Materials & Manufacturing Summer Institute
"How Things are Made"
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Introduction to Manufacturing Technologies

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I Introduction

Turning raw materials into products requires some combination of Science, Engineering, and imagination. It is often possible to make the same product using different manufacturing technologies. Using an example below, it is possible to make a pipe or tube by

Welding
Extruding
Drawing
Spray Cast
Casting
Or combinations of the above.

In selecting among the technologies, there are often no right and wrong solutions. There are only different advantages and disadvantages depending on the end use.

Manufacturing materials include Metals, Ceramics, and Polymers both singly and as composites. This brief introduction to manufacturing will concentrate on the fundamentals of metallurgy as applied to manufacturing.

II Fundamentals of Metallurgical Processing

1 Heat it
2 Beat it

III Introduction to Casting

Casting is a versitile process which can be done using Metals, Plastics, and Ceramics. The basic requirement is the material must be fluid enough to enter the mold and then solid enough to stand on its own after removing from the mold.

The basic processess for casting a material are:

Liquify some stuff, usually by heating
Pour (force) it into a mold
Solidify (Freeze) the stuff
Remove the product for subsequent processing

Science Issues	Melting Point Latent Heats Specific Heat Thermal Expansion / contraction Heat Transfer Surface Tension
Engineering Issues	Melt Temperature Mold Temperature Sprue Too much / too little Sprue – removing - Surface finishing Heat management

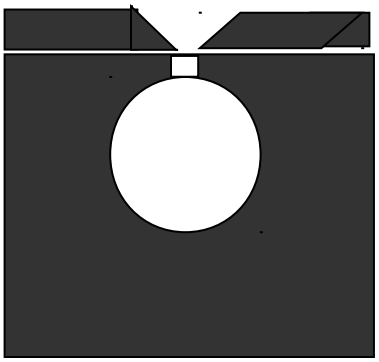
Other Casting Concepts

Single use Molds	Sand Casting Lost Wax Process
Injection Moulding	Force the material into the mold under pressure
Mouldless Casting	Shot towers
Slip Casting	Ceramic Slurries

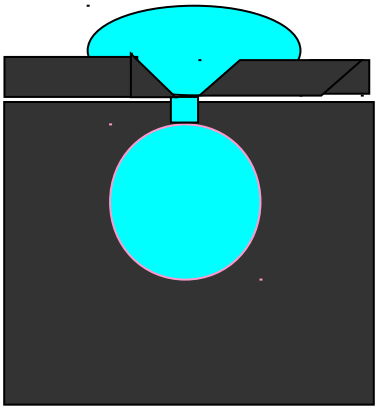
Group question: Where does this fit into a curiculum?

Casting Simplified
Clamshell Mold
(Typically Metals)

