

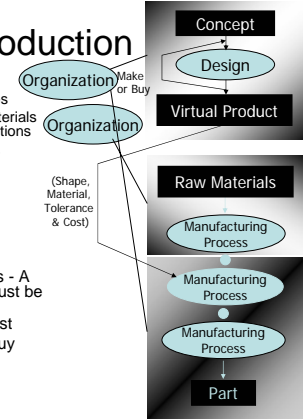
# ME477: Manufacturing Processes

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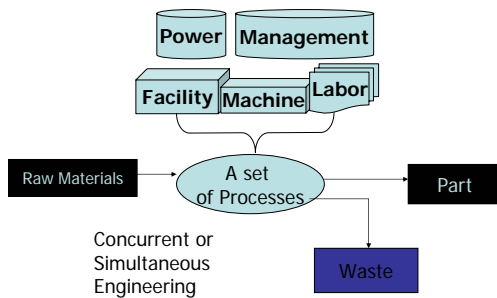
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## Introduction

- Manufacturing?
  - Making goods and articles
  - Shaping and treating Materials to perform desirable functions
- Manufacturing Processes
  - Casting
  - Powder Processing
  - Forming
  - Machining
  - Surface processing
  - Joining
- To make good and articles - A sequence of processes must be chosen, based on shape, material, tolerance and cost
- Before MFG, a Make or Buy decision
  - Process Design
  - Production Systems



## Manufacturing as a set of processes



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## Manufacturing

- Manufacturing: 20% of U.S. GNP
- Service sector: 70% of U.S. GNP (retail, transportation, banking, education, communication, insurance and government).
- Agriculture, Construction etc.: 10% of U.S. GNP
- Manufacture comes from the Latin words *manus* (hand) and *factus* (make).
- Definition: the application of physical and chemical processes to alter the geometries, properties and appearance of a starting material in order to make and assemble it into a product.

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## Manufacturing Processes

### Casting Process

Ingot Casting  
Crystal Growing  
Sand Casting  
Shell Molding  
Slurry Molding  
Investment Casting  
Evaporative Casting  
Die Casting  
Centrifugal Casting  
Squeeze Casting  
Rheocasting

### Powder Processing

Pressing  
Hot Isostatic Pressing  
Cold Isostatic Pressing  
Pressureless Sintering

### Deformation Processing

Open Die Forming  
Impression Die Forming  
Closed Die Forming  
Rolling  
Extrusion  
Drawing  
Deep Drawing  
Swaging  
Shearing  
Bending  
Stretch forming  
Bulging  
Beading, Flanging,  
Hemming & Seaming  
Explosive forming  
Electrohydraulic forming  
Magnetic-pulse forming  
Superplastic forming

### Machining

Turning  
Boring  
Facing  
Forming  
Drilling  
Milling  
Threading  
Broaching  
Sawing, Filing  
Grinding  
Honing  
Lapping  
Ultrasonic Machining  
Buffing  
Polishing  
Chemical Machining  
Electrochemical Machining  
Laser Machining  
Plasma Arc Cutting  
Electron Beam Machining

## More Manufacturing Processes

### Polymer Processing

Extrusion  
Blow Molding  
Injection Molding  
Reaction Injection Molding  
Compression Molding  
Transfer Molding  
Casting  
Thermoforming  
Rotational Molding  
Solid State Molding

### Composite Processing

• Polymer Matrix Composite  
Pultrusion  
Filament Winding  
Braiding  
Autoclave Molding  
Compression Molding  
Resin Transfer Molding  
Hand Lay-up  
Spray-up  
Automatic Tape Lay-up  
Diaphragm Molding  
Solid State Molding  
• Metal Matrix Composite  
Hot Pressure Bonding  
Hot Isostatic Pressing  
Liquid Metal Infiltration  
Electrodeposition  
Plasma Spray deposition

### Microelectronic Processing

• Crystal Growth  
Czochralski growth  
Float Zone Crystal Growth  
• Wafer Processing  
Slicing, Etching, Polishing  
• Surface Processing  
• Oxidation  
• Lithograph  
• Wet Etching  
• Dry Etching  
• Packaging

