Introduction to Metal Forming Operations

IME 340/240
Classification of Forming Processes

• There are a number of ways to divide up forming processes
  – Hot working, warm working, cold working
  – Bulk forming, sheet metal forming
  – Primary and component producing processes
  – Steady and non-steady processes
  – Continuous and incremental forming processes
Classification of Forming Processes

• Cold working
  – Temperature < 0.3 * melting point in deg. K
  – In practice for most engineering metal this means room temperature
  – Work hardening is dominant

• Hot working
  – Above the recrystalization temperature
  – Temperature > 0.5 (or 0.6) * melting point in deg. K
  – Strain rate sensitivity more important

• Warm working
  – Temperature between 0.3 and 0.5 of melting point
  – Flow stresses somewhat less than cold working
Classification of Forming Processes

• Sheet metal forming
  – Input material in sheet form
  – Thickness changes very small
  – Stress systems largely tensile

• Bulk forming
  – Input material in the form of bars, billets, etc.
  – Thickness of material usually substantially reduced
  – Stress systems largely compressive
Classification of Forming Processes

• Primary forming processes
  – Processes predominantly for producing materials for further processing
  – Examples are rolling, drawing, extrusion, etc.

• Component producing processes
  – Processes for producing component parts
  – Input materials produced by primary processes
  – Examples are forging, deep drawing, stretch forming, etc.
Classification of Forming Processes

• Steady state forming processes
  – Substantially constant stress system
  – Continuous formation of product
  – Examples are rolling, extrusion, drawing, etc.

• Non-steady forming processes
  – Stress system changes continuously during the deformation process
  – Examples are forging, deep drawing, etc.
Range of Forming Processes

- **Free forming**
  - Tool does not contain the desired shape

- **Two dimensional forming**
  - Point contact between tool and work material
  - Two relative motions required to produce geometry
  - Incremental forming processes

- **One dimensional forming**
  - Line or surface contact with work material
  - Only one relative motion required to produce geometry

- **Total forming**
  - Tool contains the desired geometry

- Process kinematics within each group differentiates the different processes
Range of Forming Processes

Total forming processes

One dimensional processes

Two dimensional processes

Free forming processes
### Free Forming Processes

<table>
<thead>
<tr>
<th>Pattern of motions</th>
<th>Workpiece</th>
<th>Tool</th>
<th>Free forming</th>
<th>Examples of processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td>Upsetting</td>
</tr>
<tr>
<td>R</td>
<td></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td>Torsion</td>
</tr>
</tbody>
</table>
# One Dimensional Processes

<table>
<thead>
<tr>
<th>Pattern of motions</th>
<th>Workpiece</th>
<th>Tool</th>
<th>One-dimensional forming</th>
<th>Examples of processes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>T</td>
<td>Direct extrusion</td>
<td>Direct extrusion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Wire drawing</td>
<td>Wire drawing</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>T</td>
<td>Indirect extrusion</td>
<td>Indirect extrusion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deep drawing</td>
<td>Deep drawing</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>R</td>
<td>Sheet and tube bending</td>
<td>Sheet and tube bending</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>R</td>
<td>Rolling</td>
<td>Rolling</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>T</td>
<td>Bar forging</td>
<td>Bar forging</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>T</td>
<td>Ring forging</td>
<td>Ring forging</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>R</td>
<td>Roll bending</td>
<td>Roll bending</td>
</tr>
</tbody>
</table>
### Two Dimensional Processes

<table>
<thead>
<tr>
<th>Pattern of motions</th>
<th>Workpiece</th>
<th>Tool</th>
<th>Two-dimensional forming</th>
<th>Examples of processes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T/R</td>
<td>T</td>
<td></td>
<td>Bar forging</td>
</tr>
<tr>
<td></td>
<td>R/T</td>
<td>R</td>
<td></td>
<td>Tube rolling</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>T</td>
<td></td>
<td>Spinning</td>
</tr>
</tbody>
</table>
# Total Forming Processes

<table>
<thead>
<tr>
<th>Pattern of motions</th>
<th>Workpiece</th>
<th>Tool</th>
<th>Total forming</th>
<th>Examples of processes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Forging</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bending</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Impact forging</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tube expansion</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td></td>
<td></td>
<td>Upsetting</td>
</tr>
</tbody>
</table>