Week 11 – Lecture 1: Fabrication of Metals

Callister 9th edition Chp 17.1 – 17.4

Materials Science A244 ⌘ Dr Melody Neaves

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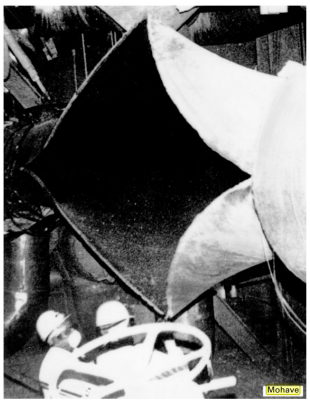
Why be concerned with fabrication techniques?

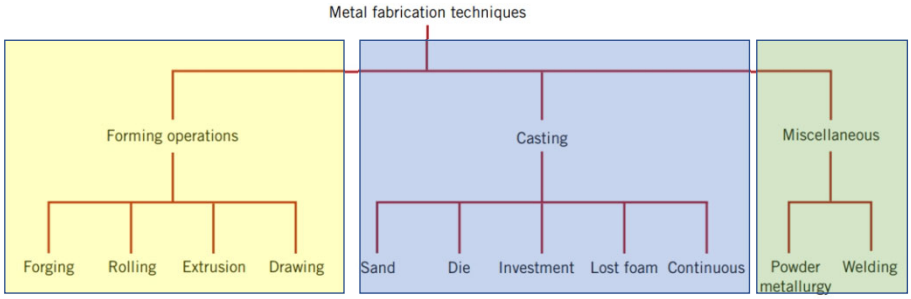


- Influences material properties
- Incorrect selection/improper methods can result in unexpected material failures
- Economic considerations

2

Metal fabrication

- *"Techniques used to form metals or manufacture components for incorporation into useful products"*
- Can involve several steps
- Selection depends on:
  - Metal properties
  - Size and shape of end product
  - Cost



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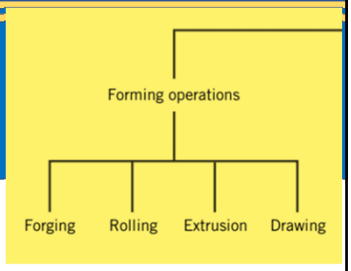
Forming operations



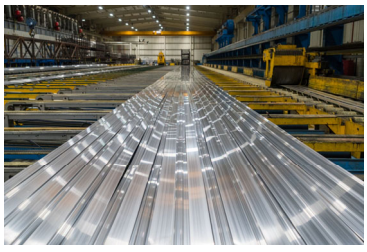
Main features:
- Shape a metal through plastic deformation
- Induced by external stress >> yield strength
- Most moderately to very ductile metals

Forming

Hot working

Youtube: mparr44114

Cold working



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Cold vs hot working

Hot working

- Forming temperature > recrystallisation temperature

Advantages:

- Large deformations possible
- Lower deformation energy requirements
- No residual stresses

Disadvantages:

- Surface oxidation
- Poor surface finish
- High temperature energy input

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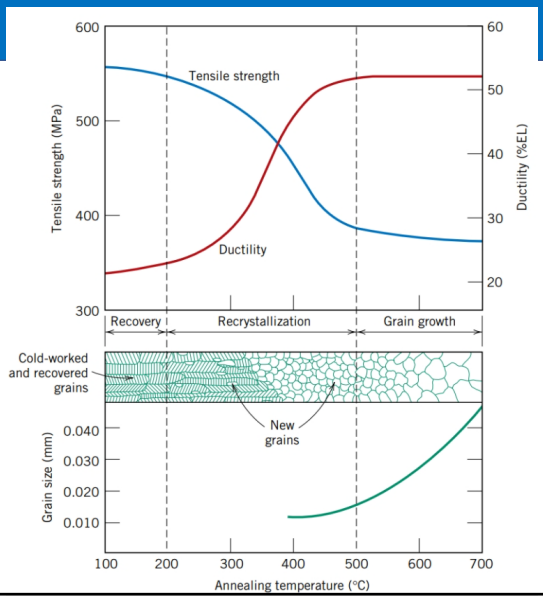

