A study of blown film plant performance

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Abstract - The blown film plant is designed to manufacture Blown Film from LDPE(low density polyethylene) & LLDPE(linear low density polyethylene). It consists of an extruder and die a head by which plastic material is heat melted and kneaded then processed into the inflated tubular film with the help of Aluminum oil ring and blower and then it is passed through set of pressure nip rollers and then to be taken out as per required size and final film is winded on two station surface winder. Also in this report study how to improve in machining parameter to increase film output rate, improve quality and reduce waste while maintaining inherent flexibility of process. Additionally find the tensile strength and gauge uniformity of film , also study effect of processing conditions of blown film plant and find best machining condition.

IndexTerms– Blown film process, Property, Stability, CO extrusion, Components of plant

I Introduction

Blown film extrusion is a widespread commercial process for the manufacture of plastic sheets, shrink-wrap, and many useful household items such as garbage bags, plastic wrap, sandwich bags, food storage bags, sausage casings. Development of polymeric film is one of the successes of the plastics industry due to its lightweight, low cost, water resistance, recyclability . These films are mostly consumed by various industries such as civil construction, agriculture, flexible packaging, food packaging and medical and health care applications.

In manufacturing of blown film different types of polymer grade like HDPE, LLDPE, LDPE grades, filler, modifier, anti block agent, additive, master batch use in different proportion. There are many types of filler like calcium base, talc base, natural filler etc. Also use modifier to improve material consistency, with modifier homogeneity of raw material is increase and with this effect process move very smoothly. This will produce blown film from selected raw material but at the end of process some problem may occurs like blocking of raw material, non uniform gauge, lines produce on blown film in extrusion direction, fish eyes produce on film also rough and wave produce on surface of the of blown film. Some time low tensile strength blown film produce.

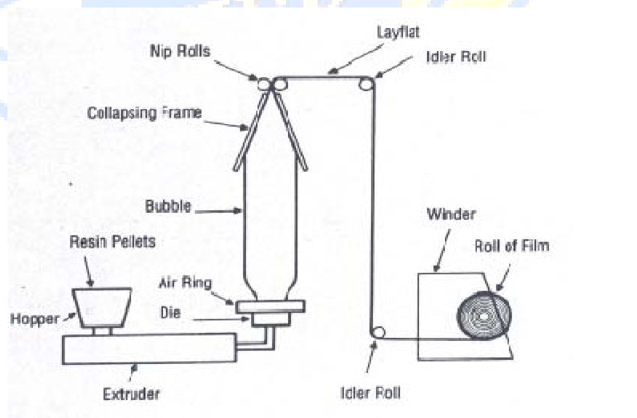

Figure 1: Basic blown film process [1]

In blown film extrusion, molten polymer is extruded through an annular die while air is fed through an inner concentric bubble-tube as shown Fig. 1. This internal air causes the cylindrical film to inflate, increasing the radius of the polymer bubble by stretching it in two directions, and decreasing the film thickness. Simultaneously, the guide rolls above the die flatten the film, and the nip rolls subject the film to tension in the axial (upward from the die) direction. The sum of the tensions provided by the nip rolls and the axial component of the bubble inflation force is called the machine tension.[1]

External air supplied from a concentric outer ring cools the film. The resulting temperature reduction increases the viscosity of the rising film and eventually induces crystallization as the temperature drops below the melting point of the polymer. The crystallization, in turn, causes an additional increase in viscosity, and the polymer solidifies. The solidification zone is called the freeze zone or frost zone. Within this region, the rapidly increasing viscous stiffness causes the bubble radius and the film thickness to stabilize, changing very little as the film heads upward toward the nip rolls. The position within the freeze zone at which the bubble radius change is imperceptible is called the frost line. The nip rolls and the bubble inflation combine to create an elongating force on the polymer bubble-tube and the inflating air causes a circumferential tension on the bubble tube. The resulting biaxial stress can induce further crystallization, an action termed flow-induced crystallization.[1]

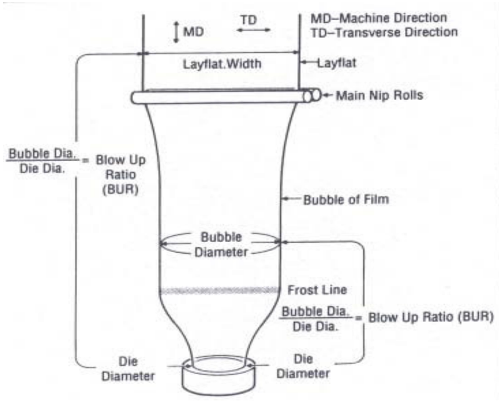

Figure 2: Elements of Blown Film [1]

II. COMPONENTS

In this section main component of machine are describe.

