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
Casting is a versatile 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 processes 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 curriculum?
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

![Diagram of slip casting process]

Fig 5 Ceramic slip casting process. (a) Drain casting. (b) Solid casting. Taken from ASM Engineered Materials Handbook

Sintering of Ceramics

![Diagram of sintering process]

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

![Diagram of sintering process]

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.

![Diagram of sintering process]

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](image)

Taken from the Copper Development 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 curriculum?
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
- 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 curriculum?