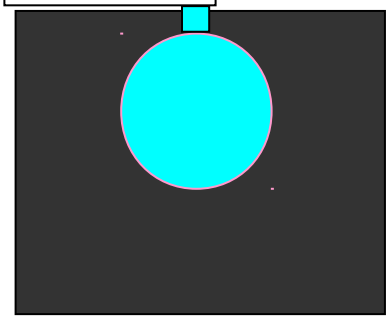
Empty Mold



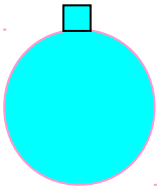
Mold filled with Metal



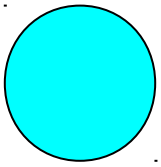
Open Mold



Remove Casting



Remove Sprue
Finish Surface If Required



Slip Casting of Ceramics

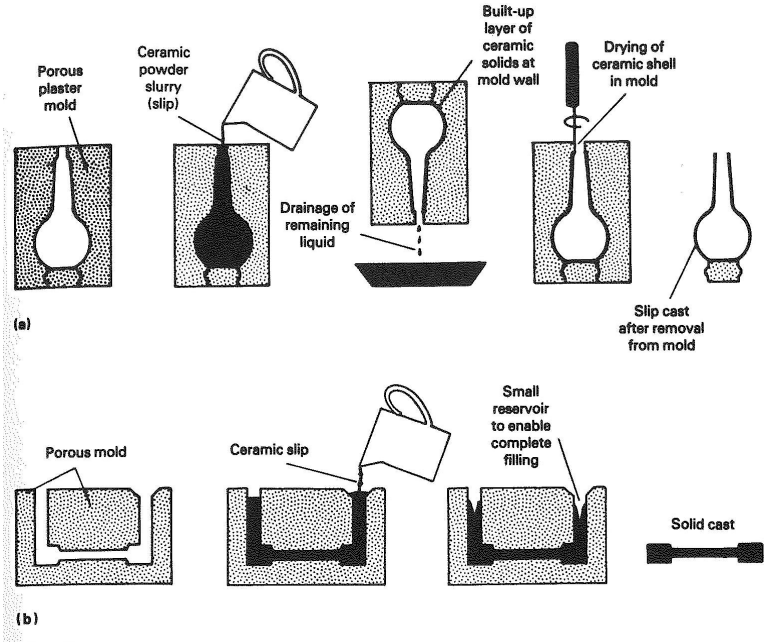


Fig 5 Ceramic slip casting process. (a) Drain casting. (b) Solid casting

Taken from ASM Engineered Materials Handbook

Sintering of Ceramics

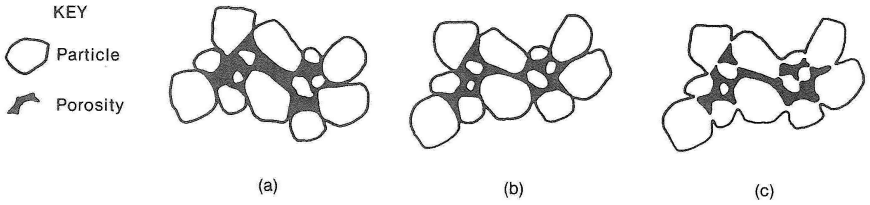


Figure 1. Changes which occur during the initial stage of sintering. (a) Starting particles, (b) rearrangement, and (c) neck formation.

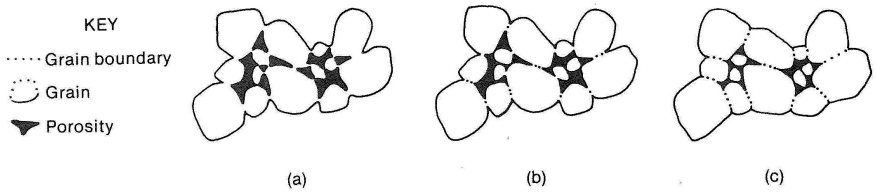


Figure 2. Changes which occur during the second stage of sintering. (a) Neck growth and volume shrinkage, (b) lengthening of grain boundaries, and (c) continued neck growth and grain boundary lengthening, volume shrinkage and grain growth.

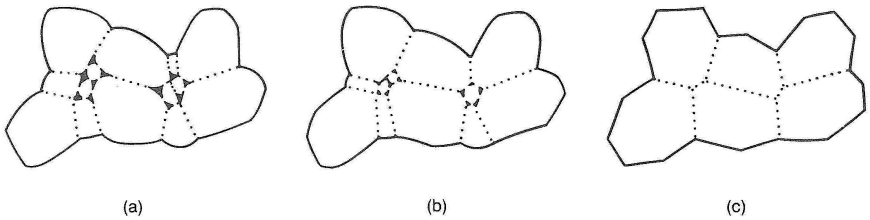


Figure 3. Changes which occur during the final stage of sintering. (a) Grain growth with discontinuous pore phase, (b) grain growth with porosity reduction, and (c) grain growth with porosity elimination.