(1) Screw extruder

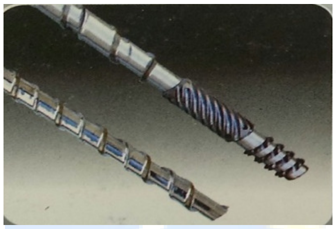

Figure 3: Screw grooved feed

45 mm Grooved feed barrier screw extruder as shown in Fig.3 mounted on sturdy fabricated frame made of heavy steel sections. Screws, 45mm diameter made of decompression type Nitro Alloy steel, Duly –nitrided for longer life. Ratio of length of diameter is 28:1.[2]

(2) Barrel:

Barrel is made of nitro Alloy Steel and Duly-nitridied for long life. The feed section is cooled by water through jacket. Band types heaters are fitted on the barrel in two zones with total heating load of 5.5 Kw. Thermo couples are provided for each zone. Second & third zones are provided with 0.25 HP Barrel cooling blower. Screw is mounted in a cast bearing housing having antifriction radial and thrust bearings, which are designed to withstand thrust developed during extrusion process.[2]

(3) Hopper:

Hopper, Steel fabrication of 45 kgs. Capacity will have a glass window for visual Inspection of raw material level. Arrangement for removal of the granules and sliding gate to block of the feed opening, when necessary is provided.[2]

(4) Drive unit

Drive consists of 20 HP A.C. Motor with A.C. variable frequency drive for infinite speed variation of screw speed up to 113 RPM. Transmission is by V-Belt pulley drive from motor to reduction gearbox. Necessary safety guards are provided.[2]

(5) Cross head & die :

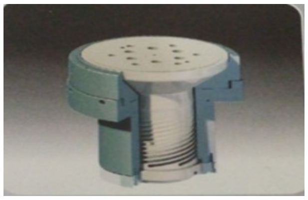

Figure 4: Die head assembly

Set of spiral type die head is shown in Fig 4 provided for following die. Center fed spiral Die head with Die 200mm – 2mm gap for LL-LLDPE are hard chrome plated. Centering screws are provided to adjust the die lip gap. There are 3 heating zones having band type heaters with total maximum heating load of 9.0 kw. Provision for fixing three thermo-couple is made.[2]

(6) Air cooling ring & Calibrating basket :

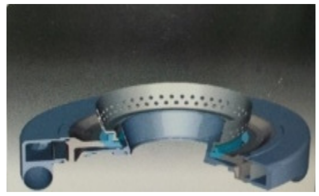

Figure 5: Air ring assembly

As shown in Fig. 5 designed single action cast aluminum cooling ring for bubble cooling is provided. Cooling ring has adjustable Single lip arrangement. Efficient bubble cooling and bubble stability can be achieved by adjustment Single lip and Calibrating Basket. The cooling is having a circular casing with numbers of air entries and circular inserts as an air guide for air impinging on the film bubble. 3 HP A.C. Blower is provided with damper to control inlet air volume.[2]

(7) Vertical take up tower unit :

Two number nip 900 mm long, one steel and other rubberized, are mounted in antifriction pedestal bearing block, rubber roller is pneumatically operated through sets of pivoted pneumatic cylinders. A.C. Drive unit of 1 HP A.C. motor with reduction Gear Box for infinite speed control from 7 to 60 Mtr./Min. Two collapsible wooden flattening boards to guide the bubble into nip rollers are provided with sets of wooden side guides. Tower structure is fabricated from steel section with required cross members. The height of tower frame from the ground is 4 meters. Necessary required guide rollers are fitted on the tower to guide lay flat downwards.[2]

(8) Signal station surface winder :

Single station surface winder, 900mm width, consisting of two changeover shafts, one number steel surface drum roller driven by 1 HP A.C. motor.[2]

(9) Control panel:

Control panel incorporates Isolator in supply line to switch on and off power to control panel. A voltmeter , 3 Nos. Pilot lamps and Voltmeter Selector Switch provided to monitor 3 phases and neutral coming to panel.[2]

(A) Barrel zone:

