GLOBAL MANUFACTURING

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Changing Schedule:

- 5 - 24/8 - Fabrication of Plastic, Ceramics and Composites
- 6 - 26/8 – Fabrication of Ceramics and Composites ~~Additive Manufacturing~~
- 7 - 31/8 - Powder Metallurgy and Additive Manufacturing ~~Metal Forming Processes~~
- 8 - 02/9 - Metal Forming Processes ~~Powder Metallurgy~~

Fabrication of Plastics, Ceramics and Composites [#5]

FABRICATION OF CERAMICS

- The fabrication processes applied to ceramic materials generally fall into two distinct classes, based on the properties of the material.
- Glasses can be manufactured into useful articles by first heating the material to produce a molten or viscous state, shaping the material by means of viscous flow, and then cooling the material to produce a solid product.
- Crystalline ceramics have a characteristically brittle behavior and are normally manufactured into useful components by pressing moist aggregates or powder into a shape, followed by drying, and then bonding by one of a variety of mechanisms, which include chemical reaction, vitrification (cementing with a liquefied material), and sintering (solid-state diffusion).

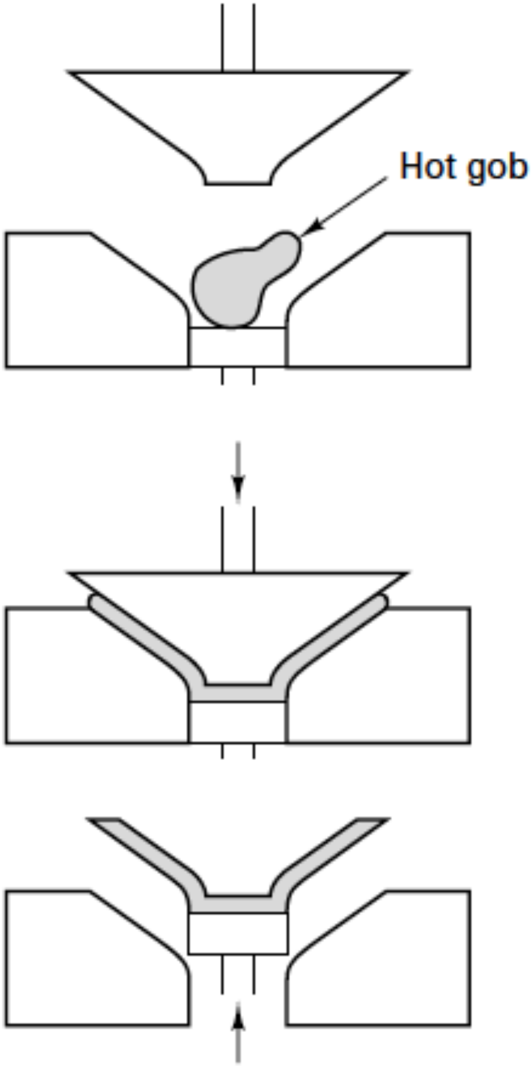


FIGURE 14-18 Viscous glass can be easily shaped by mating male and female die members.

Glassworking

Casting of Glass: How to produce glass?

The principal starting material is silica (SiO_2) combined with other oxide ceramics that form glasses. The starting material is heated to transform it from a hard solid into a viscous liquid; it is then shaped into the desired geometry while in this highly plastic or fluid condition. When cooled and hard, the material remains in the glassy state rather than crystallizing.

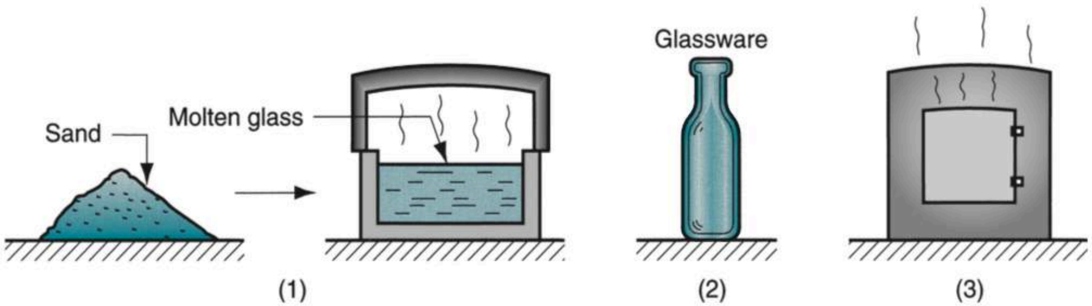


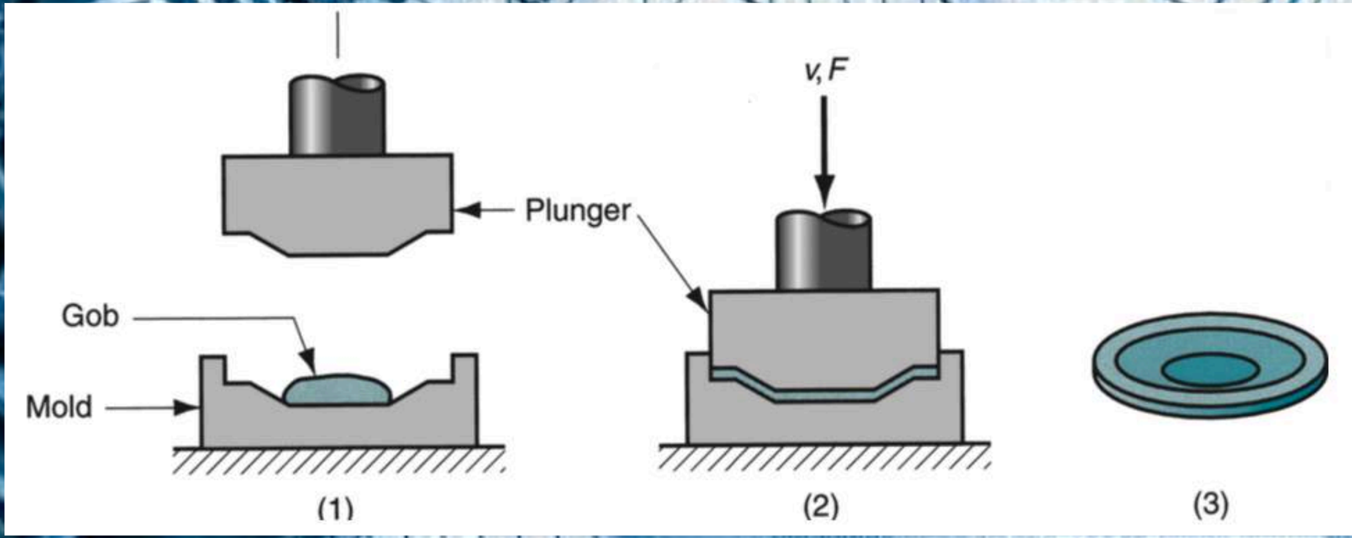
FIGURE 7.1 The typical process sequence in glassworking: (1) preparation of raw materials and melting, (2) shaping, and (3) heat treatment. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

https://www.youtube.com/watch?v=yvqLtTUlZcA

- **Prepare**
  - Washing and Classifing
- **Add**
  - soda ash (source of Na_2O) Limestone (source of CaO), aluminum oxide, potash (source of K_2O), and other minerals
- **Mix**
  - Batch of starting materials to be melted is referred to as a charge
- **Melting**
  - Glass melting is generally carried out at temperatures around 1500C to 1600C (2700F to 2900F). The melting cycle for a typical charge takes 24 to 48 hours.
- **Shape**
  - SHAPING PROCESSES

