Blown Film Extrusion in Flexible Packaging

Films produced by blown film lines is an integral constituent of most of the flexible packaging materials produced in the world today. The intent of this write-up is to touch upon extrusion, in general, and then focus on the process of blown film, representative applications, trends, hardware, polymers used, process variables and film properties.

Blown film is one the of most important constituents of flexible packaging with its versatile functions. With the increasing availability of property polymers, functional films continue to be developed for specific applications.

Khushboo C. Doshi
Executive Director

Sunil Jain
President

Rajoo Engineers Limited
Rajkot

Basic Process

Plastics extrusion is a high-volume manufacturing process in which raw plastic is melted and formed into a continuous profile. Using this process, items such as films, sheeting, pipe/tubing are produced. The process starts by feeding plastic materials (pellets, granules, flakes or powders) from a hopper into the barrel of the extruder. The material is gradually melted by the mechanical and frictional energy generated by the rotation of the screws and by heaters arranged along the barrel. The molten polymer is then forced into a die, which shapes the polymers into a form that hardens during cooling.

Extrusion, in itself, is a vast subject. Blown film extrusion is one of the most significant polymer processing methods. The scope of this write-up is limited to extrusion of films by the blown film process, which plays a significant role in flexible packaging.

Blown Film Extrusion

Polymer chemistry and molecular structure are vital in establishing film properties; but bubble geometry, resulting from processing conditions, is also significant. Molecular orientation and crystalline structure - controlled by bubble dimensions - affect properties such as tensile strength, impact toughness and clarity.

As a manufacturing process, blown film is unique, even when compared with other extrusion processes. Molten polymer generally exits the die vertically (upwards or downwards), in the form of a freely extruded bubble, either reaching the height of 25 m or more, or downwards (by quenching in water).

Applications

Versatile combination of properties that can be achieved with multilayer films make them so valuable, even in light of the substantial cost of the equipment. From dual-colour trash bags to 11-layer structure of high barrier flexible packaging, co-extrusion continues to open new markets. While the application spectrum is wide, representative examples of applications of coextruded blown film are described here.

Breathable Packaging

Packaging fresh produce (vegetables, flowers, fruits etc.) provides an interesting challenge for film manufacturers. Clarity is the first requirement achieved by several polymer types. Extended shelf-life is the second requirement, which is more challenging. Contrary to barrier films to increase shelf-life, these products require a breathable package. Modified atmosphere packaging (MAP) involves design of films that allow the producer to continue with the respiring / ripening at a controlled rate while inside the package, resulting in a changing mixture of oxygen, carbon dioxide and water vapour. The film allows gasses to pass into and out of the package at the correct rate. To make things more challenging, each type of produce has a unique respiration rate. The target film properties include clarity, oxygen transmission rate (OTR), water vapour transmission rate (WVTR), blocking force and, of course, strength. Different grades of PE with barrier polymers like PA and EVOH are used.

Collation Shrink Film

These films are used to bundle items together for packaging and transportation. Food and beverages, such as bottled water, comprise some of the largest markets for these films. With increase in popularity of warehouse type retail stores and bulk grocery stores along with reduction in the use of packaging materials such as cardboard boxes, collation shrink films have seen substantial increase in its usage. The film needs to have sufficient strength, high clarity, excellent gloss and specified shrinkage in both, machine and traverse direction. Different grades of PE are used for this application.

High Barrier Film

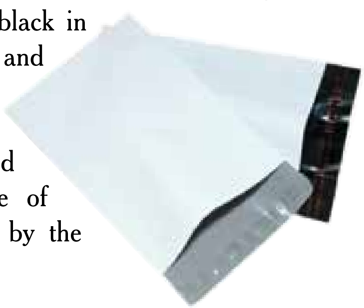
Barrier films are those designed specifically to keep gasses (such as oxygen and carbon dioxide) in addition to water vapour from permeating into or out of a package. These are predominantly used in food packaging and in India especially for edible oil packaging, to provide functions such as preventing spillage, extending shelf-life or retaining product norms. While PA and EVOH provide the required barrier properties, different grades of PE are used to provide body and sealing properties. These films can be used on their own or are lamination with polyester, BOPP or CPP films to enhance the barrier properties or, at times, when reverse printing is required on the other substrates.