On barrel there are three zones. Out of these three zones, external blower cools Zone No.2 & 3. Blower is switched on or off by two point PID temperature controller. So in zone No-1 there is single point temperature controller and in zone No. 2 & 3 are two point temperature controllers.[2]

(B) Die zone:

In die there are three Zones. Single point's temperature controller controls zone 4, 5, & 6 temperatures.[2]

(C) D.O.L starter is provided for Air Ring Blower. On/off Switch is provided for Air Ring compressor. Compressor motor is switched ON and OFF by pressure switches contacts through contractor. This system avoids single phasing of compressor motor. Control Panel incorporates individual A.C. frequency drives for speed control of different units.[2]

III. EXPERIEMENT

- **Materials**

Polymer grade

There are many type of grade available to produce plastic film.

HDPE grades:

Table 1: HDPE grade

Grade	MFI(g/10min)	Density(g/cc)
E 52009	0.30	0.946
F 46003	0.30	0.956
52GF004	0.45**	0.952
52GB002	25**	0.952

LLDPE grades:

Table 2:LLDPE grade

Grade	MFI(g/10min)	Density(g/cc)
F 19010	0.9	0.918
F18010	0.9	0.918
LL20FS010	1.0	0.920
F 22020	1.7	0.918

LDPE grades:

Table 3: LDPE grade

Grade	MFI(g/10min)	Density(g/cc)
24FS040	4.0	0.922

NOTE: MFI(2.16kg)g/10min ASTM D1238, **MFI(5kg)g/10min

Talc filler : Additive composed of hydrous magnesium silicate, used frequently as a filler or antiblock agent.

Calcium Carbonate filler : Mineral based additive used as filler, modifier, and sometimes antiblock agent.

Heat resistance = 230

MFI = 0.05 to 0.03

Bulk density = 1.40

Base polymers = LLDPE

Titanium Dioxide filler: A white powder available in two crystalline forms, the anatase and rutile types.

Natural filler: hyaluronic acid content

Master batch : A concentrated blend of slip, additives, or color pigment in a base polymer carrier resin. Master batch is a solid or liquid additive for plastic used for coloring plastics (color master batch) or imparting other properties to plastics (additive master batch). Master batch is a concentrated mixture of pigments and/or additives encapsulated during a heat process into a carrier resin which is then cooled and cut into a granular shape. Master batch allows the processor to color raw polymer economically during the plastics manufacturing process.

Plast improver: Titanium base

Pilot Experiment

In this dissertation work, pilot experiment is executed before actual design of experiment being tabulated as

(1) LLDPE grade O19010 =100kg
milky filler(calcium base)=50kg
Pressure = 65kpa

Table 4: LLDPE process data

Zone	Z1	Z2	Z3	Z4	Z5	Z6
Temp ̊c	170	165	160	170	150	155

Layflat length =640 mm
Die diameter =200 mm

$$\text{BUR} = \frac{\text{layflat length} \times 0.637}{\text{die diameter}}$$

$$= \frac{640 \times 0.637}{200} = 2.03:1$$

Tensile strength- high

Output=55 – 60 kg/hr

(2) LDPE grade 24FS040 = 100kg

Natural filler = 75kg

Pressure =65kpa

Table 5: LDPE process data

Zone	Z1	Z2	Z3	Z4	Z5	Z6
Temp˚ c	160	150	145	140	140	145

Layflat length = 635 mm
Die diameter = 200 mm

$BUR = \frac{\text{layflat length} \times 0.637}{\text{die diameter}}$

$= \frac{635 \times 0.637}{200} = 2.02:1$

Tensile strength- medium
Output= 55 – 60 kg/hr
(3) HDPE grade 52GB002 =100KG
HD filler =100 kg
Pressure = 70kpa

Table 6: HDPE process data

Zone	Z1	Z2	Z3	Z4	Z5	Z6
Temp˚c	160	150	145	140	145	145

Lay flat length =760 mm

Die diameter =200 mm

$BUR = \frac{\text{layflat length} \times 0.637}{\text{die diameter}}$

$= \frac{760 \times 0.637}{200} = 2.4:1$

Tensile strength- low

Output= 60 – 65 kg/hr

IV. EVALUATION

Properties & how to improve :

Properties of HDPE, LDPE, LLDPE-depend on the Structural parameters, such as density/crystallinity, molecular weight and its distribution, short chain branching (SCB)/ long chain branching (LCB) length and amount and crystalline morphology[3]

