CHAPTER 04

FILM BLOWING

Prior to analysis of poly bag manufacturing process, it is essential to have a better understanding of the key manufacturing process—film blowing. It was briefly discussed in the introduction. However, in this chapter, the tools, equipments, and methods of film blowing are described in detail.

4.1 Film Blowing Process

In the process of film blowing, a continuous tubular film is fabricated of which diameter varies from few centimetres to many metres. The principal polymers used in film blowing are the polyethylene (PE) which has the variations such as linear low and high density; LDPE, LLDPE, and HDPE etc. Commercially, PE film has a significant demand and therefore over 70% of the current production is LDPE and LLDPE.

The majority of polymer films are manufactured by film blowing (blown film extrusion). A single screw extruder is used to melt the polymer and pump it into a tubular die. Air is blown into the center of the extruded tube and causes it to expand in the radial direction. Extension of the melt in both the radial and down-stream direction stop at the freeze line (frost line) due to the crystallization of the melt. The nip rolls collect the film, as well as sealing the top of the bubble to maintain the air pressure inside. This process is used extensively with polyethylene and polypropylene.

Polymer granules are plasticated and metered via an extruder, normally a single screw extruder. The melt is metered to an annular die and a thin-walled tube is extruded; the flowing melt is cooled by blowing air along the film and while the film is still molten,
it is stretched in two directions. This orientation process effectively occurs in two steps. First, the tube is inflated circumferentially in the transverse direction (TD) by blowing air through the annular die. It cannot escape as the nip rolls provide a seal at the top of the inflated tube. These nip rolls run faster than the linear extrusion rate of the tube causing longitudinal elongation in the machine direction (MD); this is known as drawdown. After the nip rolls, the extruded film is wound up, the most important feature of the process, in terms of relating structure to properties, is the freeze (or ‘frost’) line. This is where the combination of cooling and orientation combine to use crystallisation. There are two important ratios which define the biaxial orientation. The blow-up-ratio (BUR) is the bubble diameter at the freeze line divided by the die diameter. The drawdown ratio (DR) is the velocity of the film at the nip rolls divided by the average melt velocity at the die exit.

The properties of the film produced depend on the polymer used and the processing conditions. It is well established that product properties are strongly influenced by morphology. Just as in melt spinning, the orientation has an enormous effect on both the crystallisation process and the morphology formed. The non-linear viscoelastic response of the polymer, especially in elongation, has a profound effect on the development of orientation and this has been the focus of much research.

The most important feature of the materials used for film blowing is that they have a broad molar mass distribution. This ensures that the polymer has a very long relaxation time and over the time-scale of the blowing operation exhibits a high degree of melt elasticity, especially in extension. Fortuitously, the earliest type of PE (LDPE) had a very broad molar mass distribution and was highly branched. Once linear grades of PE (HDPE) were developed, methods had to be devised to ensure that the polymer had sufficient melt elasticity for blown-film extrusion.
There have been many experimental and modeling studies which have focused to find the appropriate constitutive equation to use to model the experimentally observed stresses. A number of models have been applied, ranging from Newtonian to viscoelastic and viscoelastic-plastic. The predictions of these models necessarily included the bubble shape. With appropriate manipulation of the processing and modeling parameters, most of the non-linear viscoelastic models can be used to give a good fit to the bubble shape. One important feature of the film blowing process is that the ratio of stresses at the freeze line can vastly differ from the macroscopic DR/BUR ratio, indicating that the films are far from bi-axially oriented.

4.2 Film Properties

The mechanical and optical properties of blown film strongly depend on both the polymer type and its processing conditions. There are some well established correlations between the drawdown ratio and the tensile strength and the impact strength.

Some properties are dominated by the stress at the freeze line and they are the longitudinal (MD) and transverse (TD) module, the MD tensile strength, and elongation at break. Equal stresses at the freeze line will result in comparable properties across a range of extrusion lines or grades of material. Most LDPE films are used in packaging applications and one important property of it is the shrinkage. Surprisingly, the shrinkage of LDPE films is found to be independent of the crystalline morphology, but to depend on stress at the freeze line and the rheological properties of the polymer. In fact, the crystalline regions act only as cross links in terms of shrinkage and it is the non-equilibrium conformations trapped in the amorphous regions that dominate the shrinkage behaviour.
Optical properties of blown film depend mainly on surface irregularities. The crystal structure is not of sufficient size to scatter visible light well. Surface irregularities are introduced mainly from the annular die and are amplified along the process. The melt elasticity is a good indicator of optical clarity of a range of polymers from a given die. For polymers of increasing elasticity, that is, as the longest relaxation time increases, surface imperfections will take longer to diffuse out and will be trapped on freezing. The melt elasticity is the ratio, in shear flow, of the first normal stress difference to the shear stress.

4.3 Tools of Poly Bag Making

In the poly bag making plant various types of machines and accessories are used. They include Extruders, winders, cutters, colour printing machines, packaging machines, and others. Fig. 4.1 shows the single machine unit which includes extruder, winder, collapsing plate, and bubble cage. The figure of a blown film extruder unit is annexed in Appendix - B. Since the film blowing machine is the main machine of poly bag making some of its components are explained further.
4.3.1 Extruders

The main function of an extruder in a film blowing is melting the plastic pellet and input molten material into the film blowing machine. Extruders are particularly useful for processing high melt temperature materials, offering low maintenance and lower initial and operating cost. An extruder is shown in Fig. 4.2.

![Fig. 4.2 An Extruder](image)

4.3.2 Dies

Dies used for film blowing can be divided into few types.

1. Cross head die
2. Bottom fed die (Spider die)
3. Spiral mandrel die
4. Rotating die
5. Banjo manifold die
6. Multi layer die

Cross head dies are cheap and have simple construction. Non uniform flow and imbalance feeding are the problems of them. Spider dies provide balanced feeding but
spiders separate melt stock. In spiral mandrel die proper balance of feeding can be obtained. Also no spider lines are formed. High resistance to flow and increment of inlet pressure are the problems of spiral dies.

4.3.3 Air Ring

Air ring is designed to allow uniform air flow at high rates to provide exceptional cooling and stability without film chatter. It cools the bubble so as to reduce bubble temperature to 40°C at the time it arrives to nip rolls. Fig. 4.3 shows an air ring.

4.3.4 Bubble Cage

The bubble stabilizing cage is a vital component for optimum blown film bubble stability. The segmented rollers of the bubble cages, positioned between the die and the collapsers, provide a low friction contact surface, minimizing bubble drag and providing stability over a broad range of diameters. A bubble cage is shown in Fig. 4.4.
Fig. 4.4 Bubble cage