Chapter 2

PROCESSING TECHNIQUES

Manufacturing Thermoplastics and Thermosets

Plastics are changed into useful shapes by using many different processes. The processes that are used to mold or shape thermoplastics basically soften the plastic material so it can be injected into a mold, extruded through a die, or formed in or over a mold. The processes usually allow any scrap parts or material to be ground up and reused. Some of the more common processes are injection molding, extrusion, blow molding, rotational molding, calendering, thermoforming (which includes vacuum forming) and casting.

Thermosets must use a process that allows the material to flow to the desired shape and then become polymerized or cross-linked and rigid. The material cannot be remelted or reused after cross-linking occurs. Some of the processes commonly used to process thermoset materials are injection molding, transfer molding, compression molding, rotational molding, hand (or spray) lay-up, lamination and filament winding.

Injection Molding

Injection molding is used to make three dimensional shapes with great detail. The material is placed in the hopper of an injection molding machine where it is fed into a chamber to be melted. The melting is achieved by conducting heat into the material in a "plunger" machine, while the material is primarily heated by shearing or mechanically working the material in a "screw" machine. Several shots of material are being heated and held in the injection unit. The maximum volume of material a machine can inject in a single shot determines its shot capacity. The capacity is given in ounces of a material.

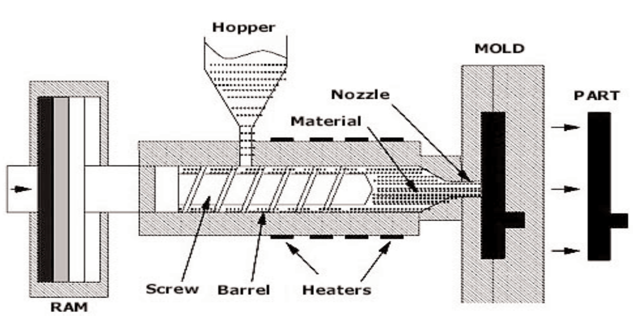

Figure 2.1

Once melted, the material is forced, under pressure, into the mold where it conforms to the shape of the cavity. The mold is temperature controlled, usually by circulating water through it. Once the part is cooled, the mold is opened and the part removed. The mold is then closed and ready for the next shot. The mold is clamped shut while the material is being injected into the cavity since the cavity pressure may be as much as 5,000 psi. The clamp is sized by the "tonnage" it holds. An injection molding machine will be referred to by its shot size in ounces and its tons of clamping ability. An example would be a 6-ounce, 80-ton machine.

The molds are most often made out of hardened steel and carefully finished. They may also be made out of prehard steel, aluminum or epoxy. The type of mold material selected depends on the number of parts to be made and the plastic material to be used. Prototype parts are often machined to test the shape and function of a part before a mold is built.

The injection molding of thermosets is similar to the injection molding of thermoplastics, except the material is kept cool until it is pushed into the heated mold where it is cross-linked. The mold is then opened and the hot, but rigid part is removed.

Extrusion

Extrusion is like squeezing toothpaste out of its tube. The process produces continuous shapes like sheet, pipe, film, tubing or gasketing. The material is fed into the extruder where it is melted and pumped out of the extrusion die. The die and the take-off line shape the material as it cools and controls the final dimensions of the cross section of the shape. The equipment is designed and controlled to produce melted plastic at a very uniform temperature and pressure which controls the size and quality of the extruded product.

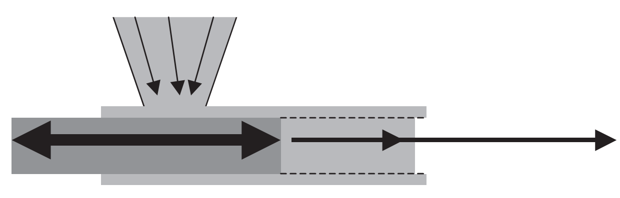

Figure 2.2

The extrusion process is also used with a system of molds and called "blow molding." This is how bottles, such as the gallon milk bottles, are produced.

