Deformation Processing & Forging Introduction

ver. 1

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Overview

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

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Types of deformation processing

- Forging
- Wire drawing
- Extrusion
- Rolling

Forging

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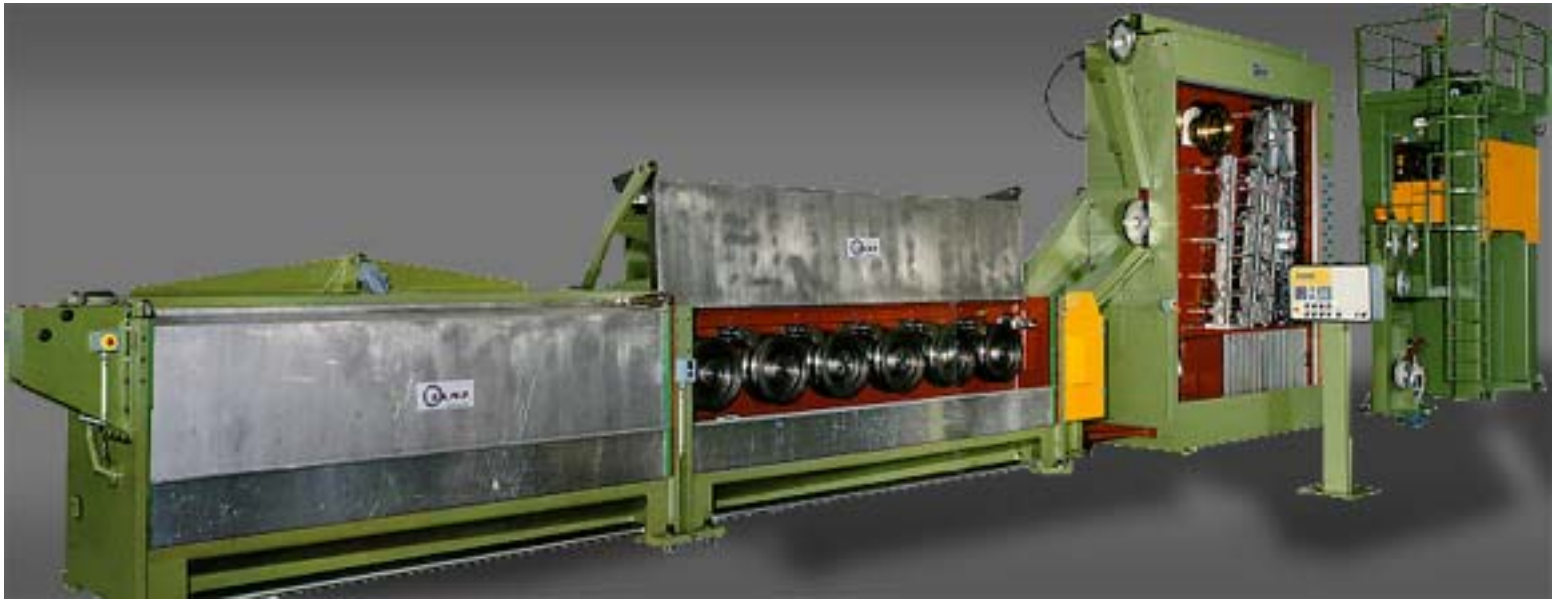
Wire drawing



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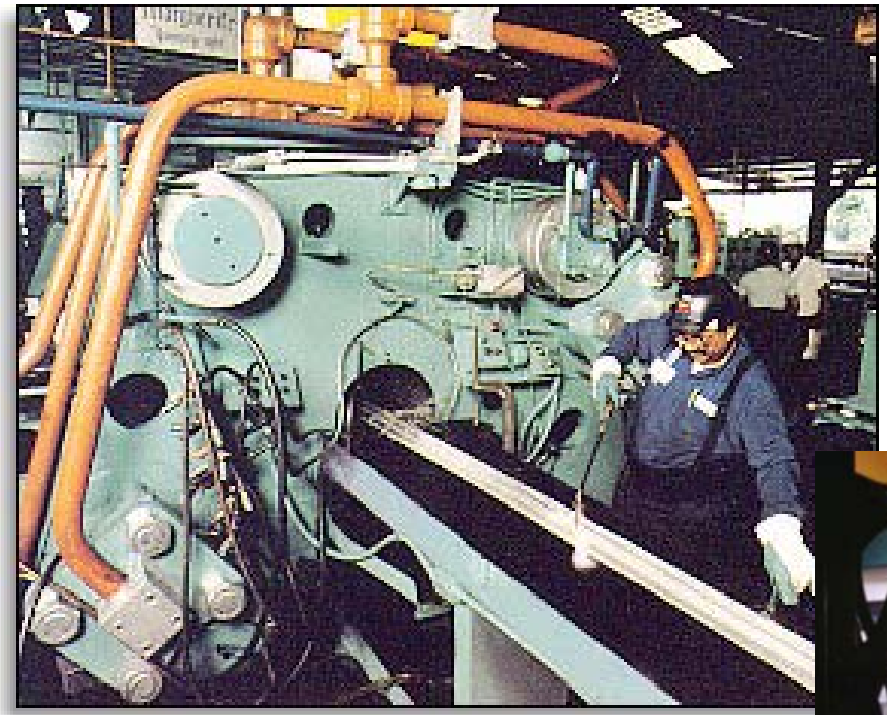
Extrusion



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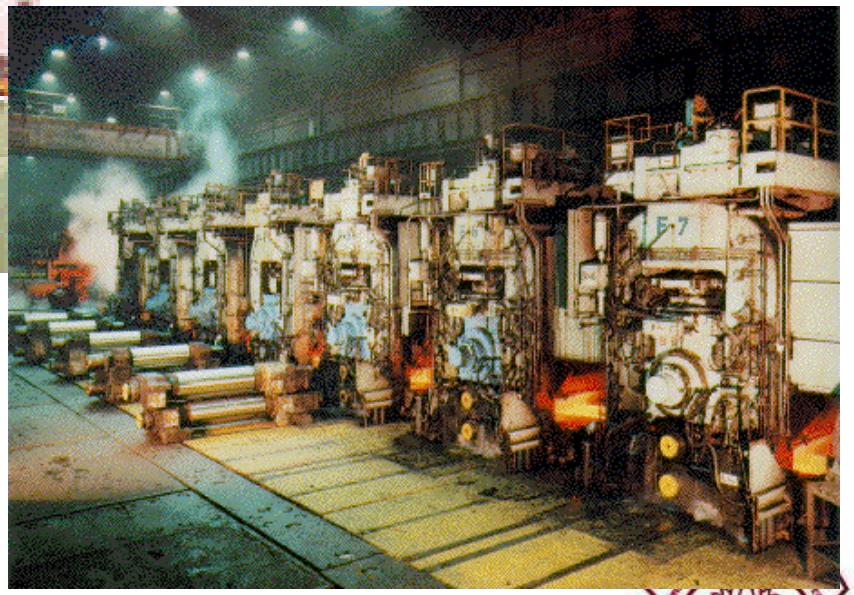
Rolling



