

19.6 Thermoforming

Thermoforming is a process for forming thermoplastic sheets or films over a mold through the application of heat and pressure (Fig. 19.16). In this process, a sheet is (a) clamped and heated to the *sag point* (above the *glass-transition temperature*, T_g , of the polymer; Table 7.2), usually by radiant heating and (b) forced against the mold surfaces by applying a vacuum or air pressure. The sheets are available as a coiled strip or as blanks, with lengths and widths of various sizes.

The mold is generally at room temperature, thus the shape produced becomes set upon contact with the mold. Because of the low strength of the materials formed, the pressure difference caused by a vacuum usually is sufficient for forming. Thicker and more complex parts require air pressure, which may range from about 100 to 2000 kPa, depending on the type of material and its thickness. Mechanical means, such as the use of plugs, also may be employed to help form the parts. Variations of the basic thermoforming process are shown in Fig. 19.16.

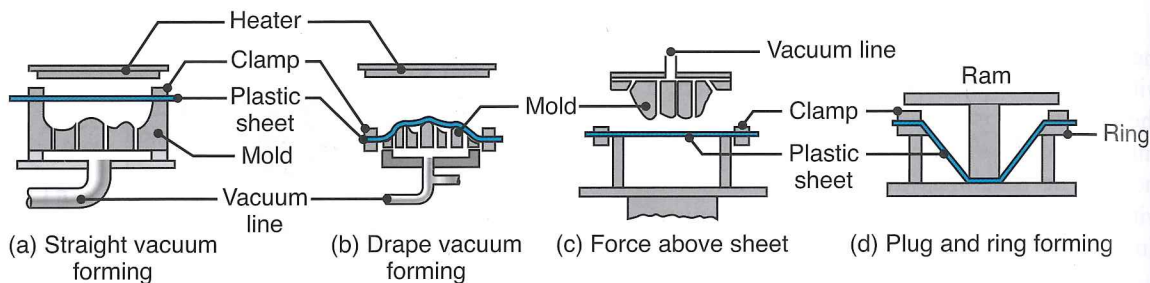


FIGURE 19.16 Various thermoforming processes for a thermoplastic sheet; these processes are commonly used in making advertising signs, cookie and candy trays, panels for shower stalls, and packaging.

Process Capabilities. Typical parts made by thermoforming are packaging, trays (such as for cookies and candy), advertising signs, refrigerator liners, appliance housings, and panels for shower stalls. Parts with openings or holes cannot be formed by this process, because the pressure difference cannot be maintained during forming. Because thermoforming is a combination of *drawing* and *stretching* operations, much like in some sheet-metal forming processes, the material must exhibit high uniform elongation, as otherwise it will neck and tear. Thermoplastics have high capacities for uniform elongation, by virtue of their high strain-rate sensitivity exponent, m , as described in Section 2.2.7.

Molds for thermoforming usually are made of aluminum, because high strength is not required; thus, tooling is relatively inexpensive. The molds have small through-holes in order to aid vacuum forming. These holes typically are less than 0.5 mm in diameter, as otherwise they may leave circular marks on the parts formed. *Defects* encountered in thermoforming include (a) tearing of the sheet during forming, (b) excessive nonuniform wall thickness, (c) improperly filled molds, (d) poor part definition, and (e) lack of surface details.