Parametric Performance Analysis of LLDPE Blown Film for Tensile Strength, Gauge and Yield with $Caco_3$ Filler

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Abstract— The blown film machine is design to manufacture blown film from HDPE, LLDPE, LDPE. Over past few year, much intrest has been placed in to the investigation of increased mechanical properties of blown film via multitude approaches. In this work use LLDPE O19010 base polymer grade and calcium carbonate use as a filler. To evaluate the cross linking effect of ca+2 cation film made from caco3. The production of blown film is carried out in two steps. First thermoplastic pellet are processed in dryer then they transferred in to thin film using a classic film blowing machine. In this study use taguchi method with 3 level of factor which are caco3 %, dryer temperature, motor rpm, inflation pressure, die exit temperature and produce the film from this factor. After this bubble diameter, BUR, gauge, tensile strength, elongation and yield measurement is carried out.

Keywords: Blown film extrusion, LLDPE, Calcium carbonate Taguchi method, ANOVA analysis, Bubble diameter, BUR, Gauge, Tensile strength, Elongation, Yield

I. INTRODUCTION

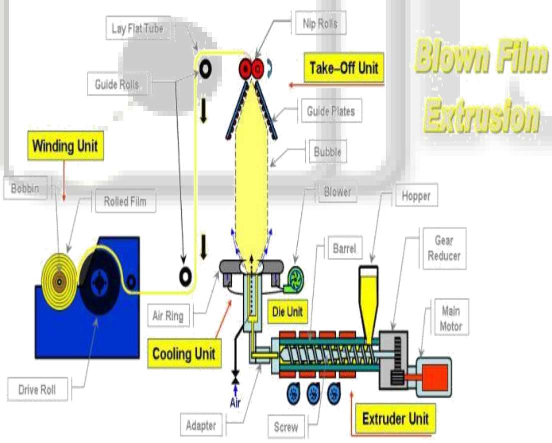

Fig. 1: Blown Film Process

During this film blowing process as shown in Fig. 1 molten polymer from the annular die is pulling upward applying the take up force; air is introduced at the bottom of the die to inflate the bubble and an air ring is utilized to cool the extrudate. The nip rolls are used to provide the axial tension needed to pull and flat the film into the winder. The speed of the nip rolls and the air pressure inside the bubble are adjusted to maintain the process and product requirements. At a certain height from the die exit, molten polymer is solidified due to the effect of cooling followed by crystallization, called freeze line height (FLH) and after this point the bubble diameter is assumed to be constant although there may be a very little or negligible deformations involved.[P1]

II. LITERATURE REVIEWS

Author	Process	Effect
P. Santamaria and J.I. Eguiazabal [P2]	Polymer-based nanocomposites (NCs) with small amounts of organoclay and poly(ethylene-co-methacrylic acid) (Pema-Zn) as a compatibilizer use as raw material	Significant improvements in mechanical, thermal and barrier properties in both machine and transverse direction
Supak Mahapram and Sirilux Poompradub [P3]	Elastomers such as epoxidized natural rubber, carboxylated nitrile rubber or vulcanized natural rubber (NR) and LDPE use to produce film.	Impact resistance and tear strength were increased with increasing NR latex content and decrease tensile strength and hardness
O. Guiot, L. Tighzert and X. Coqueret [P4]	In this process electron beam strike on final film and check the effect of irradiation on this film	Anisotropy spectra of polyethylene films are only slightly modified by irradiation & decrease in mechanical properties of polymers.
Imane Belyamani, Frederic Prochazka and Gilles [P5]	In this process calcium Caseinates and sodium calseinate use as a filler and evaluate the crosslinking effect on blown film and evaluate tensile strength and elongation at break.	By this process increase mechanical properties and resistance to moisture property and also increases stiffness and tensile strength decrease elongation at break of the films

Table-1: Literature Survey

J. Carl Pirkle and Richard D. Braatz was worked on Instabilities and multiplicities in non-isothermal blown film extrusion . In this study straightforward way of generating transient and steady-state solutions to in this study hold the bubble air mass and take-up ratio constant.