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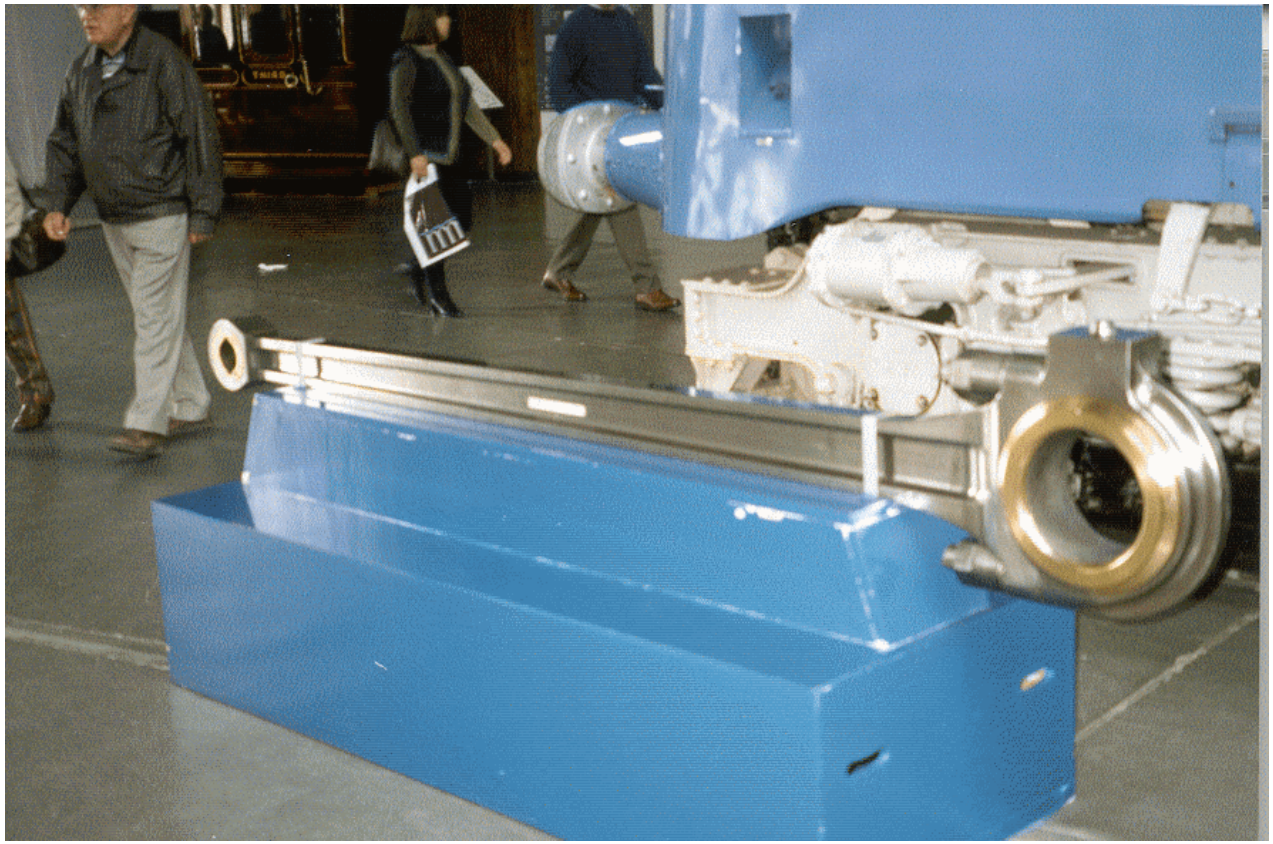
What is deformation processing?

- Process to make parts without material removal
- Deformation occurs on parts with L/D $\approx$1
- High volume

Examples of products

- Connecting rods
- Wire
- Bars
- Window frames

Railroad engine connecting rod



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Typical product dimensions

- Small:
  - coins
  - surgical wire
- Large:
  - power plant turbine shafts
  - aircraft landing gear

Aircraft landing gear

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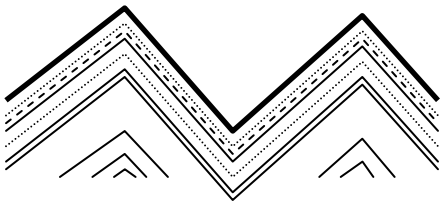
Process characteristics

