Deformation Processing & Forging Introduction

ver. 1

Prof. Ramesh Singh, Notes by Dr. Singh/ Dr. Colton
Overview

- Types of Deformation Processing
- Forging
- Wire drawing
- Extrusion
- Rolling
Types of deformation processing

- Forging
- Wire drawing
- Extrusion
- Rolling
Forging

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Wire drawing
Extrusion

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Rolling

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What is deformation processing?

• Process to make parts without material removal
• Deformation occurs on parts with L/D ≈ 1
• High volume
Examples of products

• Connecting rods
• Wire
• Bars
• Window frames
Railroad engine connecting rod
Typical product dimensions

- **Small:**
  - coins
  - surgical wire

- **Large:**
  - power plant turbine shafts
  - aircraft landing gear
Aircraft landing gear
Process characteristics

• Material is deformed
  – improvement of material properties
    • grain refinement
    • grain orientation
    • work hardening

• Material is conserved
  – minimal trimming and machining

\[ \sigma_t = \sigma_o \varepsilon^n \]
Important parameters

• Plasticity
• Friction
• Elasticity negligible
  – usually much smaller magnitude than plastic deformation
Plasticity analysis

- Slab method
  - plane strain
  - plane stress

Forging

Forging force
Strain hardening

\[ \sigma_t = \sigma_0 \varepsilon^n \]

- Tresca (maximum shear stress) yield criterion: \( \tau_{flow} = \frac{\sigma_{flow}}{2} \)
Energy / unit volume (u)

\[ u = \int_0^{\varepsilon_1} \sigma_{flow} \, d\varepsilon = \int_0^{\gamma_1} \tau_{flow} \, d\gamma \]

\[ \therefore \Delta \gamma = 2 \Delta \varepsilon \]

by Tresca (maximum shear stress) criterion
Working temperature

- **Cold**: $T < 0.4 \ T_{\text{melting}}(K)$
  - strain hardening effect
  - no strain rate effect
- **Hot**: $T > 0.6 \ T_{\text{melting}}(K)$
  - no strain hardening effect
  - strain rate effect
Forging
Forging

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Forging

- Part formation by pressing between dies
  - Dies are hard metal shapes

- Temperature
  - Hot (usually)
  - Cold

- Dies
  - Open (no lateral constraints)
  - Closed (lateral constraints)
Open Die Forging
Ring Forging
Open die forging

Forging force

Platen

Forging

Platen

Forging force
Closed Die Forging
Closed die forging
Forgings

• Coins
• Landing gear
• Crank shafts
• Turbine shafts
Forging presses

- Large machines
  - hold dies
  - form parts
Press types

- Hydraulic presses
- Mechanical presses
- Screw presses
- Hammers
  - gravity drop
  - power drop
  - counter blow (two rams)
  - high pressure gas
50,000 ton press

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Forges

Schematic illustration of the principles of various forging machines. (a) Hydraulic press. (b) Mechanical press with an eccentric drive; the eccentric shaft can be replaced by a crankshaft to give the up-and-down motion to the ram. (continued)
Forges

Schematic illustration of the principles of various forging machines. (c) Knuckle-joint press. (d) Screw press. (e) Gravity drop hammer.

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Dies

- Final part shape determined by die accuracy
- Multiple parts can be made in one die
- Progressive shaping can be done in one die set
- Need to be stronger than highest forging stress
# Forging hammer capabilities

<table>
<thead>
<tr>
<th></th>
<th>Moving mass (kg)</th>
<th>Energy at strike (J)</th>
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<tbody>
<tr>
<td>Gravity drop hammers</td>
<td>500 - 5,000</td>
<td>6,000 - 75,000</td>
</tr>
<tr>
<td>Power drop hammers</td>
<td>500 - 18,000</td>
<td>18,000 - 600,000</td>
</tr>
<tr>
<td>High energy rate forming</td>
<td></td>
<td>500,000 - 5,000,000</td>
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</table>
## Forging press parameters

<table>
<thead>
<tr>
<th>Type</th>
<th>Load capacity</th>
<th>Strokes per minute</th>
<th>Power (kW)</th>
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</thead>
<tbody>
<tr>
<td><strong>Mechanical presses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open-back, inclinable</td>
<td>150 - 1,250 kN</td>
<td>200 - 100</td>
<td>3 - 15</td>
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<tr>
<td>High-speed, straight side</td>
<td>300 - 2,000 KN</td>
<td>2000 - 200</td>
<td></td>
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<tr>
<td>Larger straight side</td>
<td>1 - 6 MN</td>
<td>100 - 20</td>
<td>10 - 60</td>
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<tr>
<td>Transfer presses</td>
<td>2 - 40 MN</td>
<td>50 - 10</td>
<td></td>
</tr>
<tr>
<td>Forging presses</td>
<td>3 - 80 MN</td>
<td>100 - 30</td>
<td>20 - 500</td>
</tr>
<tr>
<td><strong>Hydraulic presses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universal</td>
<td>4 - 25 MN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forging presses</td>
<td>2 - 500 MN</td>
<td></td>
<td>150 - 1000</td>
</tr>
</tbody>
</table>
## Hot upsetting machine parameters

<table>
<thead>
<tr>
<th>Rate size (mm) (upset diameter)</th>
<th>Forging force (MN)</th>
<th>Strokes/min</th>
<th>Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>0.5</td>
<td>90</td>
<td>5</td>
</tr>
<tr>
<td>38</td>
<td>1</td>
<td>65</td>
<td>10</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>60</td>
<td>15</td>
</tr>
<tr>
<td>75</td>
<td>4</td>
<td>45</td>
<td>25</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>125</td>
<td>8</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>150</td>
<td>10</td>
<td>27</td>
<td>60</td>
</tr>
<tr>
<td>175</td>
<td>13</td>
<td>25</td>
<td>90</td>
</tr>
<tr>
<td>200</td>
<td>16</td>
<td>23</td>
<td>110</td>
</tr>
<tr>
<td>225</td>
<td>20</td>
<td>20</td>
<td>150</td>
</tr>
</tbody>
</table>
Forging steps

• Prepare slug
  – saw
  – flame cut
  – shear

• Clean slug surfaces
  – shot blast
  – flame
Forging steps

• For hot forging
  – heat up and descale forging
  – make sure press is hot

• Lubricate
  – oil
  – soap
  – MoS$_2$
  – glass
  – graphite
Lubrication purposes

• Reduce friction
• Reduce die wear
• Thermally insulate part
  – to keep it warm
Forging steps

• Forge
• Remove flash
  – trim
  – machine
• Check dimensions
• Post processing, if necessary
  – heat treat
  – machine
Effect on grain structure

- Large grains are broken up.
- Grains can be made to flow.
Main forging defect

• Surface cracks
  – due to sticking and barreling, leading to tensile forces on the surface.
Forging Defects

(a) Blocked forging

(b) Forging begins

Web buckles

Laps in finished forging

Die cavities are being filled

Cracks develop in ribs

Cracks propagate through ribs
Summary

• Types of deformation processes
• Material deformation review
• Forging introduction