Lecture 4.6: Thermoforming

Introduction

Thermoforming is a plastic manufacturing process in which the thermoplastic sheets are formed with the application of heat and pressure in a mold. The thermoplastic sheet is held horizontally over a mold surface and clamped with a holding device. The sheet is heated up to predetermined temperature using a heating element called heater. The thermostat is used to maintain the temperature of the heater. When the temperature becomes substantially high in the mold, the temperature is controlled by adjusting the heater and providing the cooling air. The thermoplastic sheet softens with the application of heat and is pressed into or stretched over the mold surface by application of air pressure or by any other means. The softened sheet conforms to the mold shape and it is held in place until it cools. The mold cavity is opened and the thermoformed part is released. Some of the plastic materials require air cooling in order to make those rigid quickly, because plastic materials have low thermal conductivity. The excess material is then trimmed out from the formed part. Excess material can be reground, mixed with unused plastic, and again reformed into thermoplastic sheets. Thin sheet (up to 1.5 mm) and thick sheet (about 3 mm) can be formed easily.

Thermoforming set-up usually consists of the clamping unit, heaters, mold, and air cooling system. The molds should be cleaned after every cycle, as materials in the mold can cause the change in the shape of the finished goods.

There are mainly three different types of thermoforming process depending upon the pressure required i.e., vacuum forming, pressure forming and matched die forming.

(a) Vacuum Forming

In this process, the vacuum pressure is used to form the heated thermoplastic sheet into the desired shape. The thermoplastic sheet is placed on the mold surface and fixed with the help of clamping unit. The sheet is heated until it is softens and thereafter vacuum needs to be applied quickly. A surge tank is used to quickly pull the air out between the mold cavity and the sheet. When the vacuum is created, the sheet conforms to the shape of the mold cavity. The formed part is cooled and then ejected from the mold cavity. The schematic of vacuum forming process is shown in figure 1.
(b) **Pressure Forming** The pressure forming process is closely related to vacuum forming. In this process, the air pressure required is much higher as compared to the vacuum forming. The preheated plastic sheet is placed on the mold surface, and then air pressure is applied quickly above the sheet as shown in figure 2. The high pressure is developed in between the softened sheet and the pressure box. Due to high pressure, the preheated plastic sheet can be deformed into the mold cavity in a fraction of a second. The formed sheet is held in the mold cavity for cooling for a few seconds. The formed part thereby solidifies and is ejected from mold cavity. Prototype parts can also be made using pressure forming process.
**Matched die Forming** Matched die forming is also called mechanical forming. In this process, mold consists of two parts i.e. die and punch as shown in figure 3. The thermoplastic sheet is heated with the application of heat until it softenes. The preheated sheet is placed into the mold surface (that is called die) and through punch pressure is applied on the hot sheet. The air in between the die and softened sheet is evacuated by using vacuum pump, and therefore the thermoplastic sheet conforms to the mold shape. The formed part is cooled and ejected from the mold cavity.

![Figure 3 Match die forming](image)

The important process parameters that are considered during the thermoforming process are heating temperature, heating time, vacuum pressure, air pressure, mechanical pressure, cooling time and ejection mechanism.

**Materials Used**

The different types of thermoplastic materials which can be processed using thermoforming process are: Acrylic (PMMA), Acrylonitrile butadiene styrene (ABS), Cellulose acetate, Low density polyethylene (LDPE), High density polyethylene (HDPE), Polypropylene (PP), Polystyrene (PS), Polyvinyl chloride (PVC)

**Applications**
Thermoforming process is used for variety of applications, for example, food packaging, automotive parts, trays, building products and aircraft windscreens. Thick gauge parts are used as cosmetic surfaces on permanent structures such as trucks, medical equipment, material handling equipment, electrical and electronic equipment, spas and shower enclosures, vehicle door and dash panels, refrigerator liners, utility vehicle beds, and plastic pallets. Thin gauge parts are primarily used to package or contain a food item, disposable cups, containers, lids, blisters and clamshells.

The advantages and disadvantages of the thermoforming process are given below:

**Advantages:**
- Extremely adaptive to design requirement
- Rapid prototype development
- Low initial setup costs
- Low production costs
- Less thermal stresses than injection molding and compression molding
- Good dimensional stability

**Disadvantages:**
- Poor surface finish
- Parts may have non-uniform wall thickness.
- All parts need to be trimmed
- Ribs and bosses cannot be molded easily
- Limited number of materials can be used
- Very thick plastic sheets can’t be formed