

Module II: Material Shaping Processes

This module covers the fundamentals of shaping materials into desired geometries using various manufacturing techniques. These processes do not involve material addition or removal but rather change the shape of a workpiece through deformation, phase change, or consolidation.

1. Metal Casting Processes

Casting involves pouring molten metal into a cavity (mold) where it solidifies into the shape of the mold.

a) Sand Casting

- **Process:** Uses a sand mold that forms a cavity around the pattern of the desired shape.
- **Materials:** Commonly used with aluminum, cast iron, brass, steel.
- **Advantages:**
 - Low tooling and production cost.
 - Suitable for complex shapes and large components.
- **Limitations:**
 - Rough surface finish.
 - Lower dimensional accuracy.

b) Die Casting

- **Process:** Molten metal is injected under pressure into a steel mold (die), then allowed to solidify.
- **Materials:** Typically non-ferrous metals like zinc, aluminum, magnesium.
- **Advantages:**
 - High accuracy, surface finish, and production rate.
- **Limitations:**
 - High setup cost.
 - Limited to low-melting-point metals.

c) Investment Casting (Lost-wax casting)

- **Process:** A wax model is coated with ceramic material. After the wax is melted and removed, molten metal is poured into the ceramic mold.
- **Materials:** Metals like stainless steel, aluminum, and tool steels.
- **Advantages:**
 - Excellent surface finish and complex shapes.
 - High dimensional accuracy.
- **Limitations:**
 - Higher cost due to the process and tooling.

2. Bulk Deformation (Bulk Forming) Processes

These processes involve deforming metals above or near room temperature to change the shape and improve material properties.

a) Forging

- **Process:** Deforming metal using compressive forces (hammering or pressing).
- **Types:**
 - Open-die forging (simple shapes)
 - Closed-die forging (precision parts)
- **Advantages:**
 - High strength due to grain refinement.
- **Common Products:** Crankshafts, gears, connecting rods.

b) Rolling

- **Process:** Metal is passed through rollers to reduce thickness.
- **Types:**
 - Hot rolling (better formability)
 - Cold rolling (better surface finish and strength)
- **Products:** Sheets, bars, plates.

c) Extrusion

- **Process:** Pushing metal through a die to create long profiles with a fixed cross-section.
- **Types:**
 - Direct and indirect extrusion.
- **Materials:** Aluminum, copper.
- **Products:** Pipes, rods, window frames.

d) Drawing

- **Process:** Pulling metal through a die to reduce diameter and increase length.
- **Application:** Wire, tubes, metal rods.

3. Sheet Metal Forming Processes

Involves plastic deformation of metal sheets into desired 2D or 3D shapes.

a) Shearing

- **Process:** Cutting straight lines in sheet metal using punches and dies.
- **Application:** Blanking, piercing.

b) Deep Drawing

- **Process:** Flat sheet metal is formed into a hollow shape using a punch and die.
- **Products:** Beverage cans, kitchen sinks.

c) Bending

- **Process:** Metal sheet is deformed to an angle using press brakes or dies.
- **Common shapes:** V-bends, U-bends.

4. Plastic Forming Processes

Distinguished based on the type of plastic: **thermoplastics** (can be reheated and remolded) and **thermosets** (irreversible after curing).

a) Injection Molding

- **Process:** Plastic pellets are melted and injected into a mold cavity under pressure.
- **Use:** Producing high-volume plastic parts with excellent details (e.g., toys, containers, electronic casings).
- **Materials:** Polypropylene, ABS, Nylon.

b) Blow Molding

- **Process:** Air pressure is used to inflate molten plastic into the shape of a mold.
- **Types:** Extrusion blow, injection blow, stretch blow molding.
- **Products:** Plastic bottles, containers.

5. Powder Metallurgy (PM)

- **Process:**
 1. Powder production.
 2. Compaction of powder in a die.
 3. Sintering (heating below melting point to bond particles).
- **Advantages:**
 - Near-net shape.
 - Minimal material waste.
- **Applications:** Gears, bearings, porous filters, hard materials.

6. Metal Injection Molding (MIM)

- **Hybrid process** combining injection molding and powder metallurgy.
- **Process:**
 1. Mix metal powder with polymer binder.
 2. Inject into mold.
 3. Debind and sinter the part to remove binder and densify metal.
- **Advantages:**
 - Complex shapes, tight tolerances.
 - High strength and surface finish.
- **Applications:** Medical devices, aerospace components, firearm parts.

7. Glass and Composite Manufacturing

a) Layup Process (Hand Lay-Up / Spray Lay-Up)

- **Used For:** Fiber-reinforced polymer (FRP) composite components.
- **Process:**
 1. Layers of reinforcement material (like fiberglass, carbon fiber) are placed in a mold.
 2. Resin is applied manually (hand lay-up) or using a spray gun (spray lay-up).
 3. The part is cured and removed.
- **Advantages:**
 - Low tooling cost.
 - Custom and low-volume large parts.
- **Applications:** Boat hulls, windmill blades, panels.

Summary Table

Process	Material Type	Application	Key Advantage
Sand Casting	Metals (ferrous/non)	Engine blocks, pump housings	Low cost, complex shapes
Die Casting	Non-ferrous metals	Automotive parts, electronics	High volume, good finish
Investment Casting	Metals	Aerospace components, dental implants	Precision, intricate features
Forging	Metals	Shafts, gears, tools	Strength and impact resistance
Rolling/Extrusion	Metals	Sheets, pipes, profiles	Continuous production
Deep Drawing/Bending	Sheet metal	Cans, enclosures, utensils	Efficient 2D/3D forming
Injection Molding	Thermoplastics	Toys, caps, plastic parts	High production rate, fine details
Blow Molding	Thermoplastics	Bottles, containers	Hollow shapes, high volume
Powder Metallurgy	Metals (powder form)	Bearings, filters, gears	Complex shapes, low waste
Metal Injection Molding	Metal powders + binders	Medical, defense, electronics	Precision, high strength
Layup (Composites)	Glass/carbon + resin	Aerospace, marine, automotive	Lightweight, custom large parts

By understanding these shaping processes, engineers and designers can make informed decisions based on material, shape, production volume, and performance requirements, leading to efficient and cost-effective manufacturing.