Pareto Analysis to Control Denier Variation to Save Excess Weight of Woven Fabric used in FIBC

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***Abstract*— This study was carried out to obtain the information on the denier variation of several woven tapes. The predicted variance could be used in place of actual one since the deviations between then were proved to be negligible. We have taken the data of a FIBC manufacturer company in which the monthly data was analyzed. The customer used to order the FIBC in number. As per application of FIBC, the construction of bag is decided. Once the design of bag is freeze as per nature of application, quotation is prepared. This quotation is prepared as per the weight of various component used in the bag. Finally, the number of bag is converted in the weight quantity. The FIBC bag is manufactured by using woven fabric & this woven fabric is made up of extruded tapes. The fundamental unit of tape is "Denier". There is always variation in the denier of the tape (either positive or negative).The variation of denier was the major factor affecting the overall weight variation. As a result the excess weight was supplied to customer (more than bill of material). It was a big loss. In this project we have studies & control the excess weight. We have also achieved the desired property of the product within the negative side denier /weight variation.**

***Index Terms*—Denier, MFI, Tensile Test, Screw, Variation**

I. INTRODUCTION

The extrusion process is used to produce woven fabric or tapes from film [1]. These types of products are based on polypropylene or polyethylene and they have vast application in the packaging of food, pharmaceutical & other material. Windermere also used for heavy duty packing and carrying material. They are also used as string, rope or as a woven product (such as a sack). The polymer is extruded in a single screw machine into a flat sheet using the quenching tank and chill roll process. Then sheet is split into a number of tapes by either stationary or rotating knives/blades. After cutting of flat sheet into a number of tapes, godet rolls are used to stretch the tape (mono-axial orientation) while it is heated in a hot air oven. In the production of film tape, the width of the tape may decrease to 1/3 of its original slit width as a result of this stretching process. This impacts a significant strength to the tape in the machine direction (MD). Then annealing is done of the tape before it is wound in the form of bobbin packages suitable for weaving.

Tape making process is consist of various elements and its activities like Hopper, Extruder, Tape Splitter, Hot & Cold Rollers (Godet), Hot Air Oven, Bobbin Winder and a Vacuum Chamber at the end.

Raw Material- The raw material is arranged as recipe according to the work order.

Hopper- The recipe of raw material is mixed in hopper according to the required ratio. Extruder- Mixing from hopper is carried through a high temperature which helps it to melt and pass through a flat die to form a flat shape film.

Tape Splitter - Flat shape film is carried to a tape splitter consisting number of blades. Resulting into required number of tapes.

Godet I- The splitted tapes are passed through Godet-I to increase the elongation and tension. Hot Air Oven- The elonged tapes are passed through a Hot Air Oven to increase its strength.

Godet II & Godet III- The tape is passed through the Godet II & Godet III for re-strength.

Bobbins Winder- The tape is winded over the bobbins after the completion of the process.

Vacuum Suction Chamber- During tape making process if, there is any kind of tape breakage in between, the broken tape is sucked from the breaking point and stored through inward air pressure in the suction chamber [2].

The extruded tape quality is measured in a specified unit called "Denier". It is measure of continuous filament or yarn weight per unit length (linear density. It is expressed in weight in grams of 9000 meters length of the tape or yarn.

The woven fabric is consisting of inclination of two tapes (warp and weft) at perpendicular angle. The

vertical tape is called warp & horizontal tapes are called weft. The weight of fabric depends on the weight/denier of the tape. During the extrusion of tapes, there are variations the weight of the tapes. It is generally called "Denier variation". This variation may be in positive side or negative sides than required quality.

II. TEST METHOD

A. MFI (Melt Flow Index)

The shaping plastics are done by melt processes, such as extrusion or injection molding. In this case the measurement of melt flow properties is extremely important. A large number of tests have been devised but low shear rate test, such as the melt flow rate (MFR) or Melt flow index (MFI) test, is one of the most widely used tests. A volume of polymer material extruded through a die during a specified time and is expressed in g/10 min. The standard method to determine the MFI is ASTM-1238-20.

Fig. 1. MFI (Melt Flow Index) Tester [3]

B. Tensile Test

This test method covers measurement of tensile strength of tapes. The test was carried out with UTM machine (Analogue Machine). The grab length of the machine was 200±1 mm & rate of extension was 100±1 mm/min. The dimension of sample specimen of tape is 500 mm long.

Fig. 2. Tensile Tester [4]

II. RAW MATERIAL AND STANDARD RECIPE

The raw materials required for making of FIBC are Poly Propylene (P.P), Low Density Poly Ethylene (L.D.P.E), High Density Poly Ethylene (H.D.P.E), Ultraviolet (U.V) Solid particles, Master Batches, Additive Master Batches, Calpet (white or natural). The basic recipe raw materials as follows.

