Use of Varying Workpiece Distance to Study The Effects on Machine Stiffness in Plunge Grinding

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Introduction

- Importance of Machine Stiffness
- Plunge Grinding Structural loop

Testbed Design

- Machine Design
- Instrumented Spindle
- Theoretical Force Calculation

Collecting Data and Processing

- Data Processing

Design of Varying Length Workpiece

- Workpiece
- Modeling

Grinding Results

- Testing
- Results

Conclusions
One of the most important influences on precision machining operations is the effects of machine structural loop stiffness.

Is it better in precision machining to have higher or lower stiffness?

A logically accepted practice is to make the machine as large and stiff as possible but this creates large, heavy, and very expensive machines.

More research is required to find an optimal machine stiffness.
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Uniqueness of this 4R spindle
Theoretical Force Calculation

Equivalent Spindle Stiffness

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\[ K_{eff} = \frac{k_t}{LR} \]
Measured force compared to theoretical force
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Average error motion from spindle removed
Data Processing

Processed data
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Theoretical Modeling

The equations of motion for this model are:

\[ m\ddot{x} + k_r x - k_r l_1 \theta = f \]
\[ J\ddot{\theta} - k_r l_1 x + (k_r l_1^2 + k_t) \theta = f l_2 \]
Transfer function

The estimation of damping to the system:

\[ [C] = \alpha[M] + \gamma[K] \]

Base on the output to the system:

\[ Y(s) = X(s) + l_3 \Theta(s) \]

Using the equations of motion the transfer function to the system becomes:

\[ \frac{Y(s)}{F(s)} = \frac{(J + l_2 l_3)^2 \ast s^2 + (l_1 + l_2)(l_1 + l_3)k_r + k_t}{m Js^4 + (k_r J + (l_1^2 k_r + k_t) m)s^2 + k_r k_t} \]
Comparing the Frequency Response Functions

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Variables

Table: System Parameters set by user

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workpiece Velocity</td>
<td>150, 200, 300, &amp; 600 RPM</td>
</tr>
<tr>
<td>Wheel Velocity</td>
<td>1,910 RPM (5000 sf, 10 in wheel)</td>
</tr>
<tr>
<td>Coolant</td>
<td>Heavy mist of Blasocut BC40SW</td>
</tr>
<tr>
<td>Dressing Depth</td>
<td>0.01 mm</td>
</tr>
<tr>
<td>Dressing Feed rate</td>
<td>177.8 mm/min</td>
</tr>
<tr>
<td>Programmed Depth of Cut</td>
<td>constant 0.01 mm</td>
</tr>
<tr>
<td>Spark out</td>
<td>0 s</td>
</tr>
<tr>
<td>Commanded Plunge infeed Rate</td>
<td>0.0125, 0.025, &amp; 0.05 mm/min</td>
</tr>
<tr>
<td>Length from face to grind</td>
<td>0.375, 2.675, &amp; 5.875 in</td>
</tr>
</tbody>
</table>
Results

Feedrate 0.05mm/min
Feedrate 0.025mm/min
Feedrate 0.0125mm/min

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Results

Close up on force data

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Results

Close up on part data

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Comparing force and Feedrates

Results

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Comparing force, table and part

Graphs showing force, table, and part movement for different RPMs and workpiece distances.
Conclusions

- Decreasing the machine structural loop stiffness while increasing workpiece speed will result in chatter.
- There is a critical machine structural loop stiffness.
- Normal force measurements vary linearly with feedrate.
- Substantial increase of forces due to increase of feedrate.
- Material removal does not occur until steady state normal force are reached.
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