Plastic Thermoforming

Training Objective

After watching the program and reviewing this printed material, the viewer will become familiar with the basics of the various plastic thermoforming processes, the materials used, and the required tooling.

- Materials used in thermoforming are described
- Various thermoforming mold types are shown
- Clamping and heating methods are explained
- Part trimming methods, both manual and machine, are detailed

Plastic Thermoforming

Plastic thermoforming is one of the fastest growing methods of producing plastic packaging. Additionally, thermoforming is used to produce parts for many other industries including food, medical, appliance, signage, and automotive. Plastic thermoforming is used in both high and low volume production operations as well as for prototype applications. The principal advantages of the process are its low initial tooling cost and its low equipment costs when compared to plastic injection and plastic blow molding processes.

In its basic operation, a flat thermoplastic sheet of specific size is clamped in place, heated to its softening temperature, then forced against the contours of a mold or form by either air or vacuum pressure or by mechanical means. Once cooled, the thermoformed part retains the shape of the mold or form. The part is then trimmed and separated from the remaining sheet material, which is recycled for reuse.

Thermoforming Materials

The most widely used plastic materials in thermoforming are the amorphous or non-crystalline types, with the most popular including:

- 'PVC' or Polyvinyl Chloride
- Polyethylene
- Impact Modified Polystyrene
- Acrylic
- 'ABS' or Acrylonitrile Butadiene Styrene
- Polycarbonate

Material stock for thermoforming is available in two different forms, cut sheet, which is primarily used for heavier gauge products requiring thicker wall sections, and thinner gauge roll-fed sheet, which is used in high-volume, light weight packaging applications.

These materials often incorporate colors, anti-static agents, ultraviolet inhibitors, fire retardants, and other additives to enhance the final product use and packaging requirements. Additionally, thermoplastic sheets with multiple layers may be used. These can provide efficient barriers to oxygen and moisture and other attributes in critical packaging applications.

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Material Clamping & Heating

There are two main types of clamping systems used to insure that the thermoplastic sheets are firmly held in place during the heating phase and the subsequent thermoforming operation:

- Window style clamping frames, which consist of adjustable upper and lower sections that are hinged on one side. Precut sheets are placed between these sections, and the frame is closed securing the sheets.
- Transport chain systems, which are used for high production roll-fed operations. The continuous chains have teeth that pierce the edges of the rolled sheet and then drag it into position for heating and forming.

Once the thermoplastic sheet is secured in the heating area, it is heated to forming temperature using either radiant electric, gas infrared, or direct contact heating systems. Forming temperature, depending upon specific material type, range from 250^{o} to 700^{o} Fahrenheit or 120^{o} to 370^{o} Celsius.

Thermoforming Molds

Typically, thermoforming molds have protruded, or convex surfaces, and are referred to as male, or positive, molds; or they have concave, cavity surfaces, and are referred to as female, or negative, molds. Molds can be further defined as being single cavity or 'one-up' molds for single or short run production, and multiple cavity, and or 'family' molds for volume production. Family molds are multiple cavity molds used to produce more than one part design simultaneously from a single sheet of plastic stock.

Thermoforming molds for short run production or prototype work use molds made of wood, plastic, epoxy, or other relatively inexpensive material. These molds are not temperature controlled.

High production thermoforming molds are always made of aluminum because of its lightweight, machine ability, and high thermal conductivity. Aluminum molds contain channels through which water, the primary cooling medium, is pumped. Cooling rate and temperature control affect the shrinkage and other attributes of the thermoformed part.

To achieve part detail, molds must also be able to evacuate all air trapped between the plastic and mold surfaces. This is done through the use of a vacuum or providing vent holes at specific locations within the thermoforming mold.

Forming Forces & Thermoforming Processes

The force needed to form the part within the mold can be either vacuum (negative pressure) or positive air pressure, or a combination of both. The type or types of force used depends upon the material type, size and thickness, the mold material & design, product aesthetics, final product size, and the annual production volume.