Ram Extrusion

In ram extruders, a hydraulic ram forces the polymer through a die. Resin drops from a hopper into the cylinder, and a ram slides back and forth to push material into the die where it is forced into a shape and cooled. Ram extrusion is a pressure-sintering process for the continuous production of profiles from high-molecular weight polymers. It is particularly used in the processing of PTFE and UHMW-PE, and is generally used for specialty processing.

Screw Extrusion

Screw extrusion is the process where resin drops into the screw. This screw feeds the die with a constant supply of resin in which the product is forced into a shape and comes out the die. Sheet, rod and profile are made by this process. In the sheet manufacturing process, this hot plastic comes out of a die in the approximate width and thickness that you need. It then goes through three rolls that will relieve stress and apply a finish to the top and bottom surfaces.

Coextrusion

Coextrusion is a process where two different plastic materials or two different grades of the same plastic material are extruded, one above the other material. Coextrusion permits multiple-layer extrusion of film, sheet, pipe, tubing, profiles, wire coating and extrusion coating. It is used a lot in packaging applications to obtain desired barrier properties. The process eliminates the need for a laminator for plastic.

Casting

Casting is a process that involves mixing a base resin with a catalyst and pouring the mixture into the mold. These materials can be thermoplastic or thermoset and the process may or may not require adding heat to the mold. This process is used to make sheet, rod, tube and finished or semi-finished parts. The process requires considerable process control to obtain high quality parts. Tubes, rods, sheets and slabs are often made this way. Several examples of plastics that are cast include acrylic, nylon, epoxy and urethane.

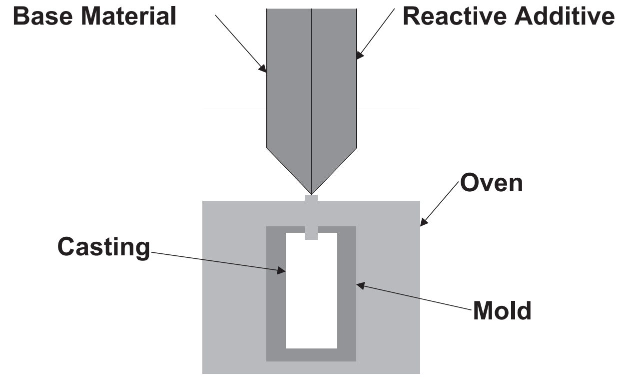

Figure 2.3

Molds can be made from steel, aluminum, urethane, epoxy, silicone, cardboard and other materials. Much of this depends on how many parts are desired off the tooling and if the part is completed to size and finish out of the mold or if post finishing is planned.

Compression Molding

Compression molding is one of the simplest methods of converting polymers. Material is poured into a cavity and leveled to provide a flat and uniform charge. A top is then put over the cavity and the blank is ready to be put into a heated press. The size and thickness of the cavity dictates the size of the finished product.

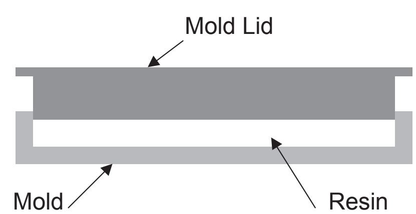

Figure 2.4

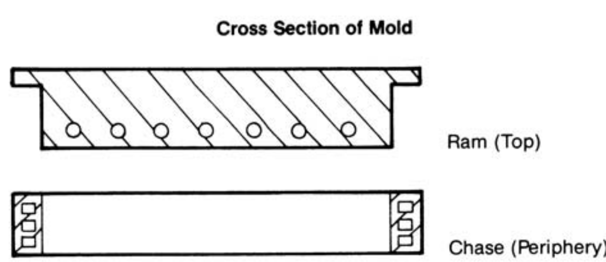

Figure 2.5

The press can be heated in a variety of ways depending on the size of the charge. For sheets and thicker parts, the press is usually steam, hot oil or electrically heated. For smaller parts, it is possible to use electrical cartridges or strip heaters. It is critical to heat the press evenly over its entire surface area to ensure proper curing.