Lamination Grade Films

These are widely used in producing flexible packaging materials for packing a wide range of products (potato crisps, liquid detergents, snacks, cereals etc.). Mostly made from different grades of PE, body and heat seal properties are provided. These films are laminated (solvent-less or solvent-based) with other barrier films - Polyester, BOPP, CPP, which are reverse printed.

Courier Bag Films

With the increasing on-line platforms, films for courier bags are providing an increasing opportunity for co-extruded blown films. Produced by a combination of different grades of PE and with black in the inner layer and white in the outer layer, the films provide safe and secure conveyance of merchandise sold by the online sellers.



Trends

Down Gaging

With the advent of new and exotic polymers, films for various applications are continuously being down-gaged (made thinner). For example, in India, liquid milk packaging is one of the biggest markets for use of blown film. From 70 microns many years ago, nowadays it is reduced to around 46 microns. The objective is to reduce cost of packaging, and more importantly, the weight of plastic used per pack. The norm today for various lamination grade applications is for thickness as low as 15 microns. This does pose a challenge in machine design and processing, but the fact is that it is being achieved.

POD Non-barrier Concept (Polyolefin Dedicated)

Cost optimisation is always a challenge and need for any brand owner. Increasing competition always puts pressure to optimise the cost so as to keep packaging cost within a certain limit of the overall product cost, and hence, brand owners always search for ways and means to optimise the cost. Conventional three-layer film and high performance polymer sometimes are not enough to achieve this objective and hence there is an increasing need for more layers where you have more opportunity to play with the formulation to optimise the cost. Introduction of high performance polymers, new applications and quest to optimise the cost are also major driving factors for shift in the trend from conventional three-layer to five-layer POD. The polymers used are all from the polyolefin family (LD/LLD/mLLD/HD/PP). The film is designed with a thick core layer while the sealant layers are thin which impart specific properties to the film. The polymers, which impart properties to the film (hot tack, seal strength, co-efficient of friction etc.), form the thin skin layers. Polymers for skin layers are expensive. Less expensive polymers are used in the core layers reducing the overall film cost. However, the advantage of the POD concept can be reaped if the overall film thickness is in excess of 40 microns. In the Indian context, POD concept has not been very successful as of now as most of the applications require film thickness below 40 microns with the increasing trend of down gaging.

Barrier Films

Typically, barrier films contain either PA (nylon) or EVOH or both. Edible oil packaging by far remains the most used application for barrier films in India. World over, barrier films were developed for packaging of meat products; but India, largely being a vegetarian country, did not find much usage of barrier films till the time it was developed for edible oil packaging. From a short shelf-life three-layer non-barrier film for

> "Increased focus on the environment has forced brand owners to develop recyclable solutions for flexible packaging, and hence, many are working on projects to develop mono-material structures like PE/PE to replace PET/PE laminates."

edible oil packaging, the industry developed higher shelf-life five-layer film with nylon that has further been improved with a seven-layer film with reduced thickness. Globally, even 11-layer barrier films are available for technical applications and high barrier requirement.

PE/PE Solution Replacing PET/PE Structures

Increased focus on the environment has forced brand owners to develop recyclable solutions for flexible packaging, and hence, many are working on projects to develop mono-material structures like PE/PE to replace PET/PE laminates. This new development opens the door for niche technology for multilayer blown films with high machine direction orientation that offers very high clarity and increased stiffness to match properties of PET. Polymer recipe formulations play a critical role in addition to configuring the blown film specifications accordingly.

> "From dual-colour trash bags to 11-layer structure of high barrier flexible packaging, co-extrusion continues to open new markets."