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## Historical Note

- Powder processing (Clay) (4000BC)
- Casting - Lost Wax...Centrifugal casting (2500BC- 1850)
- The First Industrial Revolution (1760-1830)
  - Adam Smith (1723-1790) - division of labor
  - James Watt – Steam Engine
  - John Wilkinson – Machine tools
  - Eli Whitney (1797) – Interchangeable parts
- Henry Ford (1913) – Assembly line
- The Second Industrial Revolution (1950-)
  - Invention and Use of computers
  - Microchips

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## The importance of manufacturing

Underestimated in the development of civilization.

- Cultures with better manufacturing capabilities were more successful.
- Better tools, better crafts & weapons
  - Damascus and Samurai Swords
  - Shaving blade
  - Turbine blade
    - Making Superalloys
    - Cooled blade - Small holes to cool off
    - Directionally solidified
- To a significant degree, the history of civilization is the history of humans' ability to make things

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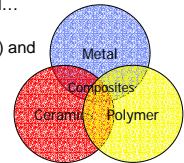
## Manufacturing Industries

- Industry consists of enterprises and organizations that produce or supply goods and services
  - Primary – Agriculture, Forestry, Mining, Fishing
  - Secondary – Aerospace, Automotive, Electronics etc.
  - Tertiary – service sectors such as Banking, Education, Government
- Consumer goods and Capital goods
- Discrete vs. Continuous production
- Production quantity and variety

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## Materials in Manufacturing

- Metals
  - Ferrous – steels and cast iron (¾ of metals used)
  - Nonferrous – aluminum, titanium, nickel...
- Ceramics
  - A compounds of metallic (semi-metallic) and nonmetallic
- Polymers
  - Thermoplastic
  - Thermosetting
  - Elastomers
- Composites – Matrix & Second phases
- Thermomechanical Behavior
  - Elastic, plastic, fatigue, thermal
  - Electrical, Magnetic, Optical, Chemical



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## Production and Energy

Materials	World Production (10 <sup>6</sup> Mg)		Energy Consumption (MJ/kg)	
	1972	1994	From Ore	From Scrap
Iron	634	750	35	14
Aluminum	11	19.4	240	13
Copper	7	11.5	120	20
Zinc	5.2	7.1	70	20
Lead	3.6	5.4	30	10
Nickel	0.6	0.9	150	16
Magnesium	0.26	0.34	380	10
Titanium	0.06	0.1	550	
Plastics		130	170	
Plywood			10	

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## Geometric Attributes (Shape)

Shape Classification	0 Uniform	1 Change at end	2 Change at center	3 Spatial Curve	4 Closed One End	5 Closed Both End	6 Transverse element	7 Irregular
Round								
Bar								
Section								
Tube								
Flat								
Spherical								
Undercut								

Tolerance and Surface Roughness

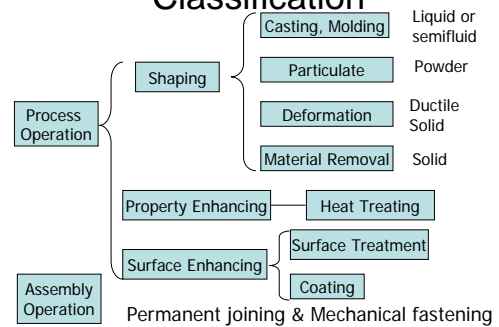
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## Scope and Purpose

- Processing
  - Information – Nature of process, Process variety
  - Physical Principal
- Standard
  - American National Standard Institute (ANSI)
  - American Society for Testing and Materials (ASTM)
  - American Society of Mechanical Engineers (ASME)
  - American Society of Precision Engineering (ASPE)
- Society
  - ASME, Society of Manufacturing Engineers (SME), ASPE
- Units – SI (and English Unit)