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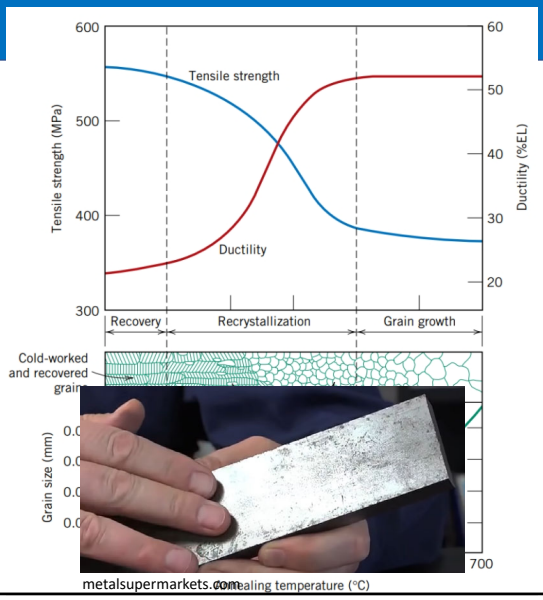

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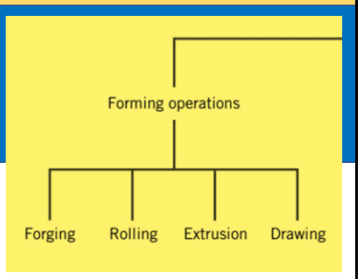
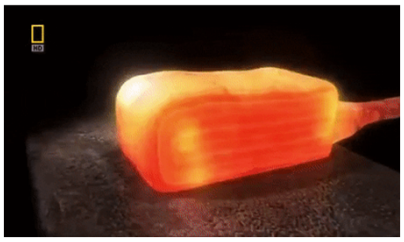
Forming



Forging:
- Deforming hot metal through repeated blows/squeezing action
- Closed die: two halves having the finished shape surround the material
- Open die: simple shapes that do not surround material (larger parts)
- Advantages: good grain structures and mechanical properties



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HBE press

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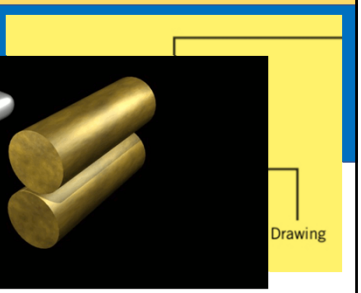
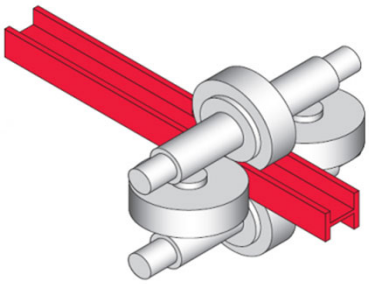
Forming



Rolling:
- Metal is thinned due to compressive stresses from rollers
- Cold rolling: Sheet, strip, foils
- Grooved rolling: I-beams and railroad rails

https://commons.wikimedia.org/wiki/File:Rolling.gif (CC 3.0)



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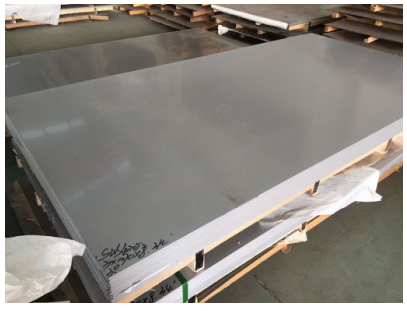

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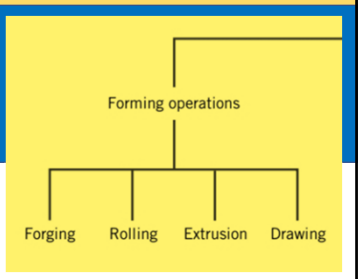
Forming



Extrusion:
- Pushing: Bar of metal compressively forced through a hole in a die
- Rods and tubing with complicated cross sections
- Seamless tubing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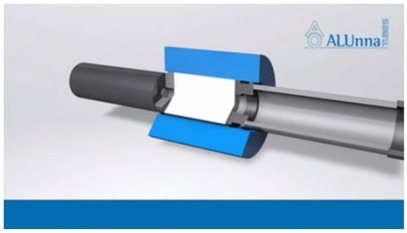

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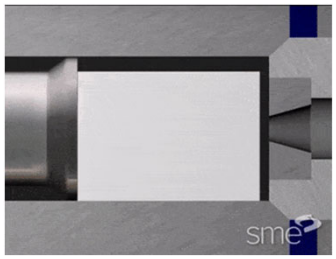