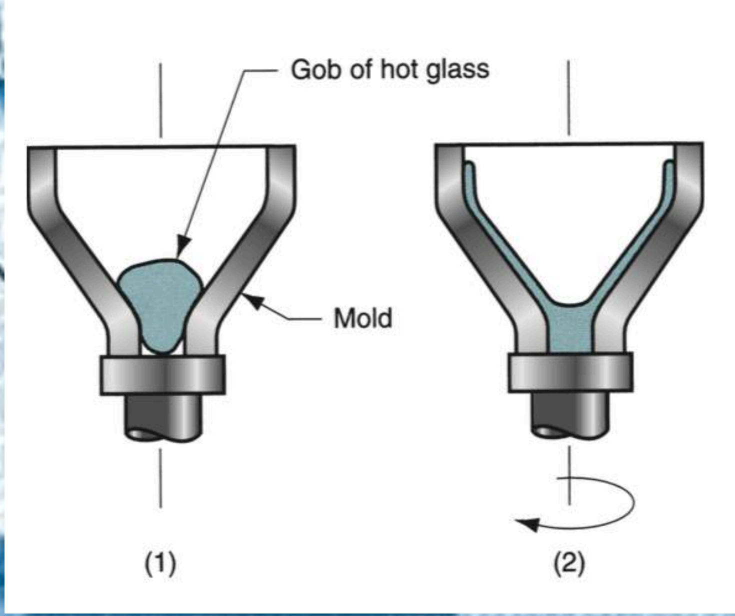
SHAPING PROCESSES

Pressing is a widely used process for mass-producing glass pieces such as dishes, bakeware, headlight lenses, and similar items that are relatively flat.



SHAPING PROCESSES

Spinning Glass is similar to Centrifugal casting of metals, and is also known by that name in glassworking. It is used to produce funnel-shaped components.



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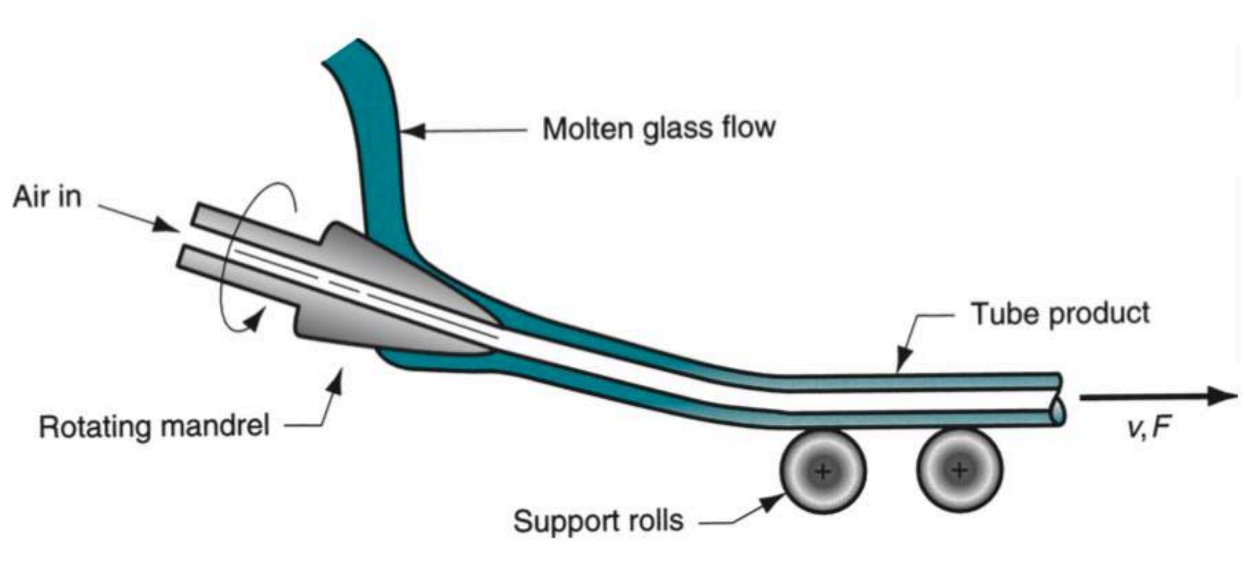
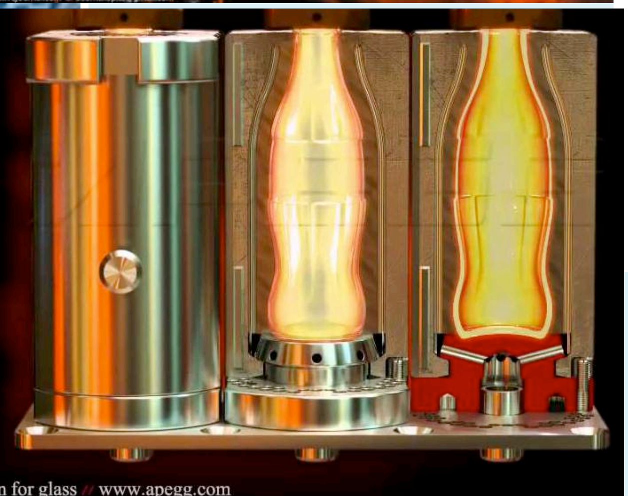
Agob of molten glass is dropped into a conical mold made of steel.
The mold is rotated so that centrifugal force causes the glass to flow upward and spread itself on the mold surface.

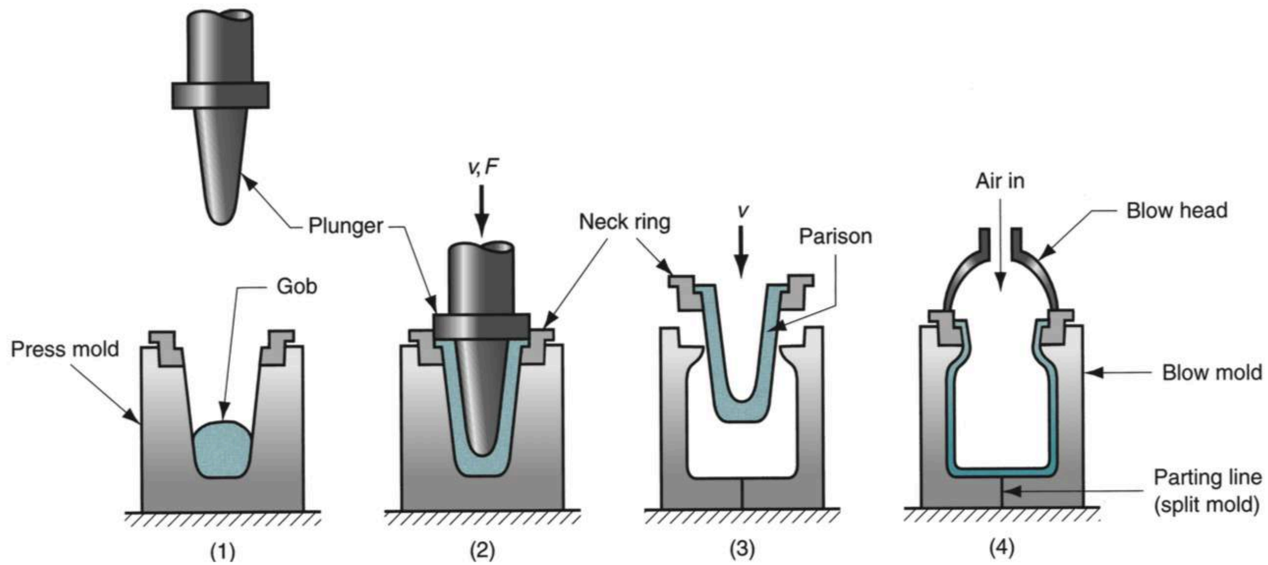
DANNER PROCESS (GLASS TUBES)