Hydraulic or pneumatic cylinders are usually used to operate the press. Again, it is critical to obtain even pressure over the entire surface area of the charge. The amount of pressure can be adjusted depending on the type of material being processed.

Rotational Molding

Plastic material in the form of a powder is placed into a hollow mold. The mold is heated and rotated about two axis. The plastic melts and evenly coats the inside of the mold. As the mold cools, the plastic solidifies. This process is good for making large light-weight parts like tanks, children's toys or canoes.

The charge is generally left in the press through the heating and cooling cycle. This helps to relieve any internal stress. Once the material has been cured and cooled under pressure, it is taken out of the press and the polymer is removed from the cavity. It is often necessary to trim the edges to finish the product.

Transfer Molding

In transfer molding, only enough material for one shot is placed in a separate chamber or pot. The material is then pushed from the pot into the hot mold and cross-linked. All of the "cured" material is removed from the machine and another charge is loaded for the next shot.

Calendering

Calendering is a process that usually uses four heated rolls rotating at slightly different speeds. Again the material is fed into the rolls, heated and melted, and then shaped into sheet or film. PVC is the most commonly calendered material.

Hand (or Spray) Lay-Up

Hand lay-up is used to produce products such as fiberglass boats and camper shells. The plastic resin, usually a polyester, is rolled or sprayed with glass reinforcement into a mold. A catalyst is added to the material to cause the material to cross-link or harden at room temperature. This process lends itself to making large and strong parts.

Laminating

Most laminates are made using thermosets. The materials to be laminated are stacked in a press, clamped and heated. Some examples of laminates using thermosets are plywood (the adhesive), electronic circuit boards, cloth reinforced phenolic sheet and counter top laminates.

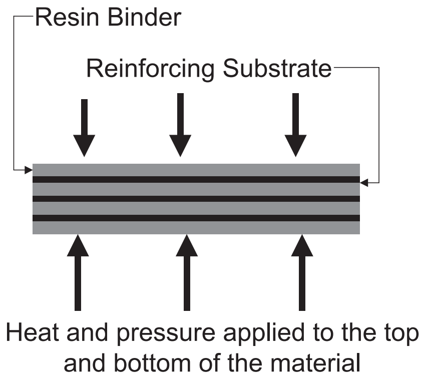

Figure 2.6

Thermoset plastic industrial laminates are identified in process by three stages – A, B and C-stages:

A-stage refers to the key raw materials – reinforcing substrates and resin binders.

B-stage refers to the product produced when reinforcing substrates and resin binders are brought together but not cured. The reinforcing substrate is unwound from a large master roll and dipped into a bath of liquefied resin binder. The reinforcing substrate becomes either saturated, as is the case with absorbent papers and cotton cloths, or coated, as is the case with glass and graphite cloths. Once the wet resin binder is joined with the reinforcer substrate in this method, it is slowly drawn through a long, conveyorized oven where the liquefied resin binder is dried. The result leaves dry semi-cured resin binder in and/or on the reinforcing substrate. Once joined and dried in this fashion, the product is referred to as B-stage or prepreg, and the process described is called B-staging, prepreging or treating.