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The most common methods of thermoforming include:

- Drape Thermoforming, in which the plastic sheet is stretched over a positive mold. Once the plastic seals against the mold edges, a vacuum is introduced pulling the material tightly against the mold contour.
- Cavity Thermoforming, in which a heated sheet of plastic is laid over a negative or concave mold. Once the materials seals at the mold edges, it is subjected to a vacuum pulling the material tightly into the mold.
- Pressure Thermoforming, in which material is positioned between a pressure plate and a mold. Air pressure is then introduced through the pressure plate forcing the plastic against the mold surface. Pressure thermoforming is used for finely detailed parts and requires strongly made molds.
- Plug Assist Thermoforming, which is similar to cavity forming but with a male plug forcing the material partially into the mold cavity. A vacuuming completes the thermoforming and is sometimes aided by positive air pressure. This thermoforming method is particularly fast and helps maintain consistent wall thicknesses.
- Twin Sheet Thermoforming, which is used to produce hollow parts. Typically two preheated thermoplastic sheets are positioned between mold halves. These mold halves are brought into position with their respective preheated sheets, sealing their top edges. A vacuum is then applied, forming the two individual part halves. Before the thermoformed sheets cool, the mold halves are brought together welding the halves into a hollow construction. Additional air pressure may be used to complete the twin sheet thermoforming operation.

Thermoformed Parts Trimming

Once parts are thermoformed, they must be trimmed from the initial thermoplastic sheet. This may be performed in-cycle within the thermoforming system, or as a post thermoforming operation. The leftover sheet material is then typically recycled or reground for reuse in future production.

Trimming methods include:

- Hand Trimming: With hand trimming, parts are held in a jig or fixture while knives, saws, or routers are used to remove the excess material.
- Punch & Die Sets: Punch and die sets are used to trim the entire perimeter of thermoformed parts and for high precision shaped openings that are difficult to produce using hand tools.
- Steel Rule Dies: Steel rule dies consist of hardened, sharpened, knife-edged steel strips assembled into a form that matches the shape of the required trimming. Typically, the thermoformed product is located on the steel rule die assembly, and pressure is applied to push the part through the steel rule die, trimming the plastic.
- Machining: Part trimming using 'CNC', or computer numerical control, machining is accomplished using semi-automatic and fully automatic machine tools, and robots. The cutting edges or teeth of the CNC tools must be of a special design compatible for use with plastic materials.
- Laser Trimming: Using a high-powered laser beam, very accurate and polished finished edges are produced. The most common type of laser used is the Neodymium-Doped Yttrium-Aluminum Garnet, or 'YAG' solid-state laser.

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Review Questions

1. Compared to plastic injection or plastic blow molding, thermoforming is:
    a. About the same in cost
    b. More expensive
    c. Less expensive
    d. Higher in tooling costs

2. The types of plastic most often used in thermoforming are the:
    a. High impact types
    b. Crystalline types
    c. Non-crystalline types
    d. Thermosets

3. In applications requiring efficient oxygen and moisture barriers, the plastic type used is typically:
    a. Polyethylene
    b. Acrylic
    c. 'ABS'
    d. Multi-layered

4. The transport chain clamping system is used primarily for:
    a. Thicker sheets
    b. 'PVC' primarily
    c. Multi-layered sheets
    d. Roll-fed sheets

5. The usual plastic heating range is approximately:
    a. 250-700^{o} F/120-370^{o} C
    b. 150-580^{o} F/65-300^{o} C
    c. 215-400^{o} F/100-200^{o} C
    d. 800-1200^{o} F/425-650^{o} C

6. High-volume production thermoforming molds are made exclusively from:
    a. Epoxy
    b. Aluminum
    c. Stainless steel
    d. Hardwood

7. Temporary, short run, or prototype molds are typically:
    a. Cooled with water
    b. Cooled with compressed air only
    c. Cooled with water & compressed air
    d. None of the above

8. The type of thermoforming commonly used for products requiring uniform wall thickness and fast production cycles is:
    a. Plug-assist molding
    b. Drape molding
    c. Pressure forming
    d. Twin sheet forming

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Answer Key

1. c
2. c
3. d
4. d
5. a
6. b
7. d
8. a