Molten glass flows around a rotating hollow mandrel through which air is blown while the glass is being drawn. The air temperature and its volumetric flow rate, as well as the drawing velocity, determine the diameter and wall thickness of the tubular cross section. During hardening, the glass tube is supported by a series of rollers extending about 30 m (100 ft) beyond the mandrel. The continuous tubing is then cut into standard lengths. Tubular glass products include laboratory glassware, fluorescent light tubes, and thermometers.

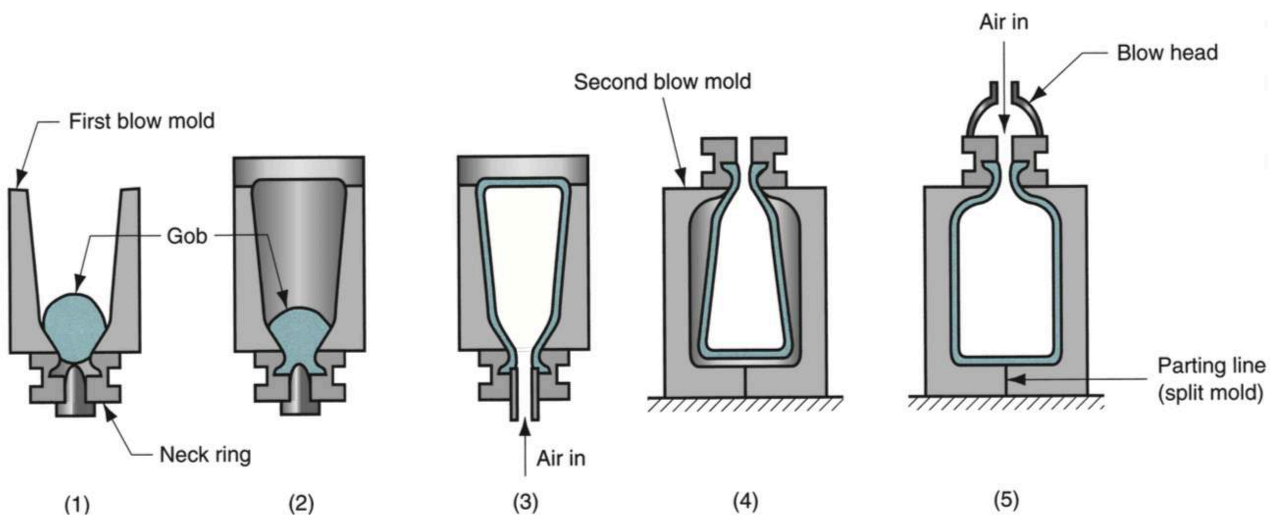




Press-and-blow forming sequence:



Blow-and-blow forming sequence:



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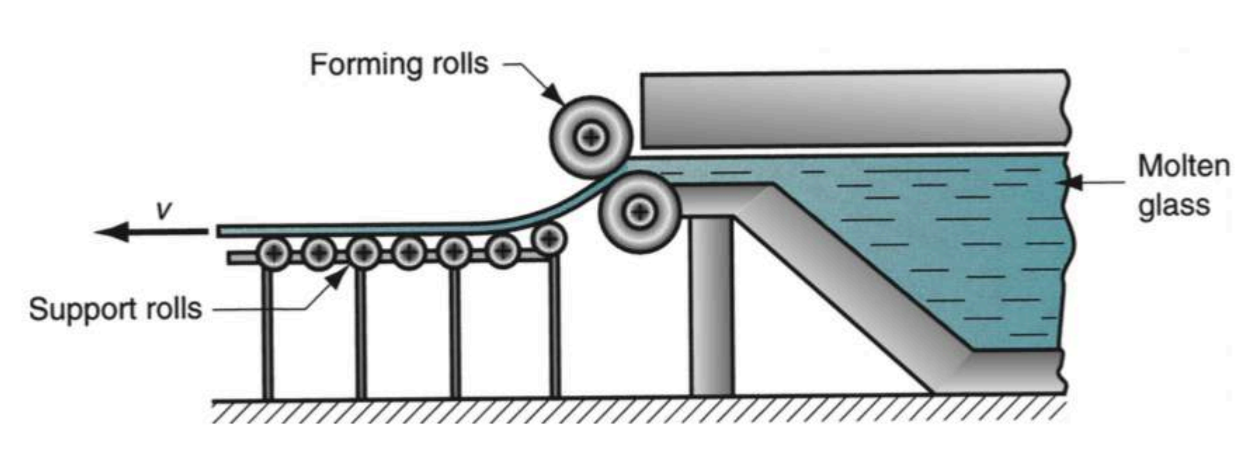
Rolling of flat glass