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



$$\sigma_t = \sigma_o \varepsilon^n$$

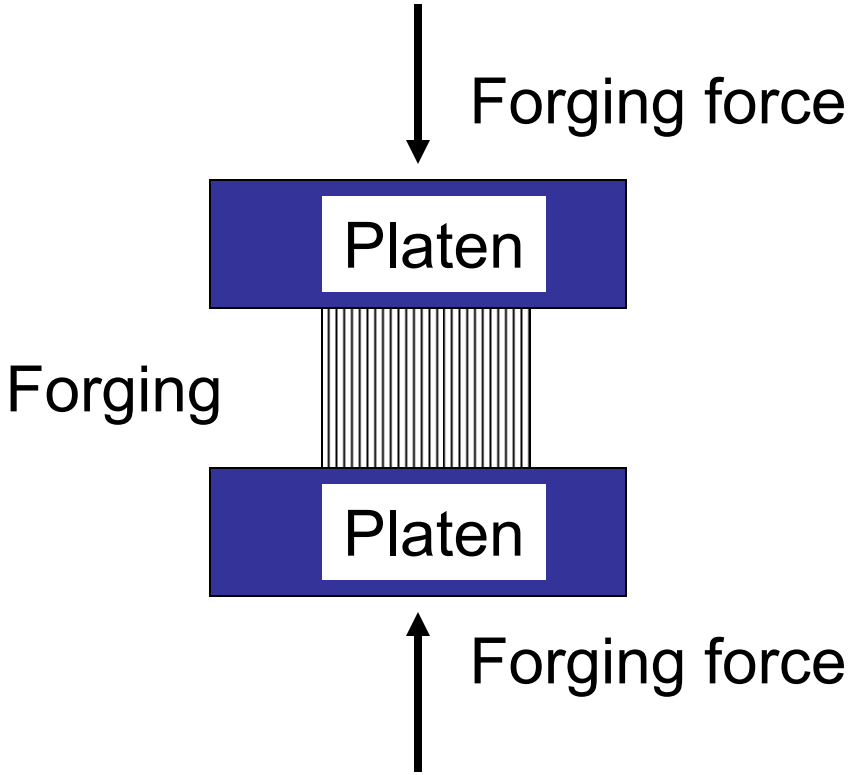
- Material is conserved
  - minimal trimming and machining

Important parameters

- Plasticity
- Friction
- Elasticity negligible
  - usually much smaller magnitude than plastic deformation

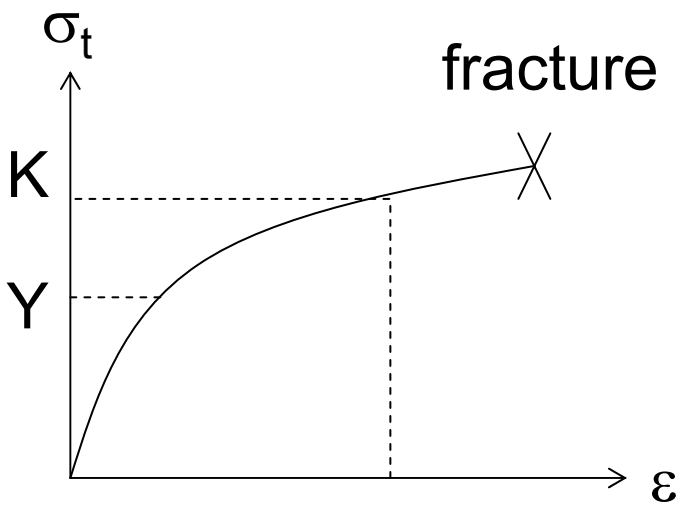
Plasticity analysis

- Slab method
  - plane strain
  - plane stress



Strain hardening

$\sigma_t = \sigma_o \varepsilon^n$



- Tresca (maximum shear stress) yield criterion: $\tau_{flow} = \sigma_{flow} / 2$

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

Forging

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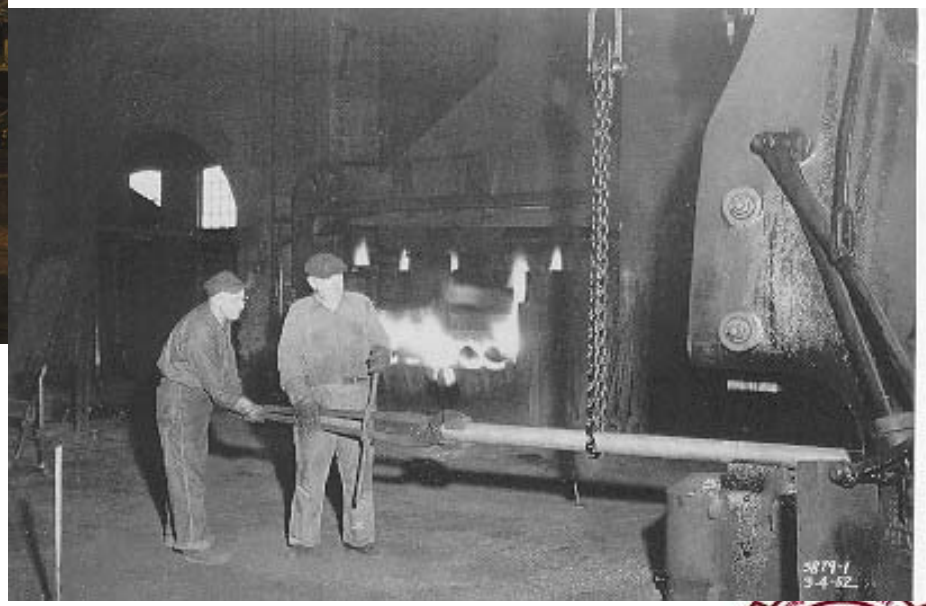
Forging