Taken from ASM MEI Ceramics

IV Introduction to Forging

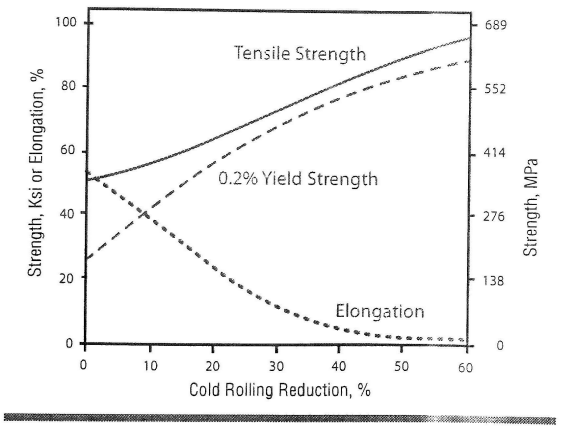
Forging is beating the raw material into shape. The basic requirement for forging is that the material be malleable. Thus forging is typically done for metals.

Science Issues	Work (Force times distance)
	Conservation of Energy
	Mechanical, thermal, and internal energy

More Science – Work Hardening – What doesn't kill you makes you stronger

When you work on a piece of metal, you put energy into it.
Some of the energy goes into deformation
Some of the energy goes into heat
Some of the energy goes into increasing the internal energy of the metal.
This internal energy affects the properties of the metal

FIGURE 4: Effect of Work Hardening on Tensile Strength, Yield Strength & Elongation (Ductility) of Annealed (Soft) Brass Alloy C26000



Taken from the Copper Devleopent Association

Processes related to forging include

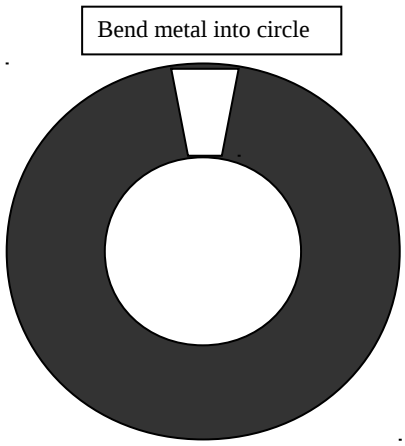
Transfer of surface features and finish	Embossing
Beating materials through a hole	Extrusion
Beating metal around corner	Bending
Forcing metal strip between roll	Rolling

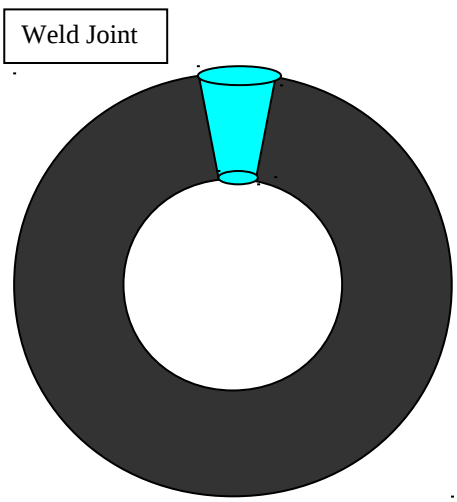
Group question: Where does this fit into a curiculum?

V Properties versus processing 2 – Welded Pipe

One common way to make pipe is to:

Cast a bar
Roll it flat to the desired wall thickness of a tube
Bend it into a tube
Weld the ends together





Microstructure of Weld Joint in Tube

A cross-section through a seam weld in a 400 series ferritic stainless steel tube. The seam exhibits a wide fusion zone and a large grain size contributing to brittleness of the weldment. (Mag: 25X)

http://www.met-tech.com/metallography.html

This gives a pipe with: A wrought structure over most of the circumference
A cast structure at the joint

These two structures have different properties

Platitude: Your manufacturing process may affect the properties of your materials

VI Other manufacturing processes which we don't have time to discuss:

Cleaning
Cleaning
Cleaning
Cleaning
Machining
Powder Processing
Cutting, shearing, slitting
Drawing
Stamping
Cupping
Joining
Heat treating / cryogenic treating
Electroforming, plating
Spraying
Vapor deposition
Dipping
Etc

VII Conclusions

Your manufacturing process will depend on:

The desired properties of your product
The properties of your feedstock
Science and Engineering
Money
Your imagination

Group question: Where does this fit into a curiculum?