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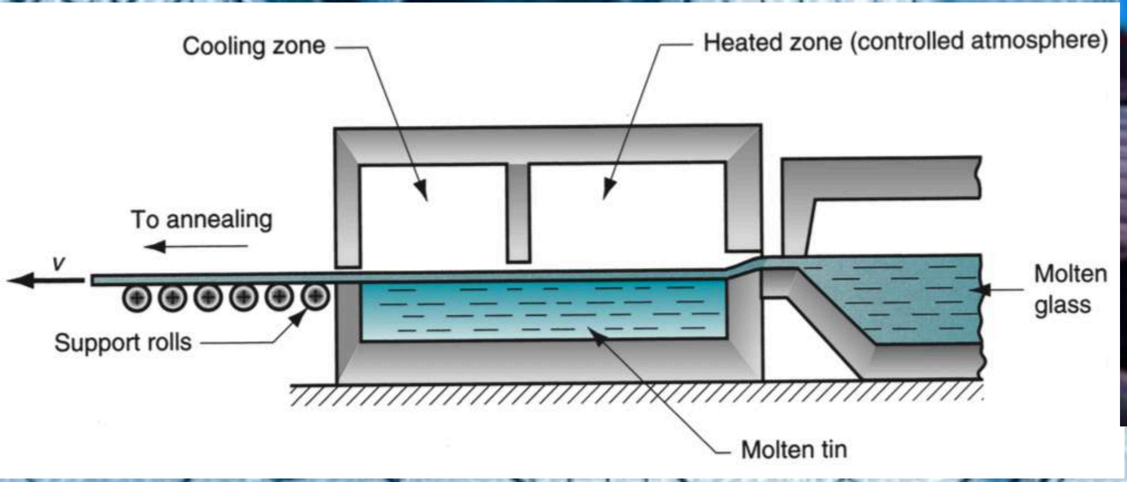
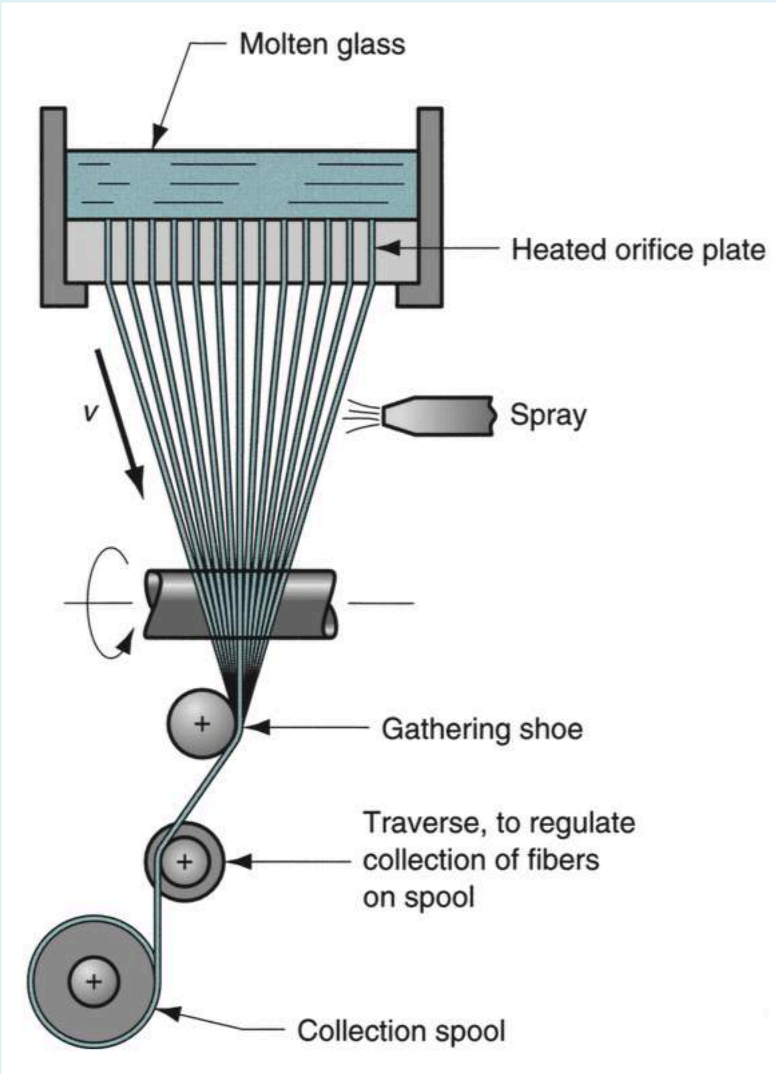
The float process for producing sheet glass.



Drawing of continuous glass fibers



Continuous glass fibers of small diameter (lower size limit is around 0.0025 mm or 0.0001 in) areproduced by drawing (pulling) strands of molten glass through small orifices in a heated plate made of a platinum alloy. The plate may have several hundred holes, each making one fiber. The individual fibers are collected into a strand by reeling them onto a spool. Prior to spooling, the fibers are coated with various chemicals to lubricate and protect them. Drawing speeds of around 50 m/s (10,000 ft/min) or more are not unusual.

Heat Treatment

Glass products usually have undesirable internal stresses after forming, which reduce their strength.

Annealing is done to relieve these stresses; Annealing involves heating the glass to an elevated temperature and holding it for a certain period to eliminate stresses and temperature gradients, then slowly cooling the glass to suppress stress formation, followed by more rapid cooling to room temperature (around 500C). Annealing in modern glass factories is performed in tunnel-like furnaces, called lehrs, in which the products flow slowly through the hot chamber on conveyors.

A beneficial internal stress pattern can be developed in glass products by a heat treatment known as tempering, and the resulting material is called tempered glass to increase the toughness of glass. The process involves heating the glass to a temperature somewhat above its annealing temperature and into the plastic range, followed by quenching of the surfaces, usually with air jets. When the surfaces cool, they contract and harden while the interior is still plastic and compliant. As the internal glass slowly cools, it contracts, thus putting the hard surfaces in compression. Like other ceramics, glass is much stronger when subjected to compressive stresses than tensile stresses.

How many pieces can be produced?

How the product looks like?

COMPOSITES MANUFACTURING

A composite is a material consisting of two or more phases that are processed separately and then bonded together to achieve properties superior to those of its constituents.

The term phase refers to a homogeneous mass of material, such as an aggregation of grains of identical unit cell structure in a solid metal.

The usual structure of a composite consists of particles or fibers of one phase mixed in a second phase, called the matrix.

Composites

1. Metal-Matrix Composites (MMC) include mixtures of ceramics and metals, such as cemented carbides and other cermets, as well as aluminum or magnesium reinforced by strong, high stiffness fibers.
2. Ceramic-Matrix Composites (CMC) are the least common category. Aluminum oxide and silicon carbide are materials that can be imbedded with fibers for improved properties, especially in high temperature applications.
3. Polymer-Matrix Composites (PMC) Thermosetting resins are the most widely used polymers in PMCs. Epoxy and polyester are commonlymixed with fiber reinforcement, and phenolic is mixed with powders. Thermoplastic molding compounds are often reinforced, usually with powders.

Fiber-reinforced polymers (FRP) can be designed with very high strength-to-weight and stiffness-to-weight ratios. These features make them attractive in aircraft, cars, trucks, boats, and sports equipment.

Production of Fiber-Reinforced Materials

FRP composite shaping processes can be divided into five categories:

(1) open mold processes,

(2) closed mold processes,

(3) filament winding,

(4) pultrusion processes, and

(5) other.

Polymer Matrix

Thermosetting (TS) polymers are the most common matrix materials. The principal TS polymers are phenolics, unsaturated polyesters, and epoxies. Thermoplastic (TP) polymers are also used in PMCs, and in fact, most molding compounds are composite materials that include fillers and/or reinforcing agents.

The Reinforcing Agent

The reinforcing phase can be any of several geometries and materials. The geometries include fibers, particles, and flakes, and the materials are ceramics, metals, other polymers, or elements such as carbon or boron. Common fiber materials in FRPs are glass, carbon, and the polymer Kevlar.