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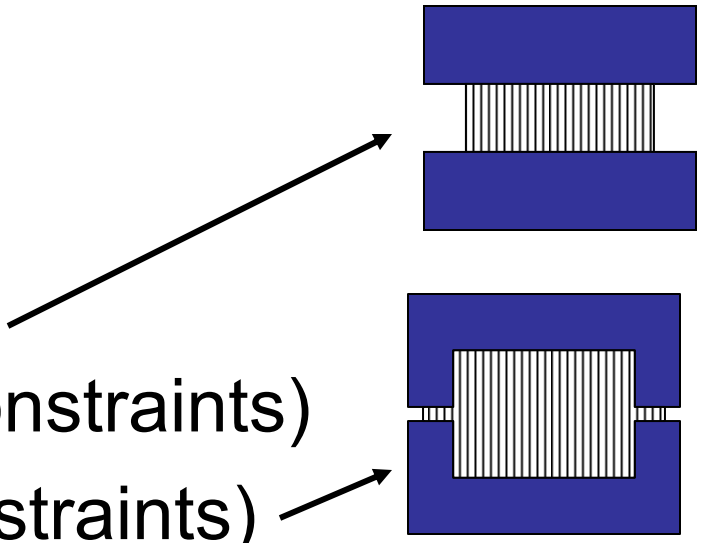
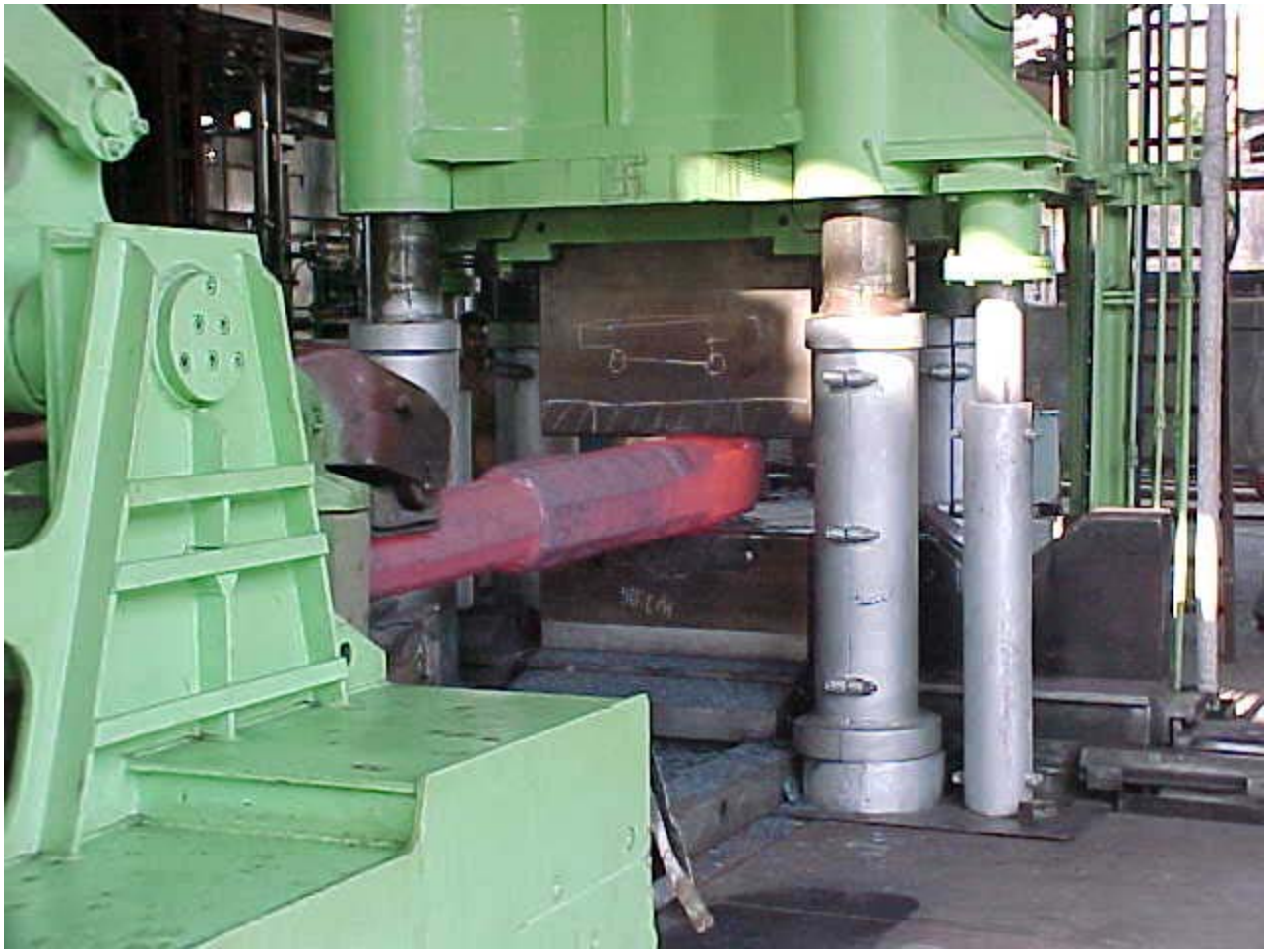
Forging

- 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



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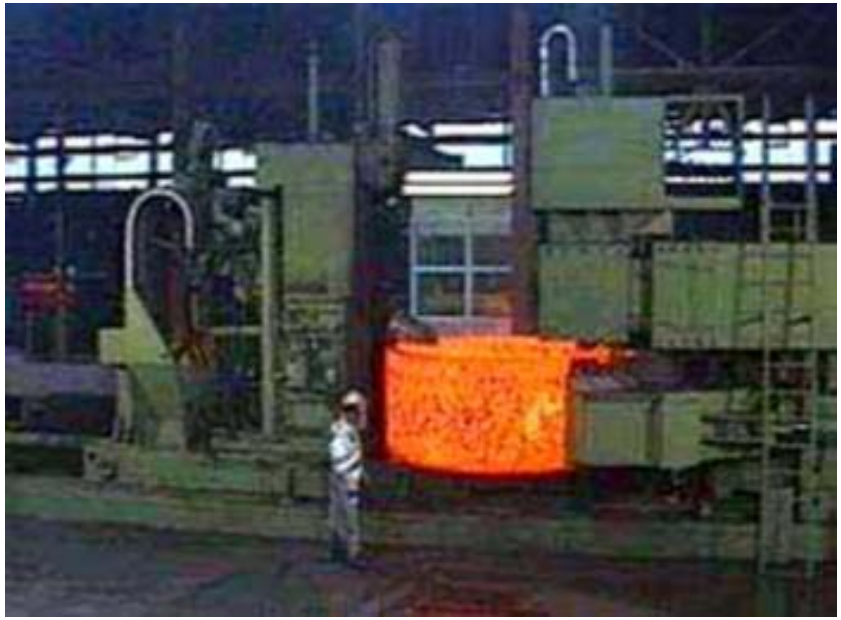
Ring Forging



