Examples of Precision Machine Design

Definition

- A precision machine device is defined as a piece of equipment with one or more moving parts whose accuracy determines the quality of the device.
- Examples of precision machine devices include:
  - Machine Tools
    - Milling Machines
    - Lathes
    - Grinders
    - Laser Cutter
    - WaterJets
    - Non-traditional machines (EDM, ECM, …)
  - Coordinate Measuring Machines
  - Production Equipment
    - Presses
  - Mechanical watches
  - Etc…
Traditional Machine Tools – Vertical Machining Center

- 3 linear axes (typical)
- 1-5 rotary axes (optional)
- 1-30 kW spindle power (typical)
- 0-10,000 rpm spindle speed (typical)
- > $50,000

Source: Mazak

Traditional Machine Tools - Lathe

- 2 linear axes + 1 rotary axis (typical)
- 1-2 rotary axes (optional)
- 1-15 kW spindle power (typical)
- 0-6,000 rpm spindle speed (typical)
- > $25,000

Source: Hardinge

3D parts (rotationally symmetric)

3D parts (rotationally symmetric) with off-axis features (requires 2nd spindle)
Traditional Machine Tools – Surface Grinder

- 3 linear axes + 1 rotary axis (typical)
- 1-2 rotary axes (optional)
- 5-15 kW spindle power (typical)
- 800-4,000 rpm spindle speed (typical)
- > $20,000

Source: Jung GmbH

Traditional Machine Tools – Circular Grinder

- 2 linear axes + 2 rotary axes (typical)
- 5-10 kW spindle power (typical)
- 800-4,000 rpm spindle speed (typical)
- > $25,000

Source: Studer GmbH

Source: Crowder Supply
New Machine Tools – Diamond Turning

- 2 linear axes (typical)
- 1-15 kW spindle power (typical)
- 0-7,500 rpm spindle speed (typical)
- > $150,000

3D parts (rotationally symmetric)

3D parts (asymmetric) with fast tool servo (optional)

Source: Precitech

New Machine Tools - WaterJet

- 2 linear axes (typical)
- Pump power (15-40 kW)
- > $20,000

2D parts (from flat stock material)

Source: OMAX

- 2 linear axes (typical)
- 4 linear + rotary axes (optional)
- 1-10 kW power supply (typical)
- > $100,000

Source: Precision Design Lab

New Machine Tools – Sinker Electro-Discharge Machine

- 2D or 3D parts (from flat stock material)
- 3 linear axes (typical)
- 0-5 kW power supply
- > $80,000

Source: Charmilles
Source: Optimation
New Machine Tools – Electro Chemical Machining

- 1 linear axes (typical)
- 3 linear + rotary axes (optional)
- 1-10 kW power supply (typical)
- > $100,000

Source: Ultra Systems Ltd.

Coordinate Measuring Systems

<table>
<thead>
<tr>
<th>Specifications</th>
<th>OM Measure 333</th>
<th>OM Measure 353</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model No.</td>
<td></td>
<td></td>
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<tr>
<td>Measuring range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-axis</td>
<td>12&quot; (300mm)</td>
<td>12&quot; (300mm)</td>
</tr>
<tr>
<td>Y-axis</td>
<td>12&quot; (300mm)</td>
<td>20&quot; (500mm)</td>
</tr>
<tr>
<td>Z-axis</td>
<td>12&quot; (300mm)</td>
<td>12&quot; (300mm)</td>
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<tr>
<td>Length standard</td>
<td>Precision linear encoder</td>
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</tr>
<tr>
<td>Resolution</td>
<td>300000&quot; (0.0002mm)</td>
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<tr>
<td>Accuracy (22°C ± 1°C)</td>
<td>E = 0.0 = 4.2 x 10^-7 mm R = 4.8 x 10^-7 mm</td>
<td></td>
</tr>
<tr>
<td>Guide method</td>
<td>Air bearing for each axis</td>
<td></td>
</tr>
<tr>
<td>Clamping method</td>
<td>Clamping screw</td>
<td></td>
</tr>
<tr>
<td>Fine feeding device</td>
<td>Optional (4&quot; / 10mm stroke)</td>
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</tr>
<tr>
<td>Z-axis balance</td>
<td>Counterweight</td>
<td></td>
</tr>
<tr>
<td>Measuring table</td>
<td>Granite sub-plate</td>
<td></td>
</tr>
<tr>
<td>Machine stand</td>
<td>Optional</td>
<td></td>
</tr>
<tr>
<td>Workpiece loading</td>
<td>Maximum height: 16.14&quot; (410mm)</td>
<td>Maximum mass: 66 lbs. (30kg)</td>
</tr>
<tr>
<td>Air Pressure</td>
<td>5.3 (PSI) or 0.35 bar</td>
<td></td>
</tr>
<tr>
<td>Air consumption</td>
<td>59.4 cfm (in normal state) or 1 CFM</td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td></td>
<td></td>
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<tr>
<td>Width (OM-Measure)</td>
<td>32.48&quot; (825mm)</td>
<td>32.48&quot; (825mm)</td>
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<tr>
<td>Depth (OM-Measure)</td>
<td>27.17&quot; (690mm)</td>
<td>35.4&quot; (890mm)</td>
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<tr>
<td>Height (OM-Measure)</td>
<td>92.56&quot; (1344mm)</td>
<td>123.4&quot; (1300mm)</td>
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<tr>
<td>Mass (OM-Measure)</td>
<td>266 lbs. (120 kg)</td>
<td>374 lbs. (170 kg)</td>
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<tr>
<td>OM Dots 300</td>
<td>2 lbs. (1 kg)</td>
<td>2.6 lbs. (1.2 kg)</td>
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</tbody>
</table>

Source: Mitutoyo
Performance Criteria

Precision Devices are rated according to:

- Manufacturing Capability
  - Accuracy
  - Resolution
  - Repeatability
- Ability to provide motion
  - Number of axes (complexity of machined geometry)
  - Speed (determines the manufacturing time)
  - Travel (determines the part size)
- Ability to provide energy required for manufacturing processes
  - Spindle power (machining centers, lathe, grinder, etc.)
  - Laser power (laser cutters)
  - Pump pressure (WaterJet)
  - Voltage, Current, Frequency (EDM, ECM)

Performance Limiting Criteria

- Most machines create geometry by selectively removing material.
- The amount and location of the material removed is a function of the amount and location of the energy transmitted from the tool (machine) to the work piece.
- The location of the energy transmission is rarely controlled directly but indirectly at remote measurement points.
- As a result, the created geometry will always deviate from the perfect shape.
- The amount of this deviation can be defined as the achievable precision of both the machine and the process.