COMBINING MATRIX AND REINFORCEMENT

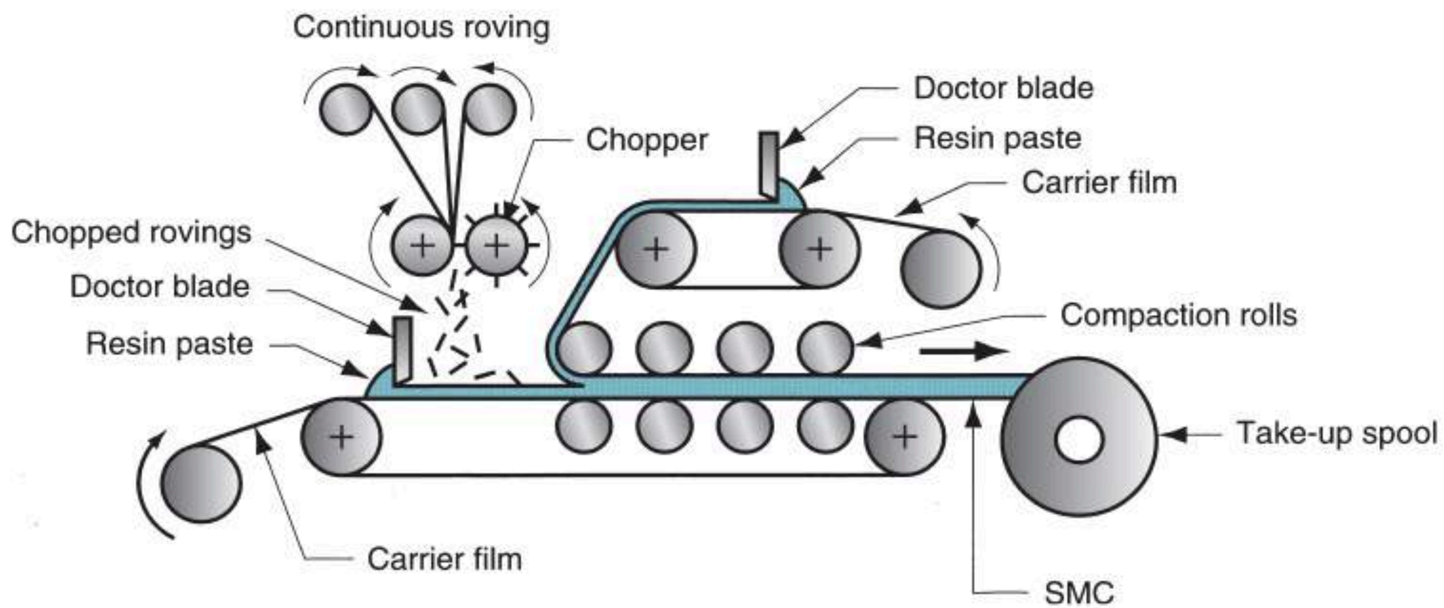


FIGURE 9.8 Process for producing sheet molding compound (SMC). (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

Sheet molding compound (SMC) is a combination of TS polymer resin, fillers and other additive and chopped glass fibers (randomly oriented) all rolled into a sheet of typical thickness . 6.5 m (0.250 in). The most common resin is unsaturated polyester; fillers are usually mineral powde such as talc, silica, limestone; and the glass fibers are typically 12 to 75 mm (0.5 to 3.0 in) long an account for about 30% of the SMC by volume. SMCs are very convenient for handling and cuttin to proper size as molding charges. Sheet molding compounds are generally produced between thi layers of polyethylene to limit evaporation of volatiles from the thermosetting resin. The protectiv coating also improves surface finish on subsequent molded parts.

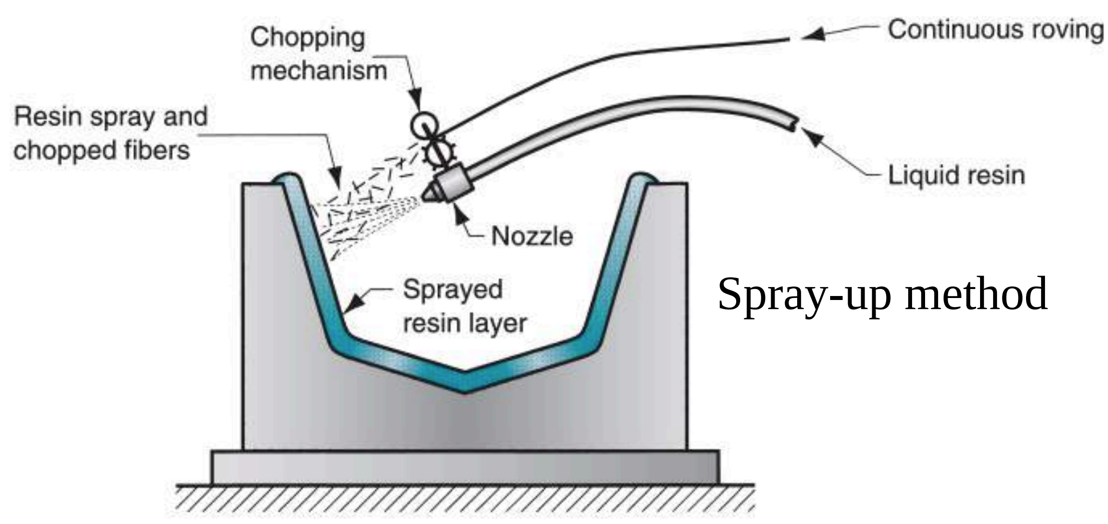
COMBINING MATRIX AND REINFORCEMENT

- Bulk molding compound (BMC) consists of similar ingredients as those in SMC, but the compounded polymer is in billet form rather than sheet. The fibers in BMC are shorter, typically 2 to 12 mm (0.1 to 0.5 in), because greater fluidity is required in the molding operations for which these materials are designed. The process for producing BMC is similar to that for SMC, except extrusion is used to obtain the final billet form.

- Prepregs: Another prefabricated form for FRP shaping operations is prepreg, which consists of fibers impregnated with partially cured thermosetting resins to facilitate shape processing. Completion of curing must be accomplished during and/or after shaping. Prepregs are available in the form of tapes or cross-plied sheets or fabrics. The advantage of prepregs is that they are fabricated with continuous filaments rather than chopped random fibers, thus increasing strength and modulus of the final product. Prepreg tapes and sheets are associated with composites that are reinforced with boron, carbon/ graphite, Kevlar, or fiberglass.

https://www.youtube.com/watch?v=-KgKcnoJypk

Open Mold / Close Mold (Injection and compression)



Spray-up method

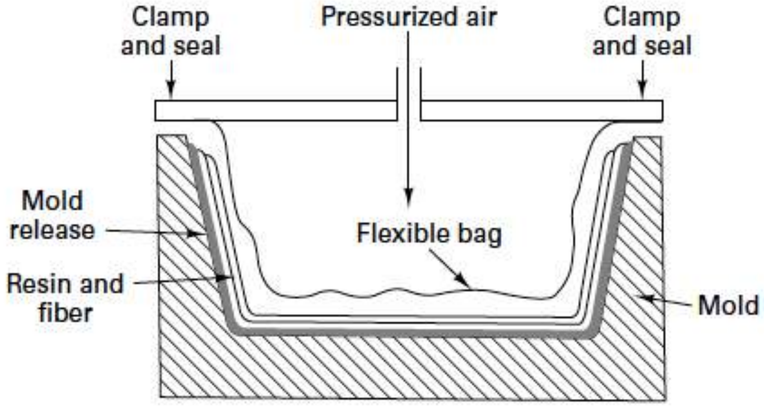


FIGURE 14-25 Schematic of the pressure-bag process.