Polymers for Blown Film

- PE - LD, LLD, HD, HM, metallocene
- PP
- PS
- EVA
- EVOH
- PVC
- PVDC
- PA
- Additives - anti-block, anti-oxidant, anti-static, processing aid, slip
- Colourants
- Fillers
- Tackifiers (PIB)

Co-extrusion is the salient process used in flexible packaging, wherein a single die is fed with two or more different melt polymer streams from two or more extruders. Within the die, the various flow streams are combined to form a single ply film comprised of the individual layers. On account of the high viscosity of polymer melts, the individual layers tend not to mix, but to retain their positions within the combined flow stream. In some cases, even 11 layers of polymer are extruded into a film. For each type of polymer layer in the final structure, a different extruder is connected to the die.

Blown Film Hardware

Components of the hardware can be categorised as follows:

- Extruder
- Breaker plate with melt filter
- Adaptor
- Die head
- Air ring
- Calibrating basket
- Collapsing frame
- Nip / Haul-off
- Film conveying
- Winder nip
- Winder
- Instrumentation

Blown Film Process Variables

Blown film processing is characterised by bubble geometry, molecular structure by orientation and film properties, primarily tensile strength and tear strength. Either of the following four main process variables (nip speed, screw speed, cooling speed and bubble volume) has an effect on each of the three main bubble geometric variables (film thickness, bubble diameter and frost line height).

When the nip speed is increased, the primary effect is for the melt to be stretched more in machine direction, making the film thinner. As a result of the film travelling past the cooling air more quickly, the height of the bubble, where the temperature has dropped to the point of polymer solidification (the frost line), increases. As the frost line increases, the small diameter stalk below the frost line height lengthens and the air volume in the bubble is displaced more to the top, because the bubble contains a fixed volume of air. The increase in bubble volume above the frost line pushes the bubble outward to a higher diameter, also contributing to film thinning.

An increase in screw speed results in an increase in all the three bubble geometry variables. The increase in output from the extruder has the primary effect of increasing film thickness. Also, a greater amount of material results in a greater amount of heat that must be removed from the film. This takes longer time under constant cooling conditions, thus increasing the frost line height. Again, as the frost line moves upwards, the bubble diameter increases. The slight thinning effect due to an increase in bubble diameter is far outweighed by the thickness increase created by greater output.

Increasing the cooling air speed causes faster heat removal from the bubble. Since the film reaches solidification temperature sooner, the primary effect is lowering of the frost line height. As a result, the bubble diameter decreases from the constant internal air volume being distributed over a great distance from the frost line to the nip rollers. Lower bubble diameter means the film is not much stretched in traverse direction, the film thickness increases.

When more air is inserted into the bubble, the bubble volume increases; primarily the diameter increases by stretching more in traverse direction. The increased traverse direction stretching results in thinner film. Thinner film cools more quickly, consequently, lowering the frost line height.

Film Properties

Following properties relevant to blown film are (along with the ASTM test methods):

- Tensile strength (D882)
- Elongation (D882)
- Dart impact strength (D1709, D3420, D4272)
- Tear strength (D1004, D1922, D1938)
- Blocking load (D3354) and coefficient of friction (D1894)
- Gel count (D3351 and D3596)
- Low temperature brittleness (D1790)
- Hot tack strength (D1790)
- Gloss (D2457)
- Transparency (D1746)
- Haze (D1003)
- Density (D1505)
- Melt index (D1238)

In Summary

Blown film is one the of most important constituents of flexible packaging with its versatile functions, including providing body to the pack, sealing properties and also shelf-life of the product being packed. With the increasing availability of property polymers, functional films continue to be developed for specific applications. Needless to add, the blown film machinery manufacturers collaborate with polymer manufacturers and the processors to meet these challenges.

References

1. *Wikipedia*
2. *Blown Film Extrusion - Kirk Cantor*