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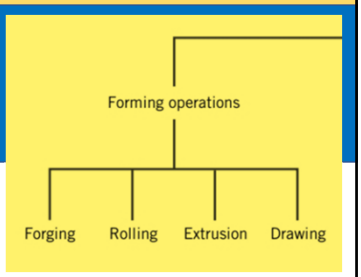
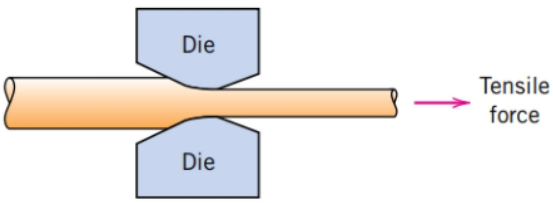
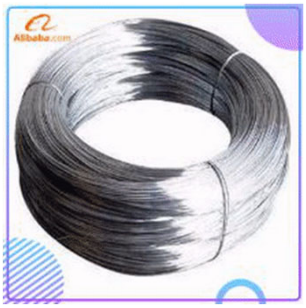
Forming



Drawing:
- Pulling: Pulling a metal piece through a tapered bore through tensile force
- Thinner cross section through multiple steps/dies
- Rods, tubing and wires

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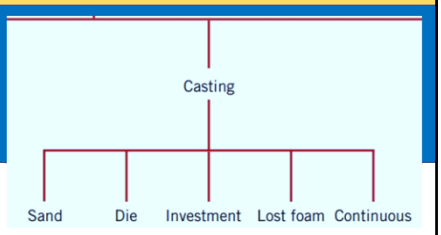
Casting



- Molten metal poured into mold
- Shrinkage after solidification
- Used for
  - Large structures
  - Low ductility metals
  - Lower costs

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emma-maersk.com

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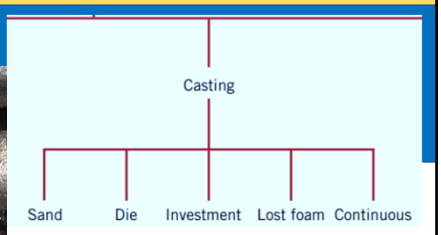
Casting

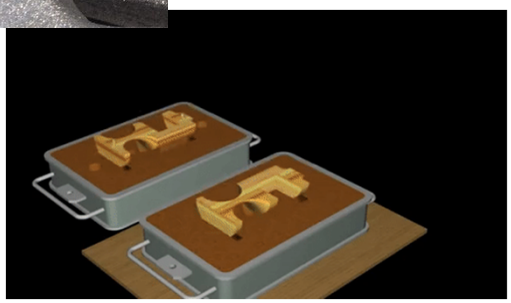


Sand casting:

- Uses sand to make mold in two halves
- Sand packed around a pattern
- Gating system transports molten metal
- Can have casting defects such as porous
- Mold destroyed after use
- Rough surface finish
- Cylinder blocks, fire hydrants, large pipe fittings

iron-foundry.com

rh-casting.com



YouTube: focusedsoft

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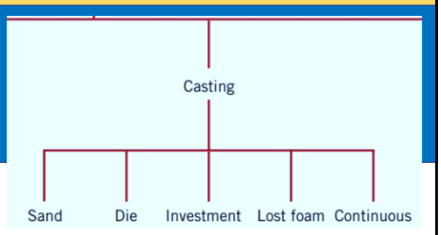
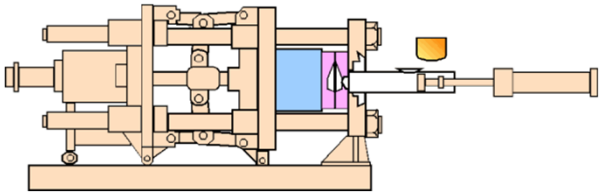
Casting



Die casting:
- Liquid metal forced into die at pressure
- Uses a permanent two-piece steel mold/die
- Once cooled, part is ejected from die
- Rapid casting rates: re-usable molds/dies
- Better control over surface finish
- Only small pieces of metal with low melting T
- Zinc, aluminum and magnesium alloys



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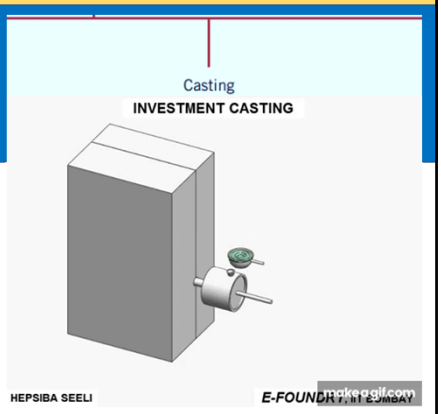
Casting