FILAMENT WINDING

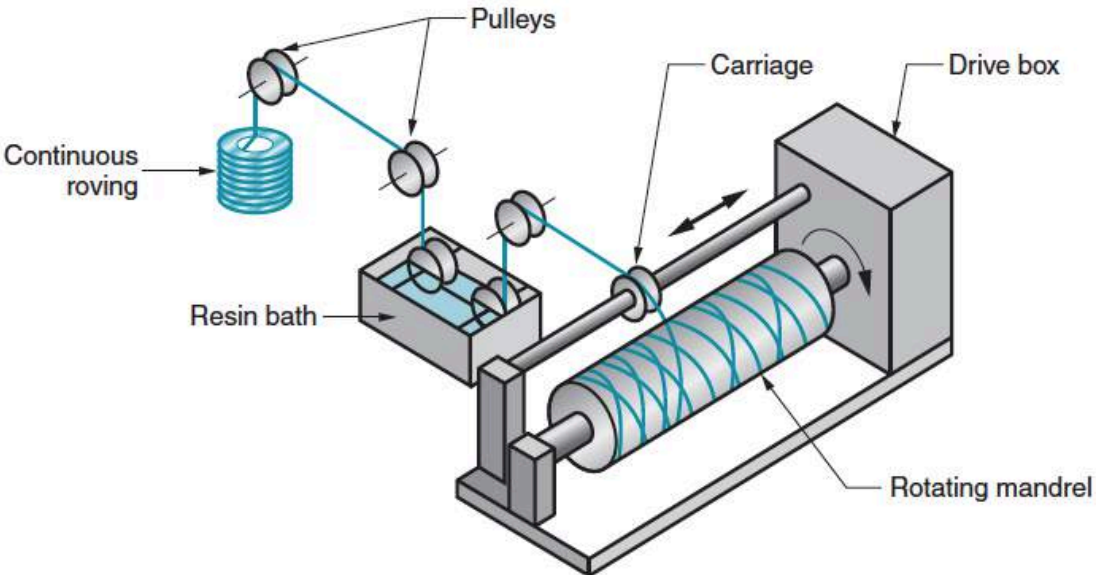


FIGURE 9.12 Filament winding. (Credit: *Fundamentals of Modern Manufacturing,* 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

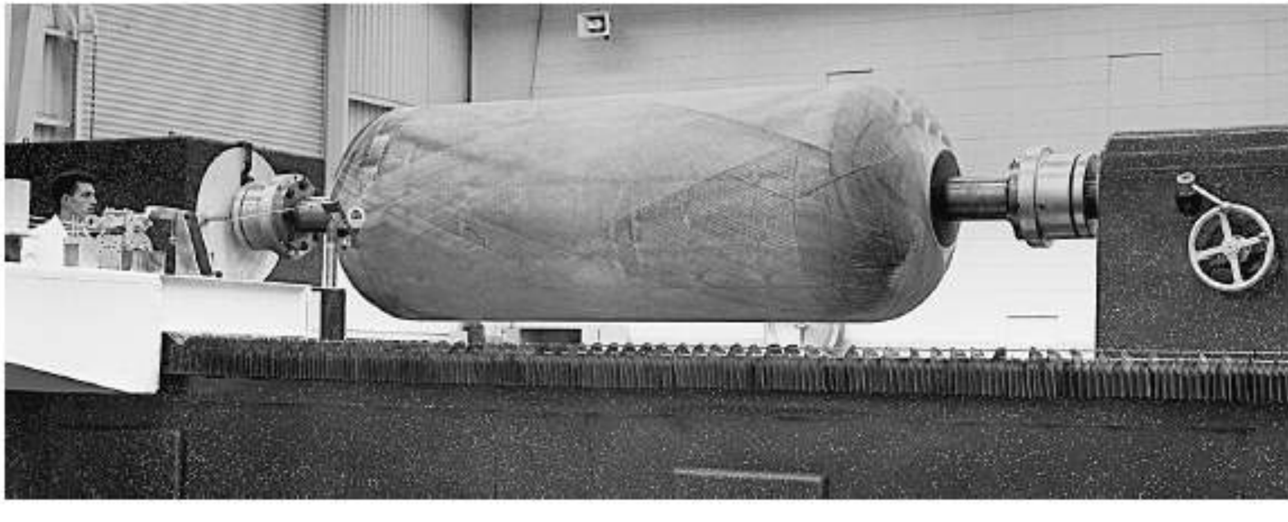


FIGURE 14-22 A large tank being made by filament winding. *(Courtesy of Rohr Inc./Goodrich)*

PULTRUSION PROCESSES

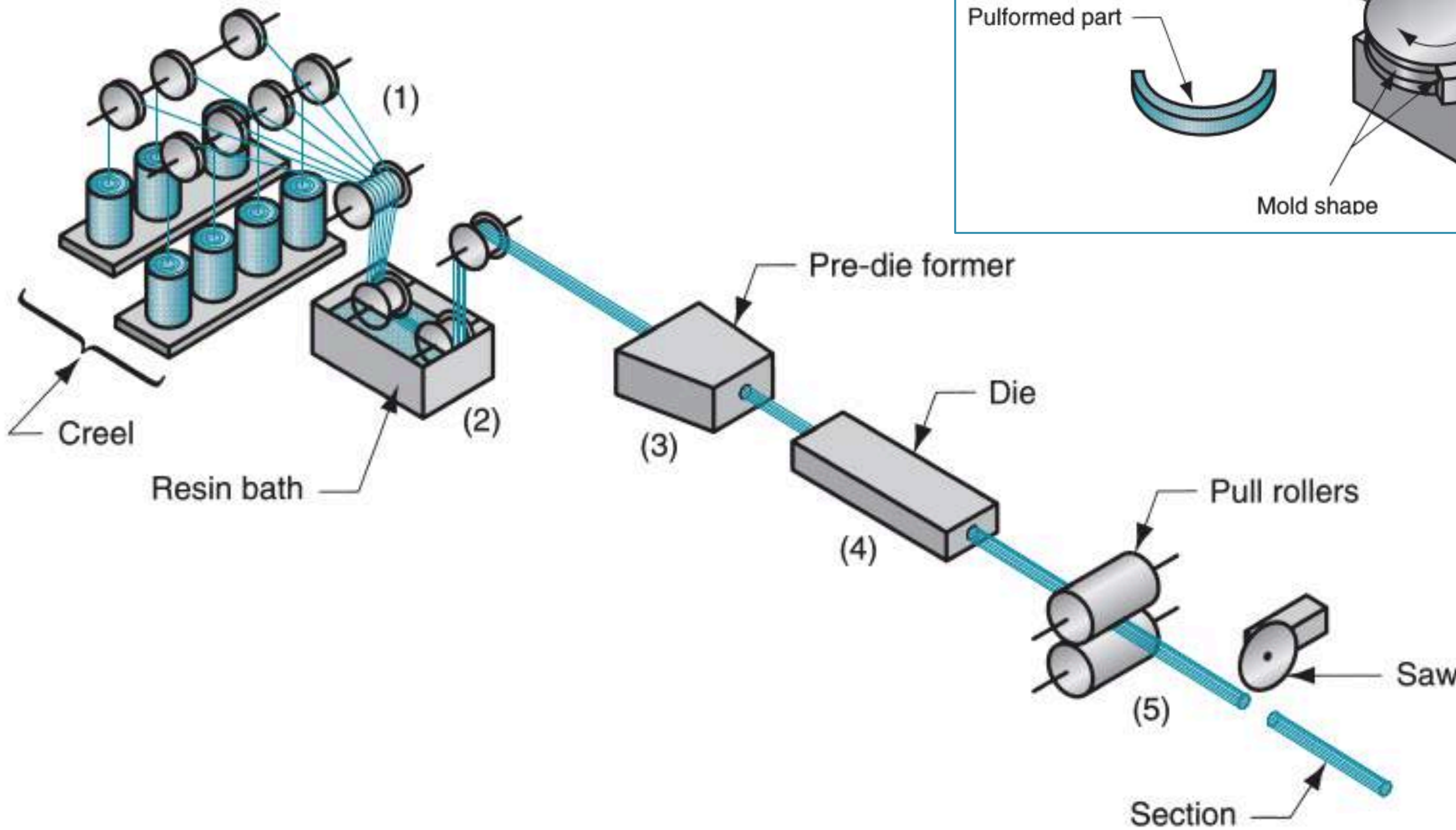
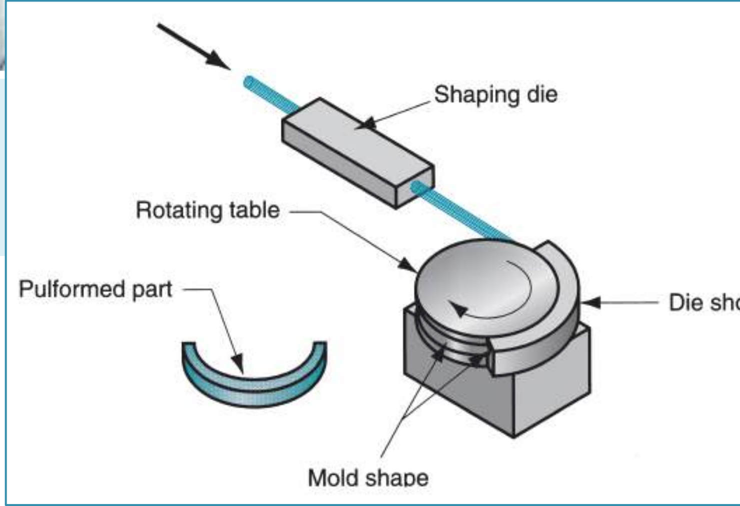