C-stage refers to sheet, rod, tube, angle or other in their "cured stage." Sheets – B-stage is sheeted into plys then laid on top of each other into predetermined stacks that will render a given thickness. These stacks are placed into the hydraulic laminating press between two flat surfaces and pressure is applied. While under pressure, heat is introduced to begin the bake cycle. The resin in the B-stage product is re-activated by the heat to a sticky state which moves slowly, filling and bonding the layers together until it eventually hardens and cures. Once plys bond to each other and cure they are referred to as C-stage laminate sheet and the process described is called laminating or pressing. Rods – the B-stage is convolutely wrapped under tension onto itself, much like a roll of paper towels is wound. Once the B-stage is rolled to form a rod it is placed into a laminating press which has upper and lower half round mold cavities. When the two half round molds close and meet each other a full round is formed. The size of the mold cavity determines the diameter of the finished rod. Once pressure is applied the layers are pressed together filling all voids. Similar pressures and heat cycles employed for making sheet are used. When the layers bond to each other and cure they are referred to as C-stage laminate rod or rolled and molded rod. Tubes – rolling tubes are nearly identical to rolling rods with the exception that a steel rod called a mandrel is employed to size and form the inside diameter of the tube. B-stage rolled tubes are usually placed into an oven chamber as opposed to a press. Tube bake cycles compare to those of sheet and rod. Once cured, the center mandrel is extracted. The final cured product is referred to as C-stage laminate tube or rolled tube. Angles – this process is nearly identical to that of sheets except the mold cavities are "V" shaped rather than flat surfaces. The final cured product is referred to as C-stage laminate angle or molded angle. Other shapes – once cured the end product is referred to as C-stage.

Filament Winding

Filament winding is an automated process producing a tube or structure composed of continuous monofilaments of controlled orientation in a resin matrix, wound on a mandrel. The mandrel is subsequently removed after the resin is cured. The number of layers and filament orientation can be varied to provide the optimum, application-dependent mechanical properties. Storage tanks, streetlight poles and reverse osmosis pressure vessels are three of the many applications of filament winding.

Polymer Orientation

Polymer orientation refers to processes used to align and elongate polymer molecules and crystal structures exclusively in one direction (uniaxial orientation), or in two directions (biaxial orientation). In the case of uniaxial orientation, the principal benefits of the process are improvements in strength and modulus in the orientation direction. Biaxial orientation improves the strength and modulus of the polymer in two directions, but also significantly improves the toughness of the polymer. Polymer orientation processes are used to manufacture polymer fibers, strapping, webbing, film, sheet and profiles.

There are many other processes too numerous to mention in this text. It is suggested that the reader obtain other literature that can provide more information, in greater depth, on the various processes.

MANUFACTURING FLOW CHART

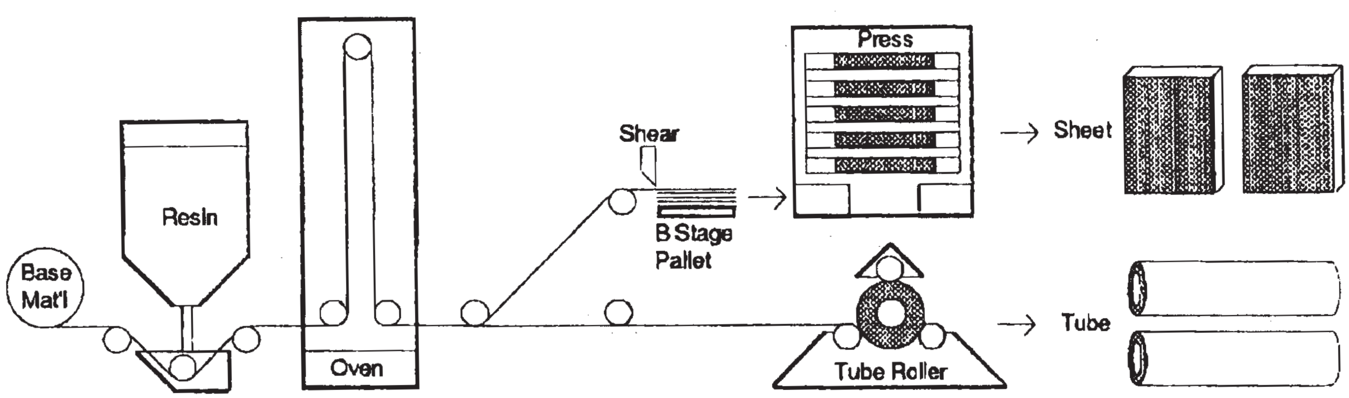

Figure 2.7