Investment casting:
- *Lost wax* casting: uses a pattern made from wax or plastic with low melting T
- Pattern is coated in slurry and ceramic powders to create mold
- Mold is heated and the pattern is lost/burnt out
- Excellent surface finish
- High dimensional accuracy/fine details
- Jewelry and dental crowns
- Turbine and impeller blades

Dexin (2018)

https://castingrfdchina.com/

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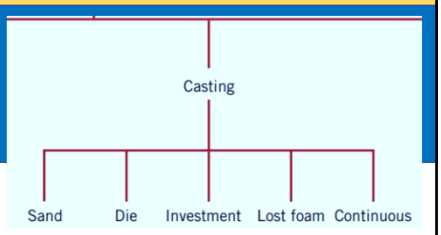
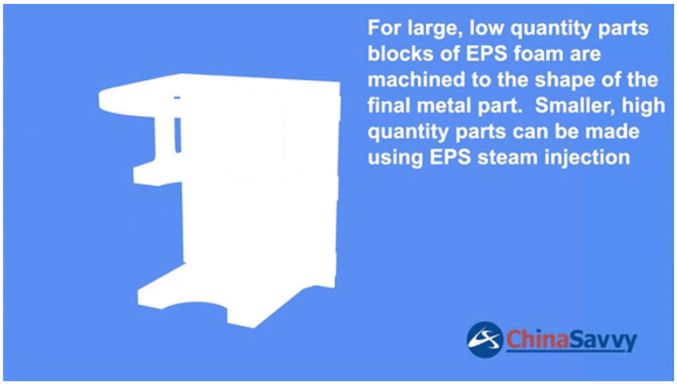
Casting



Lost-foam casting:
- Combination of sand and investment casting
- Expendable polystyrene foam pattern
- Sand packed around pattern to form mold
- Mold filled with molten metal: pattern vaporizes
- Complex geometries with tight tolerances
- Simpler, quicker, cheaper, environmentally friendlier
- Engine blocks, crankshafts, marine engine blocks: cast irons and aluminum alloys



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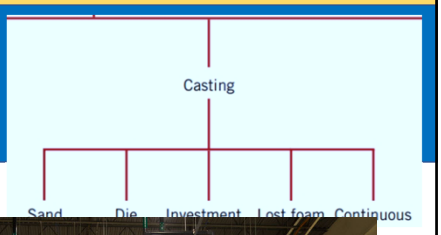

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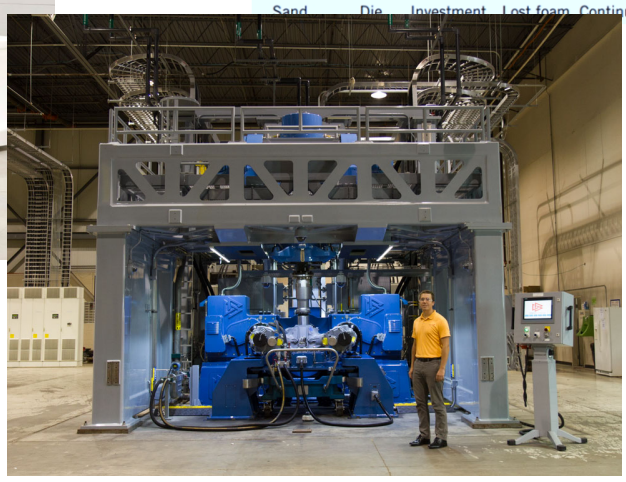

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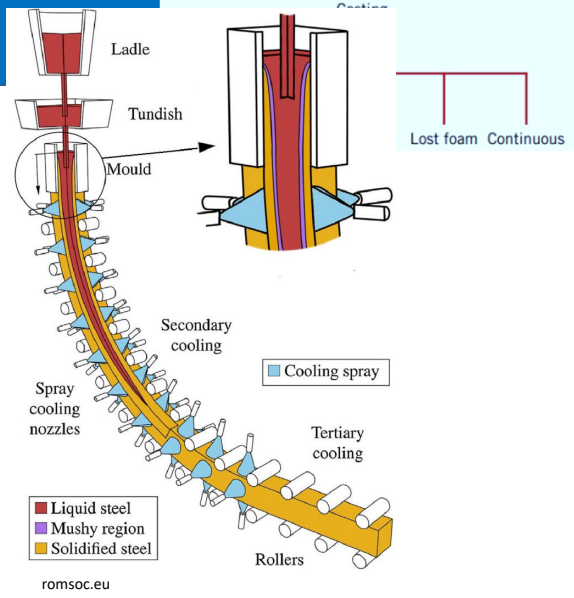
Casting