FIGURE 9.14 Pultrusion process (see text for interpretation of sequence numbers). (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)



CRYSTALINE CERAMICS FABRICATION

POWDER METALLURGY / PARTICULTE PROCESSING

Processing of metals and ceramics that are in the form of powders (very small particulate solids):

- Traditional ceramics - powders are produced by crushing and grinding common materials found in nature, such as silicate minerals (clay) and quartz.
- New ceramics – Powders based mostly on oxides and carbides), produced by a variety of industrial processes.
- Metals – Metal Powder – Powder Metalurgy

TRADICIONAL CERAMICS

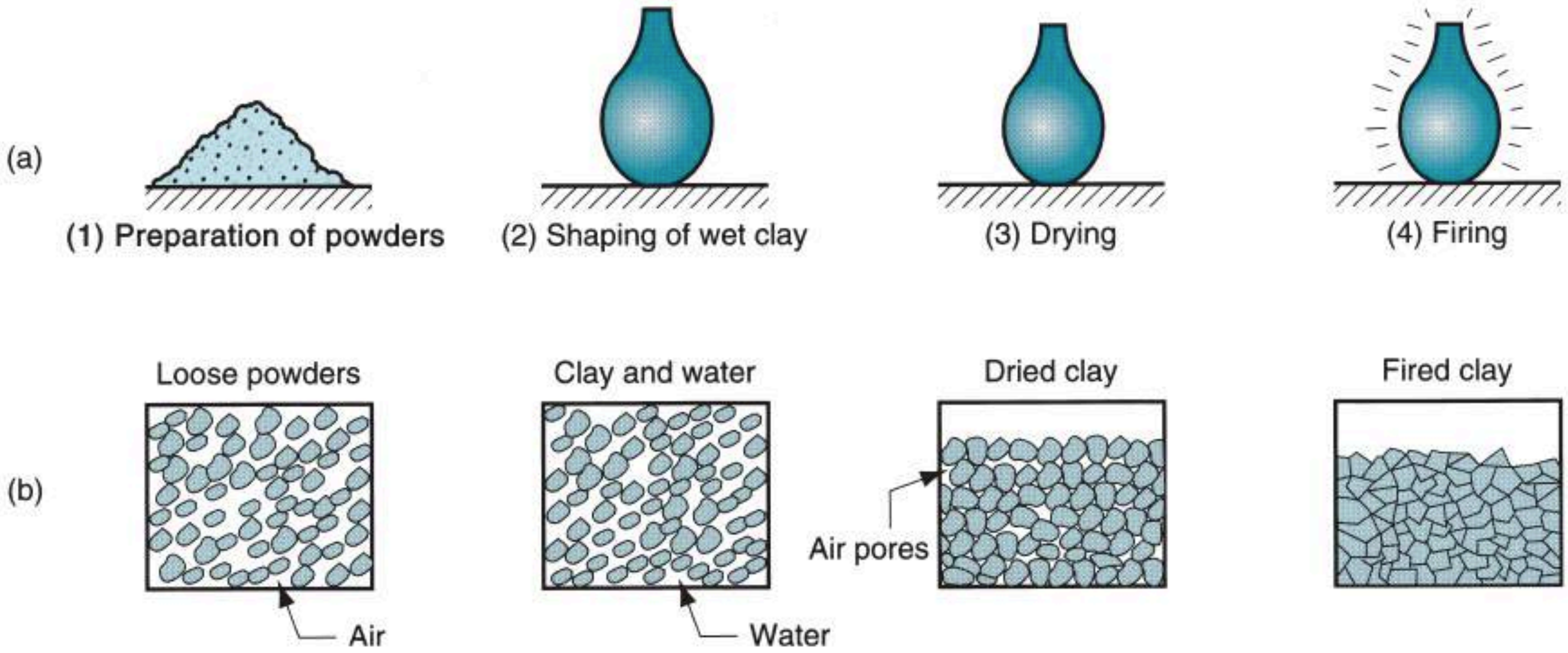


FIGURE 11.1 Usual steps in traditional ceramics processing: (1) preparation of raw materials, (2) shaping, (3) drying, and (4) firing. Part (a) shows the workpart during the sequence, while (b) shows the condition of the powders. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

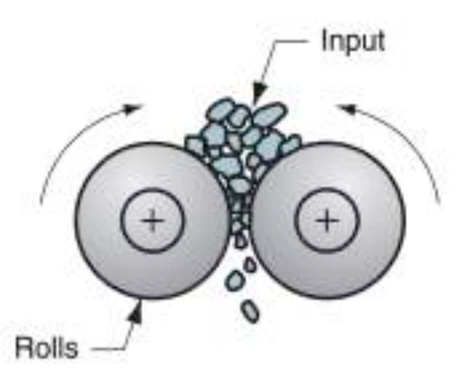
https://www.youtube.com/watch?v=iX0xJ5iZbUU