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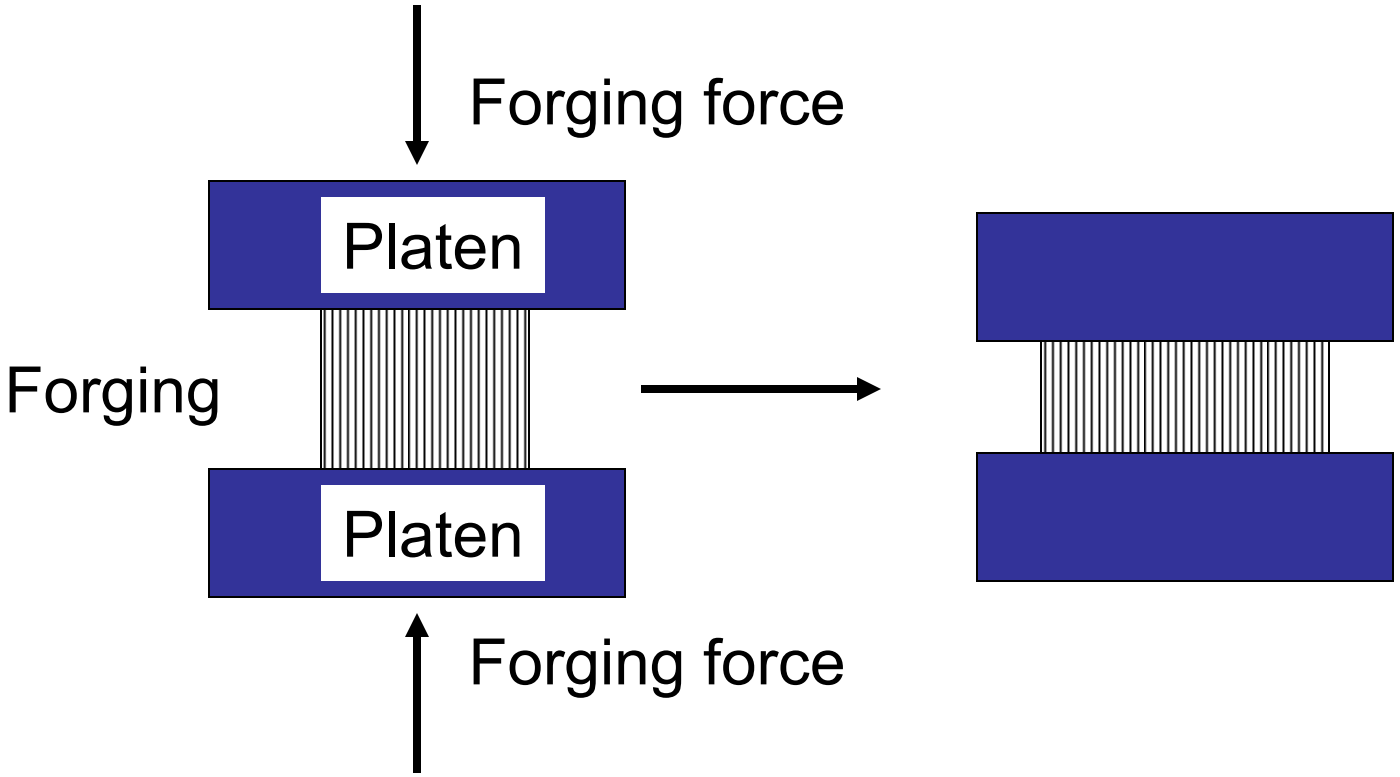
Open die forging



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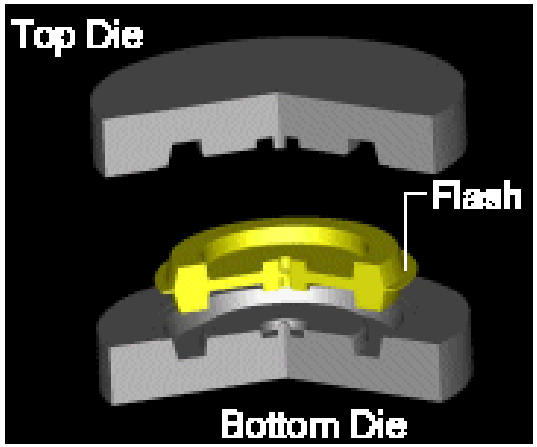
Closed Die Forging



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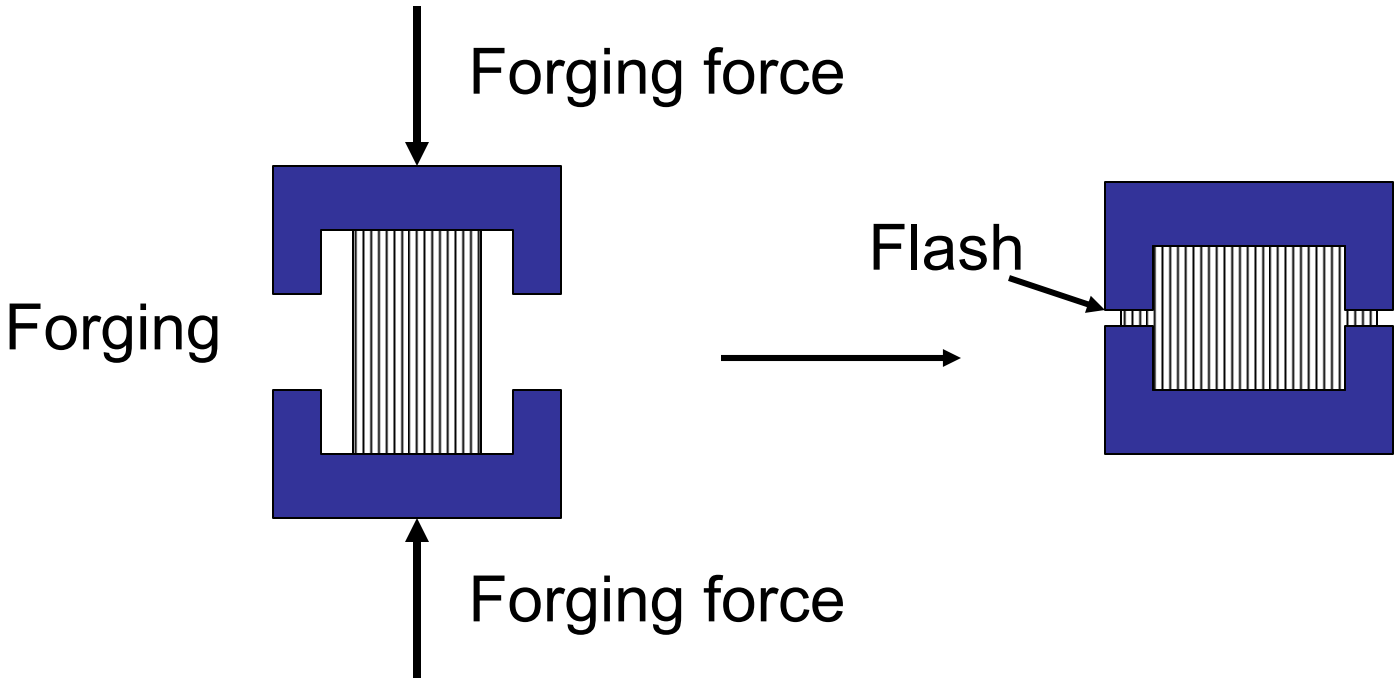
Closed die forging