Continuous casting:
- AKA strand casting (combination of casting and rolling)
- Molten metals cast into ingots and hot-rolled
- Creates flat sheet and slabs for secondary forming operations
- Cast into continuous strand with rectangular / circular cross section
- Solidified in water-cooled die
- Automated and efficient
- Uniform chemical and mechanical properties
- Large footprint and capital expense



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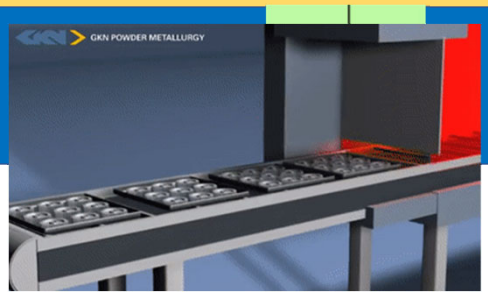
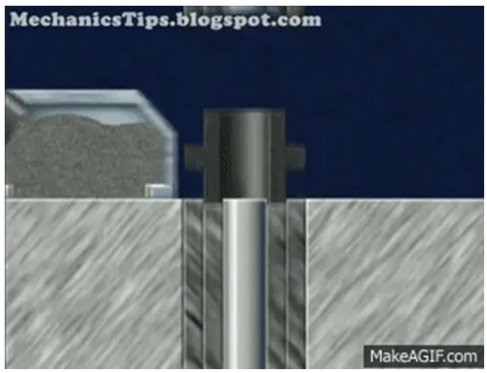
Miscellaneous: Powder metallurgy

- (1) Creation of powdered metal
- (2) Compaction of powdered metal into shape
- (3) Heat treatment to densify "green" part





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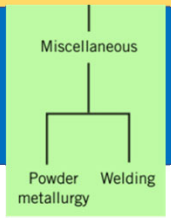
Miscellaneous: Powder metallurgy



Advantages:
- Low ductilities
- High melting temperatures
- Close tolerances
- Porosity (self-lubricating bearings)

Disadvantages:
- Porosity can serve as stress raisers for fracture
- Heat treatment and powder atomization is expensive

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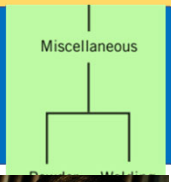
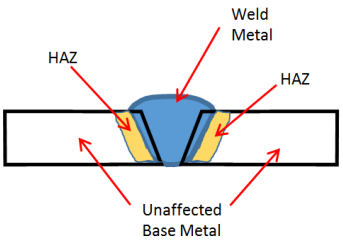
Miscellaneous: Welding



- Metallurgical joining of two or more metals to create a single piece
- Examples: arc and gas welding, brazing and soldering
- Local regions of workpieces and filler material (welding rods/wire) is heated until melted
- Molten filler material fills the fusion joint
- High temperatures: heat-affected zone (HAZ)



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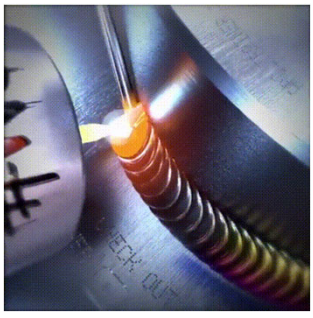

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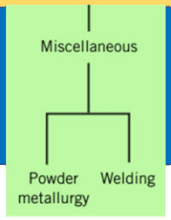
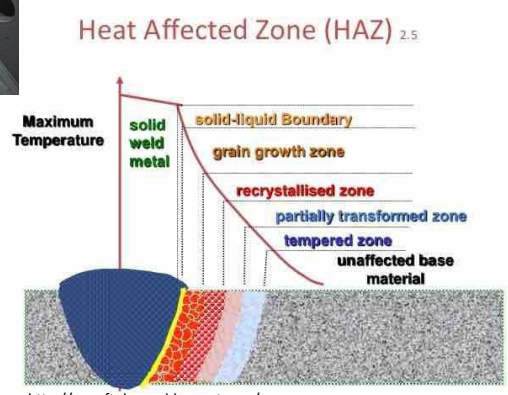
Miscellaneous: V



Changes due to HAZ:

- Heterogenous microstructure
- Cold-worked regions experience recrystallisation: reduced strength, hardness and toughness
- Temperature gradient induces residual stresses: cracking, corrosion
- Causes austenisation in steels: martensite upon cooling (brittle)
- Sensitize stainless steels: intergranular corrosion and weld decay

- Preheat the parts and cool gradually
- Use more localized heat input: laser beam welding
- Used for high precision (electronic/automotive industries)



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Next Lecture: Thermal Processing of Metals

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