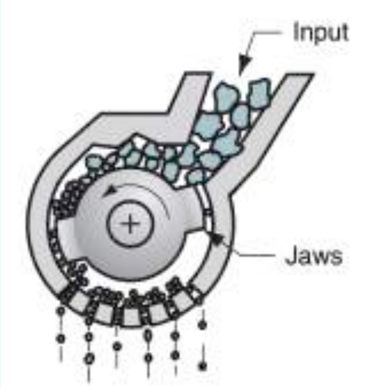
RAW MATERIAL – CERAMIC POWDER PREPARATION

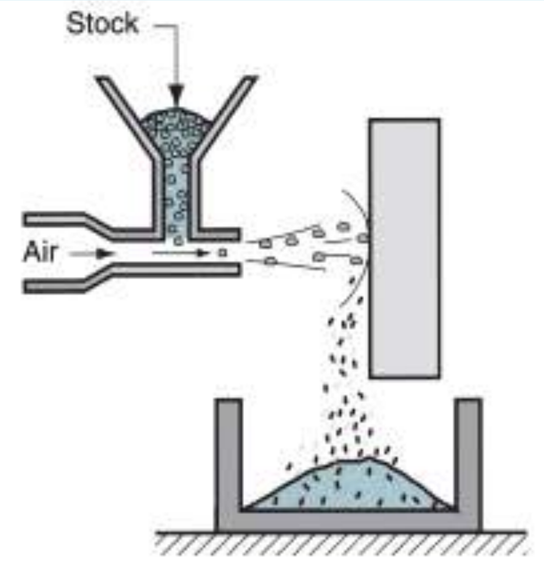
Techniques for reducing particle size in ceramics processing involve mechanical energy in various forms, such as impact, compression, and attrition.

The term comminution is used for these techniques, which are most effective on brittle materials, including cement, metallic ores, and brittle metals.

- Crushing: reduction of large lumps from the mine to smaller sizes for subsequent further reduction.
- Grinding, in our context here, refers to the operation of reducing the small pieces produced by crushing into a fine powder.

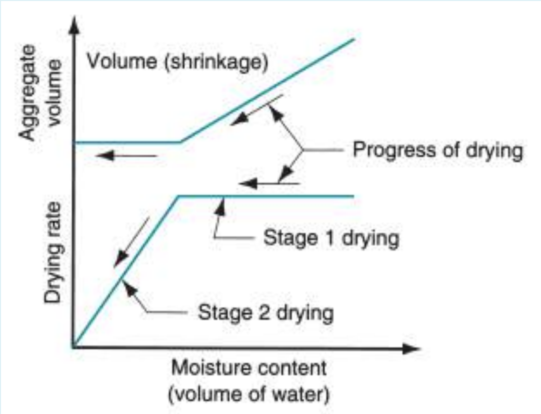






SHAPING PROCESS

DRYING (GREEN PART)



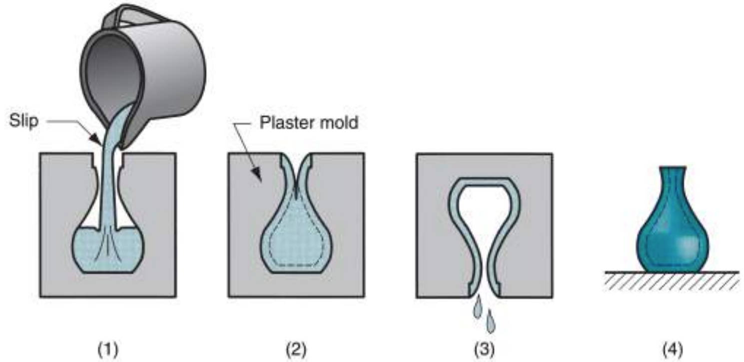


FIGURE 11.4 Sequence of steps in drain casting, a form of slip casting: (1) slip is poured into mold cavity; (2) water is absorbed into plaster mold to form a firm layer; (3) excess slip is poured out; and (4) part is removed from mold and trimmed. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

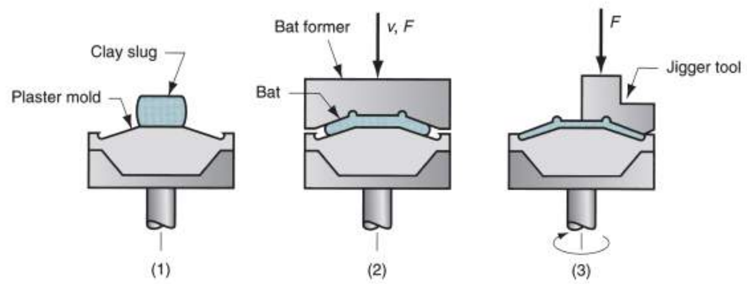


FIGURE 11.5 Sequence in jiggering: (1) wet clay slug is placed on a convex mold; (2) batting; and (3) a jigger tool imparts the final product shape. Symbols *v* and *F* indicate motion (v = velocity) and applied force, respectively. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

Firing is the heat treatment process that sinters the ceramic material to fix the part shape and achieve hardness and strength in the finished ware (furnace called a kiln). In sintering, bonds are developed between the ceramic grains, and this is accompanied by densification and reduction of porosity.

Glazing: application of a ceramic surface coating to make the piece more impervious To water and enhance its appearance.

NEW CERAMICS – HOW TO PRODUCE?

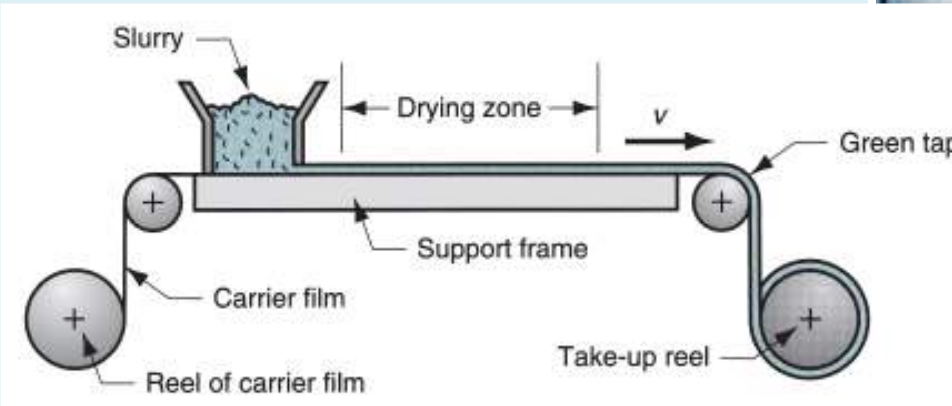
(1) preparation of starting materials

(2) shaping,

- Hot Pressing
- Isostatic Pressing
- Doctor-Blade Process
- Powder Injection Molding (PIM)

(3) sintering,

(4) finishing.



https://www.youtube.com/watch?v=z5bo5coAEwo

Global Engineering

- What are the industrial ceramic materials used?
- Ceramic Plants in your Home Country?
- For who it supplies?
- Raw material for Ceramic Plants? From whom is supplied?
- Prices? Mechanical Resistence? Shapes?

HW #4 – New Ceramics Fabrication