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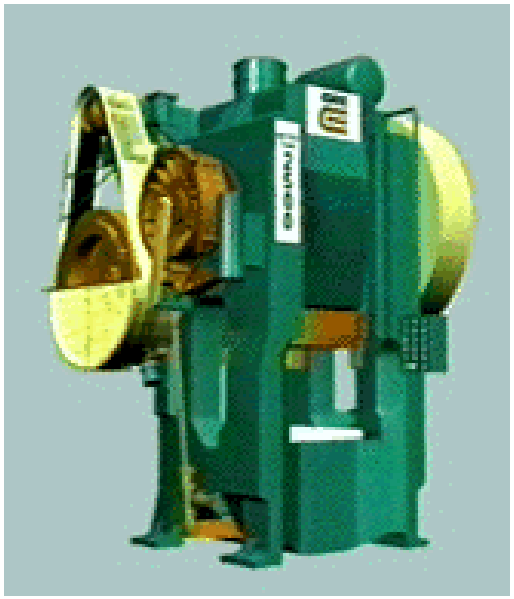
Forgings

- Coins
- Landing gear
- Crank shafts
- Turbine shafts

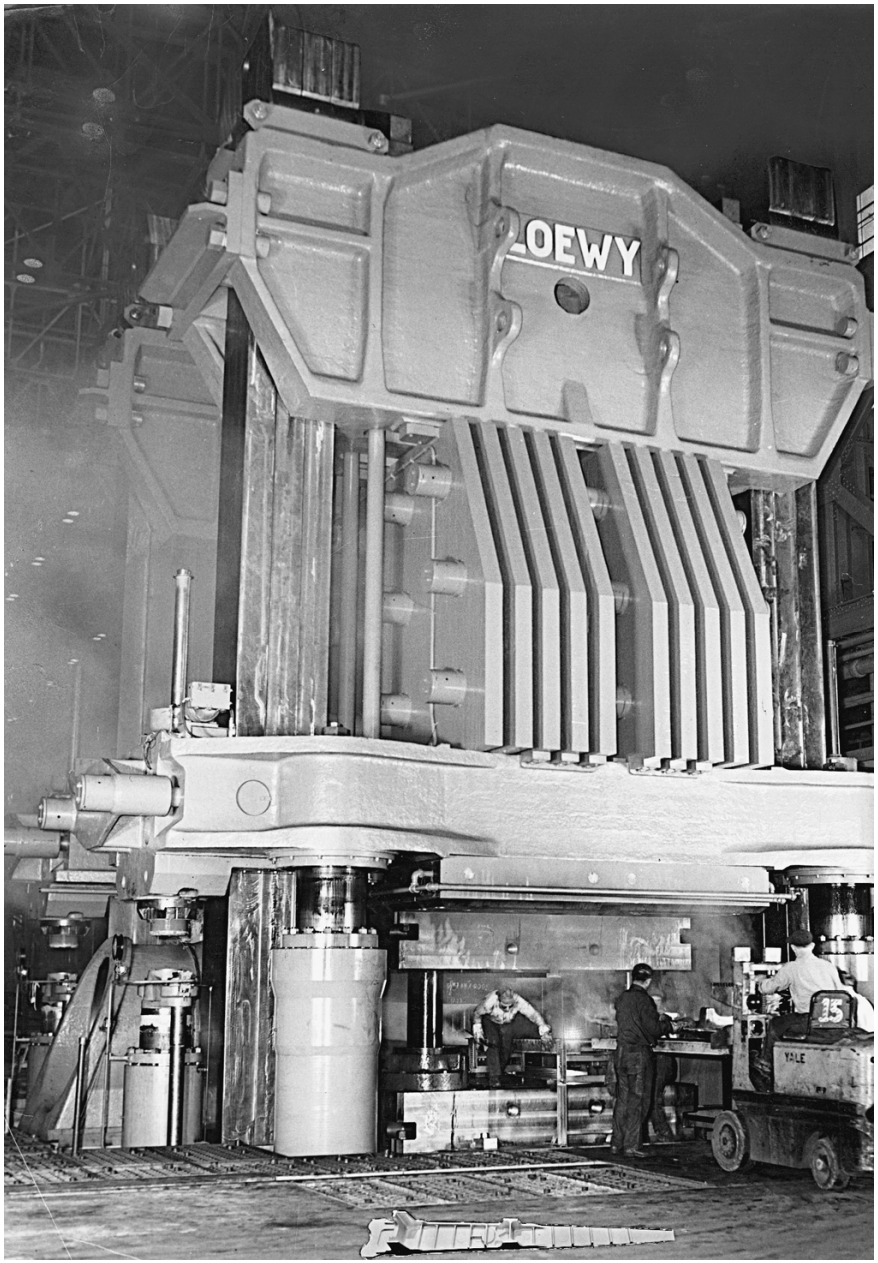
Forging presses

- 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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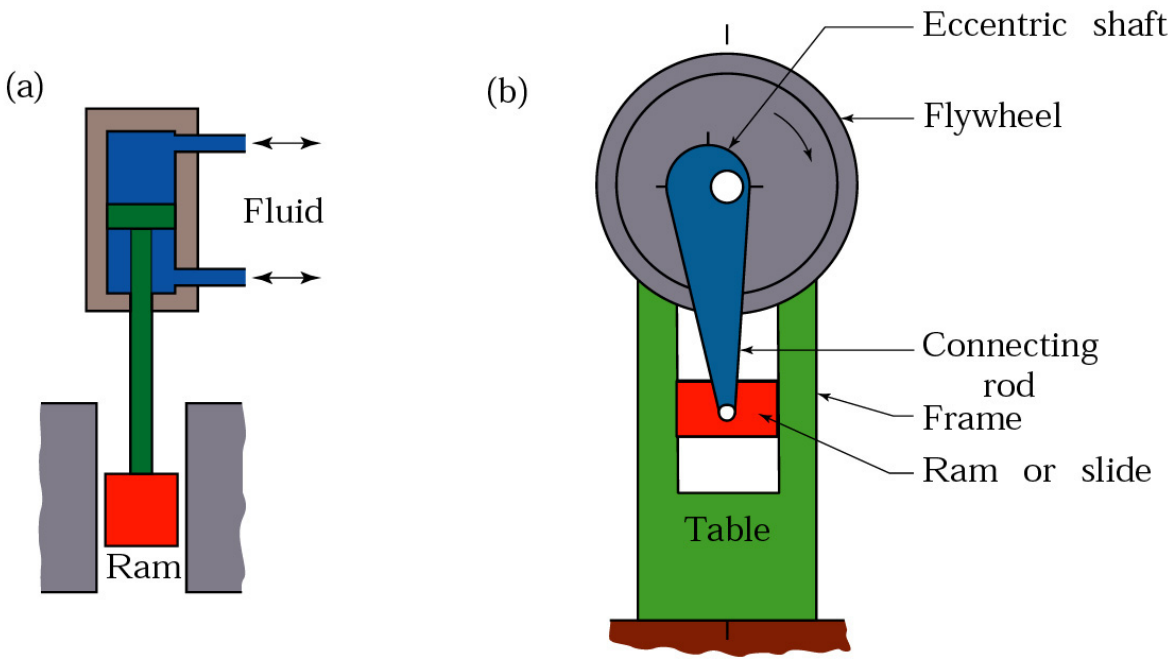
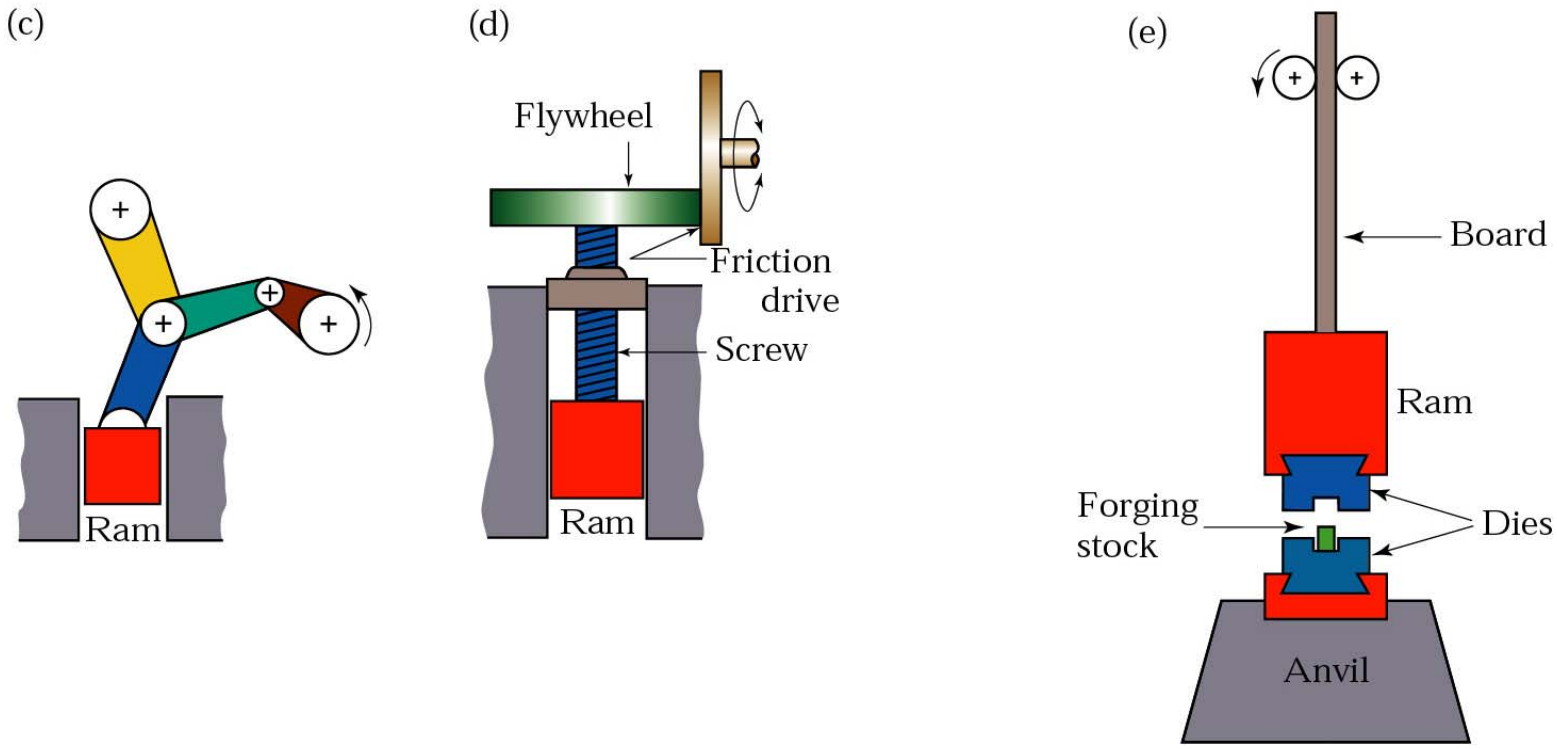
Forges



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.

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

	Moving mass (kg)	Energy at strike (J)
Gravity drop hammers	500 - 5,000	6,000 - 75,000
Power drop hammers	500 - 18,000	18,000 - 600,000
High energy rate forming		500,000 - 5,000,000

Forging press parameters

	Load capacity	Strokes per minute	Power (kW)
Mechanical presses			
Open-back, inclinable	150 - 1,250 kN	200 - 100	3 - 15
High-speed, straight side	300 - 2,000 KN	2000 - 200	
Larger straight side	1 - 6 MN	100 - 20	10 - 60
Transfer presses	2 - 40 MN	50 - 10	
Forging presses	3 - 80 MN	100 - 30	20 - 500
Hydraulic presses			
Universal	4 - 25 MN		
Forging presses	2 - 500 MN		150 - 1000

Hot upsetting machine parameters

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

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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