Conclusion - The bubble air mass M_{air} and take-up ratio are more controllable than the bubble inflation pressure and machine tension. In addition, the complete zone of stability is generated more readily by holding M_{air} and take-up ratio constant, and then treating the machine tension and bubble inflation pressure as dependent variables. [P6]

K.S. Yoon and C.W. Park was studied on stability of two layer blown film co extrusion process. Using a simple system in which the outer-layer is an upper convected Maxwell fluid and the inner-layer is a Newtonian, Conclusion - 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. [P7]

III. EXPERIMENTAL SETUP

LLDPE O19010 is octene comonomer based, with optimum levels of antioxidants, antiblocking agents, slip additives, and polymer processing aids. This grade is good for heavy duty applications and liquid packaging. The filler Calcium carbonate with melt index 3 to 5 g/10 min and density 1.65 - 1.72 g/cc, 1.4% Ca^{+2}.some amount of talc base found in $caco_3$ By adding the $Caco_3$ improve plastic properties. It is a antiblock agent. Also less permeable to water vapour. [P8]
The experimental result carried out by measuring scale which is measure lay flat length of film, gauge measure by gauge measure instrument of mitutoya, tensile strength and elongation is measured using digital tensile tester model 1.3D & 1.4F of dutron product.

A. Material Specification:

Typical characteristic	Value
Density	0.918 g/cc
MFI	0.90 g/10min
Tensile strength at yield (MD/TD)	12.5/13.0 Mpa
Elongation at break(MD/TD)	650/800 %
Dart impact strength	7.0 g/µm
Gloss(60 ˚C)	80%
Tear strength(MD/TD)	13.8/27.6 g/µm

Table-2: O19010 LLDPE Grade Characteristics

B. Control Parameters and Range Selection:

The experimental trial setup developed by using Minitab 17 software to performed L_{27} orthogonal array [P10]. The Experiment is conducted by varying five parameters and their values are given in the table 2.

Symbol	Factor	Level 1	Level 2	Level 3
A	Filler %	25	50	75
B	Dryer temp. (℃)	80	100	120
C	Motor (rpm)	1100	1350	1600
D	Inflation press.(pa)	150	250	270
E	Die exit temp (℃)	180	190	195

Table-3: Process Parameters and their Levels

C. Constant Parameters:

Die diameter = 200 mm,
Die gap = 2mm
Nip roller (rpm) = 175 rpm
Temperature zone at 1100 motor rpmZon1=165, Zon2=160, Zon3=160, Zon4=155, Zon5=145
Temperature zone at 1350 motor rpm Zon1=170, Zon2=165, Zon3=165, Zon4=160, Zon5=150
Temperature zone at 1600 motor rpm Zon1=180, Zon2=170, Zon3=165, Zon4=165, Zon5=160

Exp. No	A	B	C	D	E
1	25	80	1100	150	180
2	25	80	1100	150	190
3	25	80	1100	150	195
4	25	100	1350	250	180
5	25	100	1350	250	190
6	25	100	1350	250	195
7	25	120	1600	270	180
8	25	120	1600	270	190
9	25	120	1600	270	195
10	50	80	1350	270	180
11	50	80	1350	270	190
12	50	80	1350	270	195
13	50	100	1600	150	180
14	50	100	1600	150	190
15	50	100	1600	150	195
16	50	120	1100	250	180
17	50	120	1100	250	190
18	50	120	1100	250	195
19	75	80	1600	250	180
20	75	80	1600	250	190
21	75	80	1600	250	195
22	75	100	1100	270	180
23	75	100	1100	270	190
24	75	100	1100	270	195
25	75	120	1350	150	180
26	75	120	1350	150	190
27	75	120	1350	150	195

Table-4: L27 Orthogonal Array

IV. RESULTS AND ANALYSIS

A. Results:

Ex No	Bubble dia(cm)	BUR	Gauge (micron)	Tensile strength (N/cm^2)	Elongation (%)	Yield (kg/hr)
1	22.63	1.13	120	0.97	443	30.05
2	24.25	1.21	126	1.85	448	33.51
3	32.35	1.61	128	1.10	450	38.01
4	40.43	2.02	140	1.11	220	61.09
5	42.06	2.10	142	1.68	230	65.80
6	43.66	2.18	145	3.00	240	68.33
7	45.28	2.26	148	0.67	206	72.33
8	46.91	2.34	150	0.88	208	75.79
9	48.53	2.42	152	0.90	210	79.59
10	40.43	2.02	125	2.22	150	54.54
11	42.06	2.10	128	3.21	158	58.08
12	45.28	2.26	130	3.48	163	61.26
13	43.66	2.18	180	5.20	164	84.82
14	45.28	2.26	182	5.34	168	88.94
15	48.53	2.42	188	5.58	172	98.44
16	32.35	1.61	110	1.10	160	38.40
17	33.95	1.86	115	1.99	168	42.15
18	37.21	2.02	118	2.18	175	47.37
19	45.28	2.26	170	5.32	97	83.08
20	48.53	2.42	175	5.67	100	91.63
21	51.76	2.58	180	6.80	104	99.98
22	32.35	1.61	95	6.20	50	33.16
23	33.95	1.89	98	7.50	56	35.92
24	37.21	1.86	100	8.30	68	40.14