Table 1. Raw Material Recipe for Tape

S. No.	Material	Composition (%)
1	PP (Polypropylene)	93
2	CaCO3 (Calcium Carbonate)	4
3	UV (Ultraviolet Stabilizer)	3

III. METHODOLOGY

We have selected the major component of the process which impacts the denier variation.

- Method (Process Parameters)
- Man
- Machine
- Material

In this project the elimination method is used to achieve desired goal. A list of common cause is identified & one by one is eliminated. Simultaneously, their effect is also measured.

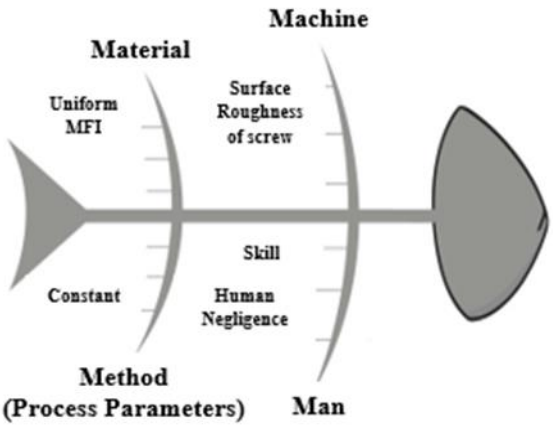

Fig. 3. Fishbone Diagram of Major Cause

IV. CASE STUDY

We have taken the data of a FIBC manufacturer company in which the monthly data was analyzed. The customer used to order the FIBC in number. As per application of FIBC, the construction of bag is decided. Once the design of bag is freeze as per nature of application, quotation is prepared. This quotation is prepared as per the weight of various component used in the bag. Finally, the number of bag is converted in the weight quantity.

As we have seen that, the raw material is extruded in the form of tape & tape is converted in the form of fabric by weaving process.

We have taken the data of 18 month. We surprised that we were continuously supplying the excess material than required (as per Bill of material).

Month	Weight (MT.)		Diff. (%)	Diff. (MT)	Cost (Rupees)
	Reqd.	Act.			
Mar-20	1269	1281.69	1	12.7	12,69,000
Apr-20	1215	1229.58	1.2	14.6	14,58,000
May-20	1310	1316.55	0.5	6.6	6,55,000
Jun-20	1140	1149.12	0.8	9.1	9,12,000
Jul-20	1205	1227.9	1.9	22.9	22,89,500
Aug-20	1315	1345.25	2.3	30.2	30,24,500
Sep-20	1095	1112.52	1.6	17.5	17,52,000
Oct-20	1260	1282.68	1.8	22.7	22,68,000
Nov-20	1320	1341.12	1.6	21.1	21,12,000
Dec-20	1244	1270.12	2.1	26.1	26,12,400
Jan-21	1180	1196.52	1.4	16.5	16,52,000
Feb-21	1085	1095.85	1	10.9	10,85,000
Mar-21	1230	1244.76	1.2	14.8	14,76,000
Apr-21	1265	1289.04	1.9	24	24,03,500
May-21	1290	1310.64	1.6	20.6	20,64,000
Jun-21	1208	1226.12	1.5	18.1	18,12,000

Table 2. Excess Weight & Cost before Study

STANDARD			ACTUAL DENIER VARIATION & STRENGTH						
GSM	Denier	Strength (Kg.)	+ Side Denier	- Side Denier	+ Side Diff.	- Side Diff.	+ Side Diff %	- Side Diff %	Strength (Kg.)
70	750	4.1	799	741	49	9	6.5	1.2	4.2
90	950	5.4	1007	946	57	4	6	0.4	5.6
95	1000	5.7	1070	977	70	23	7	2.3	5.8
120	1275	7.3	1345	1247	70	28	5.5	2.2	7.5
130	1350	7.7	1428	1329	78	21	5.8	1.6	7.9
140	1350	7.7	1411	1316	61	35	4.5	2.3	7.9
150	1540	8.6	1642	1519	102	21	6.6	1.4	8.9
170	1750	10	1876	1742	126	8	7.2	0.5	10.2
190	1750	10	1832	1732	82	18	4.7	0.9	10.2
200	1980	11.3	2117	1954	137	26	6.9	1.3	11.5
220	2180	12.4	2263	2147	83	33	3.8	1.5	12.8
240	2180	12.4	2324	2160	144	20	6.6	0.8	12.5
270	2600	14.3	2790	2543	190	57	7.3	2.2	14.9
290	2600	14.3	2720	2555	120	45	4.6	1.6	14.7
AVG.	**1661**	**9**	**1759**	**1636**	**98**	**25**	**6**	**1**	**10**

Table 3. Strength and Denier Variation before Study

V. IMPLEMENTATION

A. Human Errors/Negligence

There are many definitions of human error, though they all have a common feature. Human error is a label given to an action that has negative consequences or fails to achieve the desired outcome.

