In basic conventional casting of thermoplastics, a mixture of monomer, catalyst, and various additives (*activators*) is heated to above its melting point, T_m, and poured into the mold. The part is shaped after polymerization takes place at ambient pressure. Intricate shapes can be produced using *flexible molds*, which are then peeled off (in a manner similar to using rubber gloves) and reused. As with metals (Section 5.4), thermoplastics may be continuously cast, with the polymer carried over continuous stainless-steel belts and polymerized by external heat.

Centrifugal Casting. This process is similar to centrifugal metal casting, described in Section 11.4.6, and is used with thermoplastics, thermosets, and reinforced plastics with short fibers.

Potting and Encapsulation. As a variation of casting, particularly important to the electrical and electronics industry, *potting* and *encapsulation* involve casting the plastic material (typically a liquid resin, such as expoxy) around an electrical component (such as a transformer) to embed it in the plastic. *Potting* (Fig. 19.19b) is carried out in a housing or case, which becomes an integral part of the component. In *encapsulation* (Fig. 19.19c), the component is coated with a layer of the plastic, surrounding it completely and then solidifying.

In both of these processes, the plastic material can serve as a *dielectric* (nonconductor); consequently, it must be free of moisture and porosity, which would require processing in a vacuum. Mold materials may be metal, glass, or various polymers. Small structural members, such as hooks and studs, may be encapsulated partially by dipping them in a hot thermoplastic. A wide variety of polymer colors and hardnesses are available.

19.10 Foam Molding

Products such as Styrofoam cups, food containers, thermally insulating blocks, and shaped packaging materials, such as for shipping appliances, computers, and electronics, are made by *foam molding*, using expandable **polystyrene beads** as the raw material. These products have a **cellular structure**, wherein it may have *open and interconnected porosity* (for polymers with low viscosity) or have *closed cells* (for polymers with high viscosity).

There are several techniques that can be used in foam molding. In the basic operation, polystyrene beads, obtained by polymerization of styrene monomer, are placed in a mold with a blowing agent, typically pentane (a volatile hydrocarbon) or inert gas (nitrogen), and exposed to heat, usually by steam. As a result, the beads expand to as much as 50 times their original size, taking the shape of the mold cavity. The amount of expansion can be controlled by varying the temperature and time. Various other particles, including hollow glass beads or plastic spheres, may be added to impart specific structural characteristics to the foam produced.

Polystyrene beads are available in three sizes: (a) small, for cups with a finished part density of about 50 kg/m^3; (b) medium, for molded shapes; and (c) large, for molding insulating blocks, with a finished part density of about 15–30 kg/m^3 (which can then be cut to size). The bead size selected also depends on the minimum wall thickness of the product; the smaller the size, the thinner the part. The beads can be colored prior to expansion, thus making a part that is integrally colored. Both thermoplastics and thermosets can be used for foam molding, but thermosets are in a liquid-processing form, and are thus in a condition similar to that of polymers in RIM.

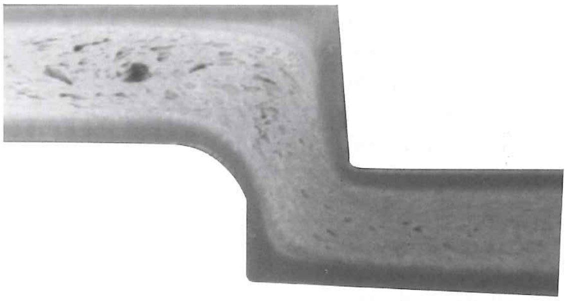

FIGURE 19.20 Cross-section of a structural foam molding, showing a dense skin and porous core. *Source:* Courtesy of M&T Industries.

A common method of foam molding is to use *pre-expanded polystyrene beads*, in which the beads are expanded partially by steam (hot air, hot water, or an oven also can be used) in an open-top chamber. The beads are then placed in a storage bin, and allowed to stabilize for a period of 3–12 h. They then can be molded into desired shapes, in the same manner described previously.

Structural Foam Molding. This process is used to make plastic products with a *solid outer skin* and a *cellular core structure* (Fig. 19.20). Typical products made are furniture components, computer and business-machine housings, and moldings (replacing more expensive wood moldings). In this process, thermoplastics are mixed with a blowing agent (usually an inert gas such as nitrogen) and injection molded into cold molds of desired shapes. The rapid cooling against the cold mold surfaces produces a skin that is rigid, which can be as much as 2 mm thick, and a core of the part that is cellular in structure. The overall part density can be as low as 40% of the density of the solid plastic. Thus, with a rigid skin and a less dense bulk, molded parts have a high stiffness-to-weight ratio (see also Fig. 3.2).

Polyurethane Foam Processing. Products such as furniture cushions and insulating blocks are made by this process. Basically, the operation starts with mixing two or more components; chemical reactions then take place after the mixture is (a) poured into molds of various shapes or (b) sprayed over surfaces, with a spray gun, to provide sound and thermal insulation. Various types of low-pressure and high-pressure machines are available, having computer controls to ensure proper mixing. The mixture solidifies into a cellular structure, the characteristics of which depend on the type and proportion of the components used.

19.11 Cold Forming and Solid-phase Forming

Processes that have been used in the cold working of metals (such as rolling, closed-die forging, coining, deep drawing, and rubber forming—all described in Part III) also can be used to form thermoplastics at room temperature (*cold forming*). Typical materials formed are polypropylene, polycarbonate, ABS, and rigid PVC. Important considerations regarding this process are that (a) the polymer must be sufficiently ductile at room temperature, thus polystyrenes, acrylics, and thermosets cannot be formed and (b) its deformation must be nonrecoverable, in order to minimize springback and creep of the formed part.

The advantages of cold forming over other methods of shaping plastics are:

- Strength, toughness, and uniform elongation are increased
- Plastics with high molecular weights (Section 7.2) can be used to make parts with superior properties
- Forming speeds are not affected by part thickness because, unlike other processing methods, there is no heating or cooling involved; also, cycle times generally are shorter than those in molding processes

Solid-phase Forming. Also called *solid-state forming*, this process is carried out at a temperature 10° to 20°C below the melting temperature of the plastic (for a crystalline polymer). Thus, the forming operation takes place while the polymer is still in a solid state. The main advantages of this process over cold forming are that forming forces and springback are lower. These processes are not used as widely as hot-processing methods and generally are restricted to special applications.