25	33.95	1.69	142	3.20	136	52.04
26	37.21	1.86	144	4.18	140	57.80
27	40.43	2.02	148	5.13	143	64.68

Table-5: Resultant Table

B. Analysis of Variance:

Analysis of variance (ANOVA) is a powerful tool to identify which are the most significant factors and it's percentage (%) contribution among all control factors for each of response. It calculates variations about mean ANOVA results for the each response. Based on P value (Significance factor value) important parameter can be identified. Table 6, 7, 8, 9, 10, 11 are ANOVA table obtained by Minitab 17 software.

Source	**DF**	**Seq SS**	**Adj MS**	**F**	**P**	**%**
A	2	29.28	14.64	10.93	0.043	2.07
B	2	12.98	6.49	4.84	0.073	0.92
C	2	1058.6	529.3	395.8	0	73.67
D	2	152.75	76.37	57.01	0.001	10.84
F	2	134.31	67.15	50.12	0.029	9.52
Residual Error	16	21.44	1.340			1.52
Total	26	1409.4				

Table-6: ANOVA for Bubble Diameter

ANOVA table contain Degree of freedom (DF), Sum of Square (SS), Mean Square (MS), Significant factor ratio (F), Probability (P) and calculate percentage contribution.

Source	**DF**	**Seq SS**	**Adj MS**	**F**	**P**	**%**
A	2	0.1211	0.0605	11,65	0.049	3.62
B	2	0.0481	0.0240	4.63	0.076	1.43
C	2	2.2389	1.1194	215.36	0.000	67.01
D	2	0.4769	0.2384	45.88	0.001	14.27
F	2	0.3727	0.1863	35.86	0.032	11.15
Residual Error	16	0.0831	0.0052			2.48
Total	26	3.3409				

Table-7: ANOVA for BUR

Source	**DF**	**Seq SS**	**Adj MS**	**F**	**P**	**%**
A	2	44.5	22.26	15.31	0.947	0.24
B	2	185.9	92.93	63.92	0.528	1.00
C	2	14775.6	7387.81	5082.06	0	77.21
D	2	3198.3	1599.15	1100.05	0.001	17.36
F	2	193.4	96.70	66.52	0.068	1.04
Residual Error	16	325.2	1.45			1.76
Total	26	18421.0				

Table-8: ANOVA for Gauge

Source	**DF**	**Seq SS**	**Adj MS**	**F**	**P**	**%**
A	2	89.788	44.8941	231.57	0.000	64.80
B	2	31.308	15.6540	80.75	0.000	22.96
C	2	4.677	2.3387	12.06	0.143	3.43
D	2	1.285	0.6423	3.31	0.199	0.94
F	2	6.186	3.0932	15.96	0.047	4.53
Residual Error	16	3.102	0.1939			2.27
Total	26	136.347				

Table-9: ANOVA for Tensile Strength

Source	**DF**	**Seq SS**	**Adj MS**	**F**	**P**	**%**
A	2	178841	89420.3	10440.4	0.000	57.73
B	2	33540	16769.9	1958.00	0.027	11.39
C	2	20820	10410.0	1215.44	0.056	7.07
D	2	60592	30296.1	3537.28	0.004	20.57
F	2	534	266.8	31.15	0.874	0.18
Residual Error	16	4583	8.6			1.55
Total	26	294463				

Table-10: ANOVA for Elongation

Source	**DF**	**Seq SS**	**Adj MS**	**F**	**P**	**%**
A	2	143.0	71.50	18.17	0.786	0.012
B	2	121	60.56	15.39	0.638	0.010
C	2	10595.5	5297.7	1346.39	0.001	88.96
D	2	429.1	214.53	54.52	0.026	3.69
F	2	438.8	219.42	55.76	0.048	3.72
Residual Error	16	265.1	3.93			2.24
Total	26	11790.5				

