, a tool with a smaller core diameter and fewer flutes will allow for heavier stepover at reduced parameters
  – For newer or linear machines, a tool with more flutes will allow for higher feeds and speeds at a smaller stepover
  – Cutting feedrates of 200-300IPM are common
    – Most box-way type machines
• Spindle speed must be a consideration when machining easy materials
Fixture and Toolholding Considerations

• High helix tools place more axial force on the part and the toolholder
• Weak fixturing can cause vibration and quality issues
• Toolholders with high rigidity can allow vibration to permeate the system and decrease tool life
  – Choose toolholders that have mass, but have high holding force
    – Milling chucks
    – High precision collet chuck systems
So What Tool is Right for You?