It was observed that there was a huge gap between standard and actual process parameters in the plant. Polymer is very sensitive material & its properties changes as a minor change in the process parameters. Controlled process parameters give us the control desired output. There were two parts of human error in the process was observed.

- Skill Error: We feel that the a few operators were not familiar with the behaviors of polymer. There was a misconception about the process parameters.
- Supervision Staff Negligence: There was a negligence happening by production & quality supervisor. They were well known with the process parameters but still this was huge gap in the department.

We freeze the process parameters & imparted training to the all concern persons. After the training, we started to monitor the process & measure the individual performance. As a result everyone started to focus their plant to improve the product quality.

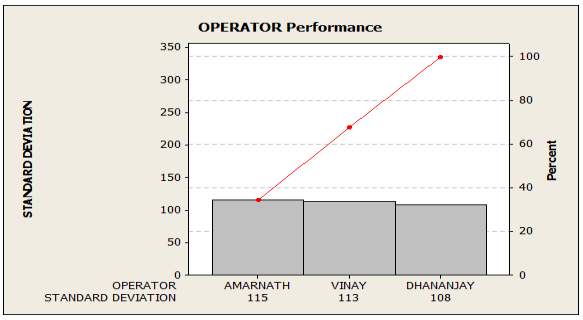

Fig. 4. Operator performance measurement

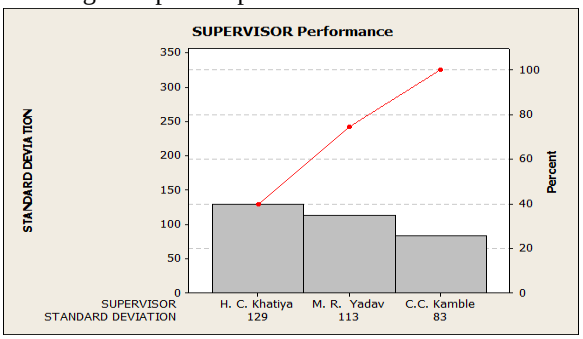

Fig. 5. Prod. Supervisor performance measurement

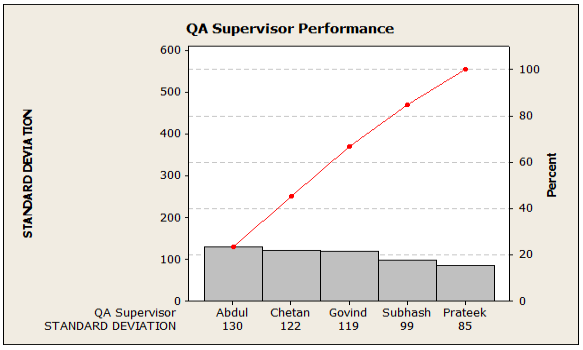

Fig. 6. Q.A. Supervisor performance measurement

After the continuous monitoring & their performance evaluation between the supervisors, a positive effect was observed. There was a little shifting of variation from positive side to negative side is observed as shown in the table.

Table 4. Impact of Human error on denier variation

STANDARD			ACTUAL DENIER VARIATION & STRENGTH						
GSM	Denier	Strength (Kg.)	+ Side Denier	- Side Denier	+ Side Diff.	- Side Diff.	+ Side Diff %	- Side Diff %	Strength (Kg.)
70	750	4.1	797	740	47	11	6.2	1.4	5.1
90	950	5.4	1005	941	55	10	5.8	1	5.9
95	1000	5.7	1061	975	61	25	6.1	2.5	5.8
120	1275	7.3	1341	1243	66	32	5.2	2.5	8.4
130	1350	7.7	1374	1327	24	23	1.8	1.7	8.2
140	1350	7.7	1404	1319	54	31	4	2.3	8.5
150	1540	8.6	1632	1512	92	28	6	1.8	8.8
170	1750	10	1874	1736	124	14	7.1	0.8	12.2
190	1750	10	1820	1734	70	16	4	0.9	12.2
200	1980	11.3	2103	1952	123	28	6.2	1.4	12.1
220	2180	12.4	2252	2145	72	35	3.3	1.6	12.8
240	2180	12.4	2320	2160	140	20	6.4	0.9	12.5
270	2600	14.3	2782	2538	182	62	7	2.4	16
290	2600	14.3	2707	2556	107	44	4.1	1.7	15
AVG.	**1661**	**9**	**1748**	**1634**	**87**	**27**	**5**	**2**	**10.3**

B. Uniform MFI

There were a verity of material were used having a wide range of properties. One of the major properties of polymer is MFI. The variation in MFI result the denier variation. We select the appropriate material & freeze that the PP having the MFI 3-4 gm/10 minutes will be only in use. The uniformity of the MFI result the uniform flow of melted material from the die.