Table-11: ANOVA for Yield

V. RESULTS AND DISCUSSIONS

The Taguchi method aims to find an optimal combination of parameters that have them smallest variance in performance. The signal-to-noise (S/N) ratio measures how the response varies relative to the nominal or target value under different noise conditions. [P9]

A. Result Discussion for Bubble Diameter:

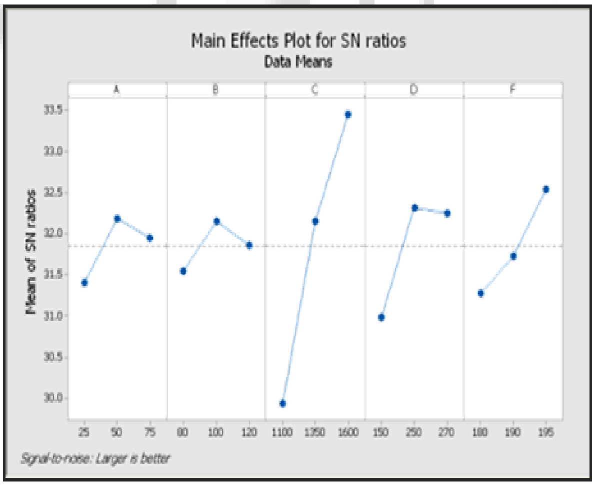

Fig. 2: Main Effect Plot for SN Ratio Vs Bubble Diameter

Graph(fig.2) and show that bubble diameter is increase with increase motor rpm ,die exit temperature and sufficient inflation pressure is required for proper functioning the blown film plant and this three factor are significant is shown in table 6. There is a little effect of filler % and dryer temperature on bubble diameter.

B. Result Discussion for BUR:

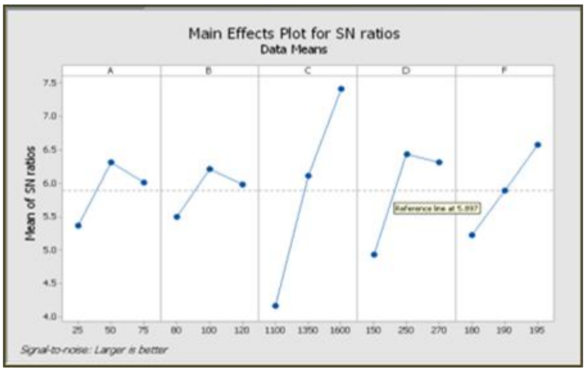

Fig. 3: Main Effect Plot for SN Ratio Vs BUR

BUR is nothing but ratio of bubble diameter to the die diameter and in this paper die diameter is constant 200mm so BUR results are same as bubble diameter results.

C. Result Discussion for Gauge:

Fig. 4: Main Effect Plot for SN Ratio Vs Gauge

Graph (fig. 4) show that motor rpm is most significant factor for gauge as compare to other factor. Motor rpm increase so more material is drawn from the die so gauge of blown film is increases.

Inflation pressure increase so bubble stretch in transverse direction so gauge decrease.

Gauge increase with increase die exit temperature because at high temperature viscosity of material is low and low viscous material is freeze very fast as compare to high viscous material so relaxation time is low for high temperature low viscous material gauge increase.

As shown in table 8 little contribution of filler % and dryer temperatureon gauge. Filler percentage and dryer temperature increase at that time gauge decrease. So high amount of filler percentage and dryer temperature is required to produce less gauge.

D. Result Discussion for Tensile Strength:

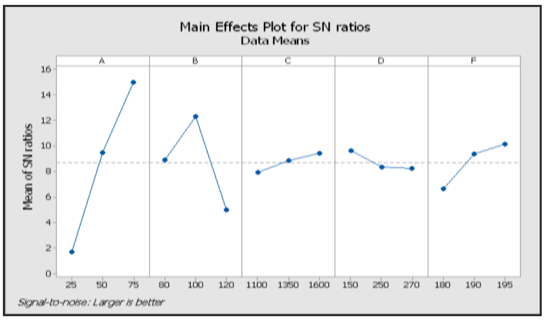

Fig. 5: Main Effect Plot for SN Ratio Vs Tensile Strength

Graph (fig. 5) show that tensile strength increase with increasing filler percentages, motor rpm, die exit temperature and decreasing inflation pressure. Appropriate dryer temperature required to achieve a high tensile strength. As shown in table 9 a little contribution of motor rpm, inflation pressure, die exit temperature for tensile strength of blown film.