HDPE - most crystalline PE, its chains are linear and contain very little branching. It shows high modulus, medium tensile properties, poor impact and tear resistance.[3]

LDPE - containing LCB in the order of 1–3 per 1000 carbon atoms as well as 10–30 SCB per 1000 C shows low tensile strength and modulus, medium impact and tear resistance.[3]

LLDPE - wide range of SCB, depending on the type of catalyst and comonomers (butene, hexene or octene), it has good tensile, impact and tear resistance, the type and amounts of SCB have a significant effect on the physical properties.[3]

Physical properties of blown film are

Tensile strength: low molecular weight material in the inter-lamellar region may be responsible for reducing the number of tie molecules and tensile strength.[4]

Tear strength: Tear strength determines the energy necessary to propagate a tear in the film.

In the tearing process, the predominant mechanism is the breaking of chains.[4]

Impact strength: Usually die gap and BUR have a significant effect on the dart impact strength of the blown film. Higher degrees of planar orientations result when BUR is increased which is increase impact strength.[4]

Shrinkage properties- Thermal shrinkage is a measure of chain extension in the amorphous phase. This is considered to happen mainly due to the relaxation of extended.[4]

Optical properites: Haze properties mainly depend on two 1)crystallinity (crystal size, lamella thickness etc.) of the material(2) surface defects. A higher freeze line height (FLH) allows greater relaxation or smoothing out of surface irregularities caused by the die, resulting in a glossier and less hazy film.[4]

Table 7 :Improve Properties

Process	Effect
polymer-based nanocomposites (NCs) with small amounts of organoclay and poly(ethylene-co-methacrylic acid) (Pema-Zn) as a compatibilizer use as raw material[5]	significant improvements in mechanical, thermal and barrier properties in both machine and transverse direction.[5]
Elastomers such as epoxidized natural rubber, carboxylated nitrile rubber or vulcanized natural rubber (NR) and LDPE use to produce film.[6]	impact resistance and tear strength were increased with increasing NR latex content and decrease tensile strength and hardness.[6]
In this process electron beam strike on final film and check the effect of irradiation on this film.[7]	anisotropy spectra of polyethylene films are only slightly modified by irradiation & decrease in mechanical properties of polymers. [7]
In this process Caseinates and Protein crosslinking approch use and also study on CaCAS/NaCAS mixtures use as raw material.[8]	By this first process increase mechanical properties and resistance to moisture property and second process increases stiffness and resistance to break of the films.[8]

Stability :

Bubble stability increase by holding M_{air} and blown-up ratio constant, and then treating the machine tension and bubble inflation pressure as dependent variables because the bubble air mass M_{air} and blown-up ratio are more controllable than the bubble inflation pressure and machine tension.[9]

Using a simple system in which the outer-layer is an upper convected Maxwell fluid and the inner-layer is a Newtonian, and find that bubble stability is depend on the fixed A (amount of air trapped in the bubble) and fixed v_f (the take-up velocity at the freeze line). bubble is unstable when the BUR is greater than a certain critical value. Also conclude that stability of bubble is depend on the relaxation time λ As λ decreases stability of bubble increase.[10]

Three type of instability

1. Axisymmetric periodic variations of the bubble diameter, known as bubble instability (BI).
2. Helical motions of the bubble, described as helical instability
3. Variations in the position of the frost line height (FLHI).[11]

Co extrusion :

Despite of the technical progress in blown-film extrusion, the production of plastic films with improved optical, mechanical and barrier properties (e.g., shrink films, stretch films) may require the use of specific process variants, such as co-extrusion (to make multi-layered structures), or bi-orientation (to achieve a balanced mechanical response).

Co extrusion may be achieved in two ways. In some lines, the so-called primary tube is extruded and cooled intensively at the die exit, then the tube is re-heated up to a temperature slightly below T_m and stretched biaxially (via axial drawing), the resulting film being cooled down by air convection in order to minimize relaxation of the orientation induced. So by this way produce film has superior tensile strength.[12]

Structural model :

The study of film structure can provide the knowledge about the structural formation process during film blowing and, the effect of processing conditions on film properties.

Keller proposed that the crystal b-axis in PE blown films has a orientation perpendicular to the MD, a and c axes are randomly distributed with cylindrical symmetry.[13]

Then crystallization processes take place depending upon the magnitude of the stress in the melt.

