Lecture 4.3: Extrusion of Plastics

Extrusion
Extrusion is a high volume manufacturing process. The plastic material is melted with the application of heat and extruded through die into a desired shape. A cylindrical rotating screw is placed inside the barrel which forces out molten plastic material through a die. The extruded material takes shape according to the cross-section of die. The schematic of extrusion process is shown in figure 1.

Working Principle
In this process, plastic material in the form of pellets or granules is gravity fed from a top mounted hopper into the barrel. Additives such as colorants and ultraviolet inhibitors (liquid or pellet form) can be mixed in the hopper. The plastic material enters through the feed throat and comes into contact with the rotating screw. The rotating screw pushes the plastic beads forward into the barrel. The barrel is heated using the heating elements up to the melting temperature of the plastic. The heating elements are used in such ways that gradually increase the temperature of the barrel from the rear to the front.

There are three possible zones in a rotating screw i.e. feed zone, melting zone, and metering zone. In the feed zone, the plastic beads melt gradually as they are pushed through the barrel. The plastic material is completely melted in the melting zone. A thermostat is used to maintain the inside temperature of the barrel. The overheating of plastics should be minimized which may cause degradation in the material properties. A cooling fan or water cooling system is used to maintain the temperature of the barrel during the process.

At the front of the barrel, the molten plastic leaves the screw and travels through a screen pack to remove any contaminants in the molten plastic. The screens are reinforced by a breaker plate. The breaker plate assembly also serves to create back pressure in the barrel. The back pressure gives uniform melting and proper mixing of the molten plastic material into the barrel. After passing through the breaker plate, molten plastic enters into die. The die gives the desired shape of plastic product. An uneven flow of molten plastic would produce unwanted stresses in the plastic product. These stresses can cause warping after solidification of molten plastic. Plastics are very good thermal insulators and therefore it is very difficult to cool quickly. The plastic product is cooled by pulling through a set of cooling rolls.
**Extrusion Process Parameters**

There are five important process parameters to be considered before extrusion process:

- Melting temperature of plastic
- Speed of the screw
- Extrusion pressure required
- Types of die used
- Cooling medium

**Screw Design:**

The design of screw is important for plastic processing. It has mainly three different functions: namely, feeding mechanism; uniform melting and mixing of plastic and finally it generates the pressure to push the molten material through die. A screw length (L) is referenced to its diameter (D) as L/D ratio. Generally, L/D ratio is used as 24:1, but for more mixing and output, it may increase up to 32:1. There are three possible zones in a screw length i.e. feed zone, melting zone, and metering zone.

(a) **Feed zone:** In this zone, the resin is inserted from hopper into the barrel, and the channel depth is constant.

(b) **Melting zone:** The plastic material is melted and the channel depth gets progressively smaller. It is also called the transition or compression zone.
(c) **Metering zone**: The molten plastic is mixed at uniform temperature and pressure and forwarded through the die. The channel depth is constant throughout this zone.

**Types of Extrusion Process**

The extrusion process is broadly classified into seven different types depending upon the specific applications.

(a) **Sheet/Film Extrusion**

In this extrusion process, the molten plastic material is extruded through a flat die. The cooling rolls are used to determine the thickness of sheet/film and its surface texture. The thickness of sheet can be obtained in the range of 0.2 to 15 mm. The thin flat sheet or film of plastic material can be made. Generally, polystyrene plastic is used as a raw material in the sheet extrusion process.

(b) **Blown Film Extrusion**

In the blown film process, the die is like a vertical cylinder with a circular profile. The molten plastic is pulled upwards from the die by a pair of nip rollers. The compressed air is used to inflating the tube. Around the die, an air-ring is fitted. The purpose of an air-ring is to cool the film as it travel upwards. In the center of the die, there is an air inlet from which compressed air can be forced into the centre of the circular profile, and creating a bubble. The extruded circular cross section may be increased 2-3 times of the die diameter. The bubbles are collapsed with the help of collapsing plate. The nip rolls flatten the bubble into double layer of film which is called layflat. The wall thickness of the film can be controlled by changing the speed of the nip rollers. The layflat can be spooled in the form of roll or cut into desired shapes. Bottom side of the layflat is sealed with the application of heat, and cut across further up to form opening; hence it can be used to make a plastic bag. The die diameter may vary from 1 to 300 centimeters. Generally, polyurethane plastic is used in this process. The schematic of blown film extrusion is shown in figure 2.
(c) Over Jacketing Extrusion
This is also called wire coating process. In this process, a bare wire is pulled through the center of a die. There are two different types of extrusion tooling used for coating over a wire i.e. pressure or jacketing tooling as shown in figure 3. If intimate contact or adhesion is required between the wire and coating, pressure tooling is used. If adhesion is not desired, jacketing tooling is used. For pressure tooling, the wire is retracted inside the die, where it comes in contact with the molten plastic at a much higher pressure. For jacketing tooling, the wire will extend and molten plastic will make a cover on the wire after die. The bare wire is fed through the die and it does not come in direct contact with the molten plastic until it leaves the die. The main difference between the jacketing and pressure tooling is the position of the wire with respect to the die.
(d) Tubing Extrusion
In this process, the molten plastic is extruded through a die and hollow cross sections are formed by placing a mandrel inside the die. Tube with multiple holes can also be made for specific applications, by placing a number of mandrels in the center of the die.

(e) Coextrusion
Coextrusion is the extrusion process of making multiple layers of material simultaneously. It is used to apply one or more layers on top of base material to obtain specific properties such as ultraviolet absorption, grip, matte surface, and energy reflection, while base material is more suitable for other applications, e.g. impact resistance and structural performance. It may be used on any of the processes such as blown film, overjacketing, tubing, sheet/film extrusion. In this process, two or more extruders are used to deliver materials which are combined into a single die that extrudes the materials in the desired shape. The layer thickness is controlled by the speed and size of the individual extruders delivering the materials.

(f) Extrusion Coating
Extrusion coating is used to make an additional layer onto an existing rollstock of paper, foil or film. For example, to improve the water resistant of paper polyethylene coating is used. The applications of extrusion coating are liquid packaging, photographic paper, envelopes, sacks lining for fertilizers packaging and medical packaging. Generally, polyethylene and polypropylene are used.

Materials Used
The different types of plastic materials that can be used in extrusion process are Polyethylene, Polypropylene (PP), Acetal, Acrylic, Nylon (Polyamides), Polystyrene, Polyvinyl Chloride (PVC), Acrylonitrile Butadiene Styrene (ABS) and Polycarbonate.

Applications
The extrusion process is used for manufacturing rods, plates and tubes, wire and cable coating, hose liners, hose mandrels, filaments, sheet, multilayer film, medical packaging and food packaging, etc.
Advantages

- High production volumes
- Relatively low cost as compared with other molding process
- Design flexibility
- Short lead times
- Coating of wire can be done to achieve desired properties
- Continuous part can be produced

Disadvantages:

- Limited complexity of parts
- Uniform cross section can only be produced