Waveform roughing strategy is a high speed machining technique that maintains a constant tool cutting load by ensuring the tool engagement into the material is consistent. The tool path moves in a smooth path to avoid sharp changes in direction which maintains the machine tool’s velocity.

**Maximum Material Removal**

The Waveform Pattern
To maintain a constant chip load the cycle uses the philosophy that we machine from “Stock to part”. This reduces the amount of intermittent cuts, particularly on external regions, which means the tool is engaged with the material for longer without lifting clear. Traditionally, cycles generally offset the component until they meet the stock. This can lead to the generation of sharp corners and discontinuous tool paths.

For pocket regions the tool will helical in to depth at the centre and open the pocket up so that it can create a continuous spiral cut until the edge of the pocket is reached. Any remaining corners are then removed. Waveform automatically detects open areas and uses them for tool entry, rather than cutting an open region like a closed region.

Adjusted Tool Engagement
To maintain the tool engagement and the chip load the tool path is automatically adjusted to compensate. When cutting into a concave area tool engagement is increased. The cycle adjusts the step over between the passes to compensate and maintain the desired engagement.

When cutting a convex area the opposite affect occurs. As the material falls away the tool path step over is increased to maintain the desired engagement.

Intelligent Linking
To improve cycle efficiency, Waveform provides the ability to stay at depth whilst moving between milling areas or go up and over and stepping off the component.

**Benefits include:**
- Reduces cycle time
- Tool life maximised
- Full flute of tool utilised
- Minimum tool vibration
- Constant chip load
- Intelligent toolpath linking
- Cuts deeper and faster

**Constant Engagement**
Although the Concentric pattern looks much simpler at the first glance the problem is that the tool “digs” into each corner causing the tool to overload, leading to reduced tool life or tool breakage. In reality the machine tool operator may have to reduce the cycle feed rate to compensate and thus, increase manufacturing time.

As Waveform maintains a constant engagement with the material, the feed rate can remain at the optimal value throughout the cycle. This will improve the tool life and greatly reduce the risk of tool breakage - it is very simple to switch from traditional roughing to Waveform to see the toolpath pattern.
Waveform Roughing greatly improves standard roughing cycles by removing a constant volume of material.

Cutting along as much of the flute length as possible distributes wear evenly along the entire flute length, rather than just the tip, massively reducing tool vibration. The radial cut depth is also reduced to ensure a consistent cutting force, allowing cut material to escape from the flutes. Tool life is further extended as most of the heat is removed in the chip.

**CoroMill® Plura solid carbide square shoulder end mill**

- Solid Carbide P1F7
- 50° Flute Helix Angle
- 4 flute - 90° Pitch
- PVD Coated

<table>
<thead>
<tr>
<th>Objective</th>
<th>To Measure Tool Performance Utilising Edgecam Waveform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td>Test 1 - Traditional</td>
</tr>
<tr>
<td>Tool Details</td>
<td>R216.24-12050EC26P</td>
</tr>
<tr>
<td>Machine</td>
<td>Mazak Integrex i200</td>
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<tr>
<td>Coolant</td>
<td>Soluble 8-10%</td>
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<tr>
<td>Tool Holders</td>
<td>Hydraulic – Capto CS</td>
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<td>Material</td>
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<td>Speed (RPM)</td>
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<tr>
<td>Feed (mm/min)</td>
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<td>Ap (mm)</td>
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<td>Ae (mm)</td>
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<tr>
<td>Entry Strategy</td>
<td>Helical Ramp</td>
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<tr>
<td>MRR (cm³)</td>
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<tr>
<td>Cycle Time (mins)</td>
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<table>
<thead>
<tr>
<th>Test Data 1</th>
<th>Test Data 2</th>
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<tbody>
<tr>
<td>Tool Life (mins)</td>
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<td>Tool Life (metres)</td>
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<tr>
<td>MRR (cm³)</td>
<td>8.0</td>
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### Traditional v’s Waveform - Financial Savings (£)

<table>
<thead>
<tr>
<th></th>
<th>Test Data 1</th>
<th>Test Data 2</th>
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<tbody>
<tr>
<td><strong>Component</strong></td>
<td>Waveform Bracket</td>
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<tr>
<td><strong>Batch Size</strong></td>
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<tr>
<td><strong>Machine</strong></td>
<td>Mazak Integrex i200</td>
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<td><strong>No Of Components Per Tool</strong></td>
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<td><strong>Tool Cost</strong></td>
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<td>£25.00</td>
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<tr>
<td><strong>Cycle Time / Component</strong></td>
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<td>20.93 mins</td>
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<td><strong>Productivity Increase</strong></td>
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<tr>
<td><strong>Batch Savings (hours)</strong></td>
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<td>540 Hours</td>
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<tr>
<td><strong>Batch Savings (£)</strong></td>
<td>£69,875</td>
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</table>

#### Tool Life (m)

- **Data 1**
- **Data 2**

#### MRR (cm³)

- **Data 1**
- **Data 2**

#### Time Per Part (mins)

- **Data 1**
- **Data 2**

### Cost per component

- **GBP**
  - Reference
  - Recommended
  - Savings

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**Note:**

To achieve above 8000 mm/min G05 must be used. When using RPM Speed Reduction for helical approach G05 P2 must be disabled prior to S Block then reinstated at depth as per sample code as follows:

- G3 X31.321 Y-13.628 I3.6J10
- G05 P0.
- S12000
- G05P2 (HIGH SPEED)
- G1 X31.055 Y-14.389 F8000

**See a movie on your smart device by scanning HERE**
Starting with tooling, using an odd number of flutes helps with rigidity. Recommendations are to use 5 to 7 flute cutters on Steel and 3 to 5 flute cutters on Aluminium. Using hydraulic, shrink fit or collet chucks are highly recommended. Weldon chucks are not recommended because they don’t encompass the full diameter of the cutter, throwing the cutter out of balance.

Place the designated material in your machine’s fixture leaving a machinable amount of stock above the work fixture. Assigning the work offset at the lower right corner will simplify the NC code. Looking into the machine, we will test cut the front of the stock from right to left creating a straight line climb cut. A large lead-in will ensure machine acceleration to proper feed rate before entering the cut. Starting with a depth of cut (DoC) of 1 to 1.5 X diameter, calculate speeds and feeds based on suppliers recommendations.

**Sample Straight Line Test Code**

```%O1000
N1 G90 G20 G00 G40
N2 T1 M6
N3 S[RPM] M3
N4 M8
N5 X3. Y[%Stepover X Tool Dia]
N6 G43 Z0.25 H01
N7 Z[Depth of Cut]
N8 G1 X-10 F[Feedrate]
N9 G0 Z0.25
N10 G28 Z0
N11 G28 X0
N12 M30```

Key factors to consider for straight-line test cuts are chip colour, chip edges, load meter, and sound.

**Proper chips should have a smooth edge from start to end (see photos).** In Steel, heat from machining will be removed with the chips, leaving them a bluish brown colour.

**Fixturing and Starting Location**

**Traditional Toolpath**

**Fixture and Starting Location**

**Test Block**

** Traditional Toolpath**

**Undesirable Result**

**Desirable Result**

**Waveform Toolpath**

Based on your tool type and material, adjusting one parameter at a time, depth of cut or width of cut, will optimise feeds and speeds.