Under low-stress conditions, the lamellae grow radially outward in the form of twisted ribbons, with the crystallographic b-axis parallel to their growth axis. As a result of this lamellar growth process, the a-axis of the crystal unit cell is oriented preferentially along the MD of the blown film.[13]

Under high-stress conditions, the radially grown lamellae extend directly outward without twisting.[13]

V. DISCUSSION

Through extensive study some concrete points are keenly studied like blown film process in which detail procedure of blown film production with study of machine tension, freeze line, inflated air, temperature of bubble, freeze line height and parameter of blown film plant in which study of machine direction, transverse direction, drawn down ratio, blown up ratio, bubble diameter, film thickness. Through this review it is also studied that property of blown film in which significant differences in physical properties have been observed in low LDPE, LLDPE and HDPE blown films. Structural parameters, such as density/crystallinity, molecular weight and its distribution, short chain branching (SCB)/ long chain branching (LCB)

length and amount and crystalline morphology are the key factors that control the properties with tensile strength, impact strength, tear strength, shrinkage properties, optical properties. This review also cover structural model of poly ethylene in which study of film structure can provide the knowledge about the structural formation process during film blowing and, in turn, the effect of processing conditions on film properties and improve properties of blown film in which study different type of additive, compatibilizer., agent, blend etc use and produce effective blown film and also include co-extrusion process.

VI. CONCLUSION

From pilot experiment find out that per hour production increase 55-60 to 60-65 with increase blown up ratio 2.03 to 2.4 and blown up ratio is directly depend on layflat length. Blown film layflat length is increase or decrease by maintaining the blown pressure. So blown pressure 70 kpa is required to produce high production rate. From production rate we found the gauge of blown film in next experiment. And also from pilot experiment find out that tensile strength is depend on the percentage of filler. High amount of filler produce low tensile strength blown film and low amount of filler percentage produce high tensile strength blown film.

REFERENCES

1. How to solve blown film problem By Equistar a lyondellcompany
2. Shubham extrusion an advance blown film techanology
3. Oriented structure and anisotropy properties of polymer blown films: HDPE, LLDPE and LDPE By X.M. Zhang, S. Elkoun, A. Ajji, M.A. Huneault. Received 17 June 2003, received in revised form 29 September 2003, accepted 6 October 2003.
4. Blown Film Extrusion: Experimental, Modelling and Numerical Study by Khokan Kanti Majumder march 2008
5. Structure and mechanical properties of blown films of ionomer compatibilized LDPE nanocomposites By P. Santamaría, J.I. Eguiazabal Received 17 November 2011 Accepted 30 December 2011
6. Preparation of natural rubber (NR) latex/low density polyethylene (LDPE) blown film and its properties. By Supak Mahapram, Sirilux Poompradub, Received 3 May 2011, Accepted 17 June 2011
7. Electron beam crosslinking of extrusion-blown LDPE films:1. Mechanical properties By O. Guiot, L. Tighzert, X. Coqueret Received 20 April 1998; accepted 17 June 1998
8. Mechanical and barrier properties of extruded film made from sodium and calcium caseinates By Imane Belyamani, Frede ric Prochazka , Gilles Assezat , Frederic Debeaufort Received 5 May 2014 Received in revised form 16 July 2014 Accepted 24 July 2014 Available online 8 August 2014
9. Instabilities and multiplicities in non-isothermal blown film extrusion including the effects of crystallization the Journal of Process Control By J. Carl Pirkle Jr., Richard D. Braatz, Received 25 February 2010, Accepted 17 December 2010, Available online 6 January 2011.
10. Stability of a two-layer blown film coextrusion By K.-S. Yoon1, C.-W. Park Received 14 September 1998; received in revised form 15 March 1999
11. Numerical modelling and experimental verification of blown film processing By S. Muke, H. Connell, I. Sbarski, S.N. Bhattacharya* Received 17 November 2002; received in revised form 20 August 2003; accepted 20 September 2003
12. Small-scale production of co-extruded biaxially oriented blown film By O.S. Carneiro, R. Reis, J.A. Covas Received 8 January 2008 Accepted 21 February 2008
13. Dual crystalline texture in HDPE blown films and its implication on mechanical properties By J. Lua, H.-J. Suea, T.P. Riekerb. Received 7 April 2000; received in revised form 7 September 2000; accepted 21 September 2000