Filler proposition in LLDPE material is most significant effect for tensile strength. Filler contain calcium carbonate when high amount of filler use to produce a blown film which have high amount of calcium carbonate material so increase orientation of crystalline phase in both direction of blown film that is a main reason to increase the tensile strength.

As shown in fig. 5 sufficient dryer temperature required for high tensile strength. 100℃ is effective temperature to achieve high tensile strength. At low level of dryer temperature water particles are stay in the raw material and at high temperature material becomes very dry. So proper dryer temperature is required to maintain.

As shown in graph(fig. 5) tensile strength increase with increasing die exit temperature. At high temperature material mixturing process becomes very effectively that is a reason to produce high tensile strength of blown film.

E. Result Discussion for Elongation:

Fig. 6: Main Effect Plot for SN Ratio Vs Elongation

Graph (fig. 6) show that elongation increase with decreasing inflation pressure, filler % and increasing die exit temperature. Sufficient dryer temperature and motor rpm required to achieve a high elongation. As shown in table 10 a little contribution of filler percentages and die exit temperature for elongation of blown film.

Filler % is first significant effect on ductility or elongation at break. The ductility (measured as elongation at break) of film as a function of caco$_3$ content. As shown in fig. 6 ductility of film is decrease with presence of filler. The effect of filler is attributed to its clusters, which can lead to stress concentration and corresponding to decreasing the ductility or elongation.

Inflation pressure is second significant effect for elongation. At low pressure molecular of blown film are close to each other so elongation is high at lower pressure as shown in graph 150 pa elongation is maximum

Dryer temperature is also significant effect on elongation. Sufficient dryer temperature is required. As shown in graph 80℃ is effective temperature for high elongation.

F. Result Discussion for Yield:

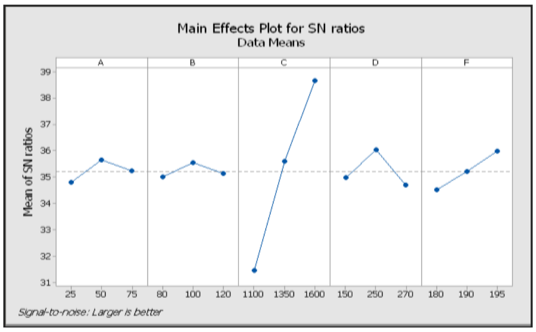

Fig. 7: Main Effect Plot for SN Ratio Vs Yield

Graph (fig. 7) show that yield increase with increasing motor rpm and die exit temperature. Sufficient filler percentage dryer temperature and inflation pressure required to achieve a high output. As shown in table 11 little contribution of filler percentages, dryer temperature is required to produce high output.

Motor rpm is most significant factor to produce high output because output rate is depend on how much material is drawn from the die and high motor rpm give more material drawn from the die so high yield produce at high motor rpm.

Motor rotation increase so more material is drawn from the die so high die temperature is required to melt the material so high die exit temperature is preferred to produce high output so as shown in graph yield is increase with increase die exit temperature.

Sufficient pressure is preferred to produce high output rate. As shown in graph (fig. 7) 250 pa is most preferred pressure to produce high output. At 270 pa pressure bubble get puncher so machining process interruption occurred at 270 pa so output rate decrease at 270pa.

Sufficient Filler percentage and dryer temperature required to produce high output. 50 kg filler and 100 ℃ is preferred to produce high output.

VI. Conclusion

This study emphasizes the crosslinking effect of Ca^{+2} on mechanical properties like tensile strength, elongation and also physical property like gauge of extruded films based on calcium carbonate. The tensile strength is increase with increase filler percentage and elongation is decrease with increase filler percentage. From this study found that medium level of dryer temperature is required to produce high quality film so 80 to 100 ˚C temperature is effective for tensile strength and elongation. Also found that high motor rpm yield rate is increase. Gauge of film is depend on the motor rpm and inflation pressure. Die exit temperature is also effective factor for tensile strength and elongation gauge and yield.

By controlling the extrusion of different calcium carbonate based proportion, it is possible to produce suitable packing for each application. For example, films totally or partially based on calcium carbonate appear to be more attractive for food packaging as they possess better mechanical resistance .

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