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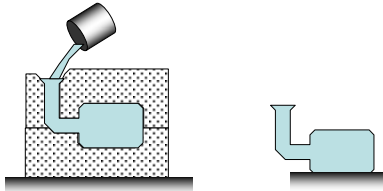
## Manufacturing Processes - Classification



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## Solidification Processes

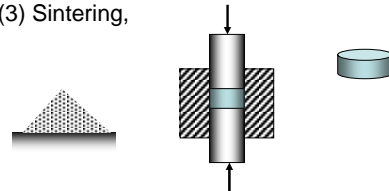
- Starting material is heated sufficiently to transform it into a liquid or highly plastic state
- Examples: Casting for metals, molding for plastics



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## Particulate Processing

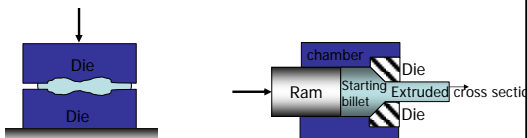
- (1) Starting materials: powders of metals or ceramics
- (2) Pressing
- (3) Sintering,



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## Deformation Processing

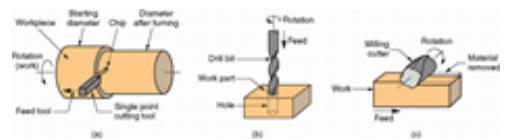
- Starting workpart is shaped by application of forces that exceed the yield strength of the material
- Examples: (a) forging, (b) extrusion and etc.



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## Material Removal Processes

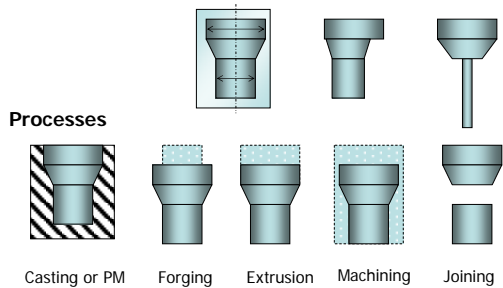
- Excess material removed from the starting workpiece so what remains is the desired geometry
- Examples: machining such as (a) turning, (b) drilling, and (c) milling; also grinding and nontraditional processes



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## Alternative Processes

Design: Geometry, Material, Surface finish, Tolerance



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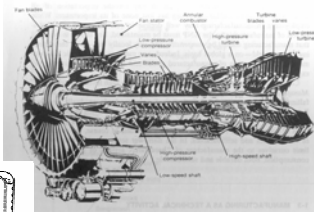
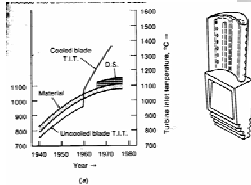
## Other Processing Operation

- Property Enhancing Processes
  - Heat Treatment: Improve physical properties of the material without changing its shape
  - Alloying:
  - Composites
- Surface Processing – cleaning, surface treatment and coating deposition

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## Example (from Ashby & Jones)

- Turbine blade
  - High Temperature Alloy
  - Directional Solidification
  - Cooling – making holes on High Temperature Alloys



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## Manufacturing Capability

- Technical process capability
  - A capable set of manufacturing processes
- Physical product limitation
  - Size and weight limitation
- Production capacity
  - An important influence on the way its people, facilities, and procedures are organized

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## Production Systems

- Production facilities
  - Low-quantity Production (1~100 units/year) – job shop, prototyping
  - Medium-quantity Production (100~10,000 units/year) – Batch production and cellular manufacturing
  - High-quantity Production (10,000~millions of units/year) – mass production
  - Two categories of mass production:
    1. Quantity production - Mass production of single parts on single machine or small numbers of machines
    2. Flow line production - Multiple machines or workstations arranged in sequence, e.g., production line

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## Manufacturing Support Systems

- A company must organize itself
  - To design the processes and equipment,
  - To plan and control the production orders, and
  - To satisfy product quality requirements
- Manufacturing support systems to manages its production operations
  - Manufacturing Engineering – planning mfg processes
  - Production planning and control – logistics problems in manufacturing
  - Quality control

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