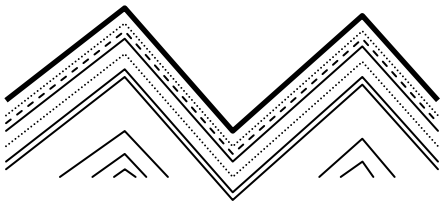
- Reduce friction
- Reduce die wear
- Thermally insulate part
  - to keep it warm

Forging steps

- Forge
- Remove flash
  - trim
  - machine
- Check dimensions
- Post processing, if necessary
  - heat treat
  - machine

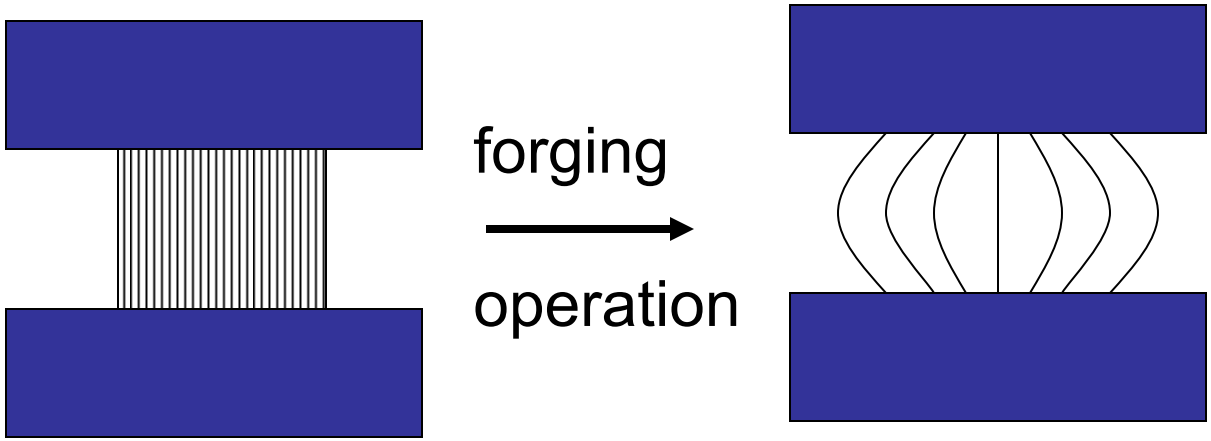
Effect on grain structure

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

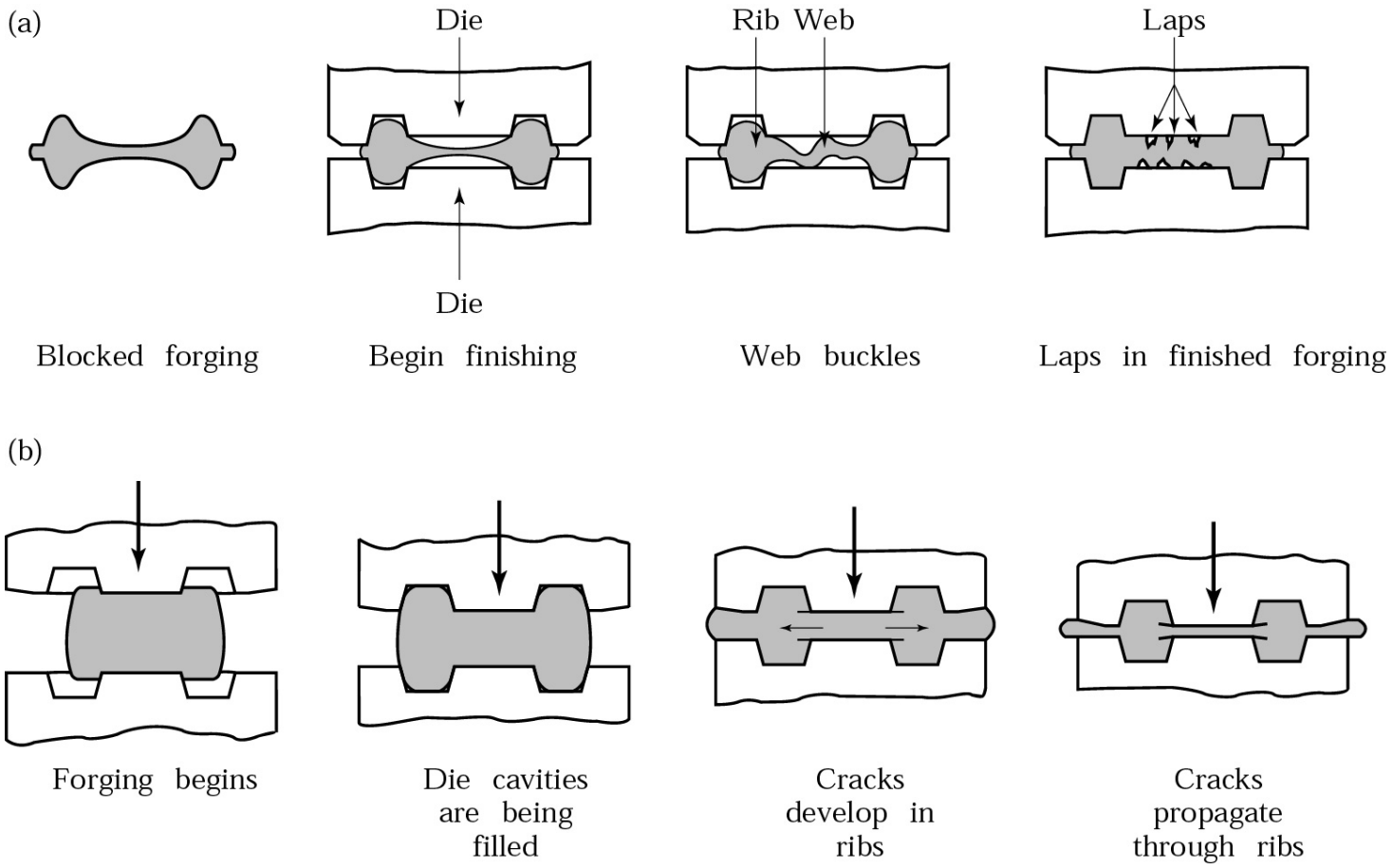


Main forging defect

- Surface cracks
  - due to sticking and barreling, leading to tensile forces on the surface.



Forging Defects



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Summary

- Types of deformation processes
- Material deformation review
- Forging introducttion