Table 5: Impact of Uniform MFI on denier variation

STANDARD			ACTUAL DENIER VARIATION & STRENGTH						
GSM	Denier	Strength (Kg.)	+ Side Denier	- Side Denier	+ Side Diff.	- Side Diff.	+ Side Diff %	- Side Diff %	Strength (Kg.)
70	750	4.1	791	731	41	19	5.5	2.5	5.1
90	950	5.4	999	923	49	27	5.2	2.8	5.9
95	1000	5.7	1055	960	55	40	5.5	4	5.8
120	1275	7.3	1326	1224	51	51	4	4	8.4
130	1350	7.7	1377	1310	27	41	2	3	8.2
140	1350	7.7	1391	1283	41	68	3	5	8.5
150	1540	8.6	1602	1494	62	46	4	3	8.8
170	1750	10	1855	1698	105	53	6	3	12.2
190	1750	10	1803	1715	53	35	3	2	12
200	1980	11.3	2079	1921	99	59	5	3	12.1
220	2180	12.4	2245	2093	65	87	3	4	12.5
240	2180	12.4	2289	2071	109	109	5	5	12.5
270	2600	14.3	2756	2470	156	130	6	5	15
290	2600	14.3	2691	2522	91	78	3.5	3	15
AVG.	**1661**	**9**	**1733**	**1601**	**72**	**60**	**4**	**3.5**	**10.1**

C. Screw

The screw/barrel system has been called the “heart” of the operation. Not only does it melt the solids and pump the polymer through the die, it also prepares the melt to be homogeneous and of constant temperature and pressure. Any deviations in composition or fluctuations in temperature or pressure lead to variations in the final product.

The screw is a long shaft with a thread wrapped helically around it. The thread is called a flight. Between adjacent sections of the flight is the channel. There are many different screw designs, but most screws have three primary sections: feed, transition (or compression), and metering section. Channel depth – an important variable to screw compression – is generally largest and constant in the feed section, smallest and constant in the metering section. Channel depth decreases along the transition section. There was surface roughness on the screw due to tear & wear. We replaced the screw & its effectiveness is measured. It was observed that this was major component & responsible for the denier variation.

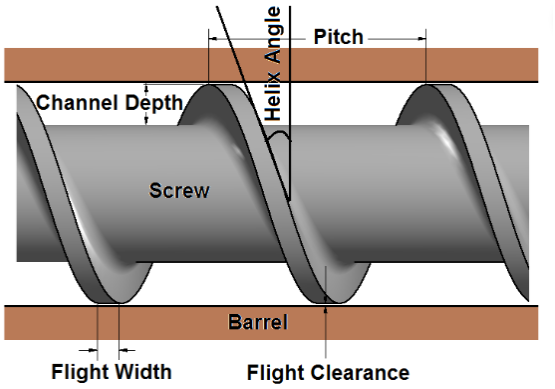

Fig. 7. Screw Diagram [5]

Table 6: Impact of Screw Surface on denier variation

STANDARD			ACTUAL DENIER VARIATION & STRENGTH						
GSM	Denier	Strength (Kg.)	+ Side Denier	- Side Denier	+ Side Diff.	- Side Diff.	+ Side Diff %	- Side Diff %	Strength (Kg.)
70	750	4.1	758	699	8	51	1.1	6.75	5
90	950	5.4	954	874	4	76	0.4	8	5.6
95	1000	5.7	1023	923	23	77	2.3	7.7	8.9
120	1275	7.3	1303	1201	28	74	2.2	5.8	8.4
130	1350	7.7	1372	1270	22	80	1.6	5.9	8.2
140	1350	7.7	1381	1270	31	80	2.3	5.9	8.6
150	1540	8.6	1562	1435	22	105	1.4	6.8	8.7
170	1750	10	1759	1615	9	135	0.5	7.7	12.2
190	1750	10	1769	1631	19	119	1.1	6.8	12
200	1980	11.3	2006	1843	26	137	1.3	6.9	12.1
220	2180	12.4	2213	2060	33	120	1.5	5.5	12.5
240	2180	12.4	2206	2017	26	164	1.2	7.5	12.5
270	2600	14.3	2665	2395	65	205	2.5	7.9	15
290	2600	14.3	2644	2371	44	229	1.7	8.8	15
AVG.	**1661**	**9**	**1687**	**1543**	**26**	**118**	**2**	**7**	**10.3**

VI. RESULT

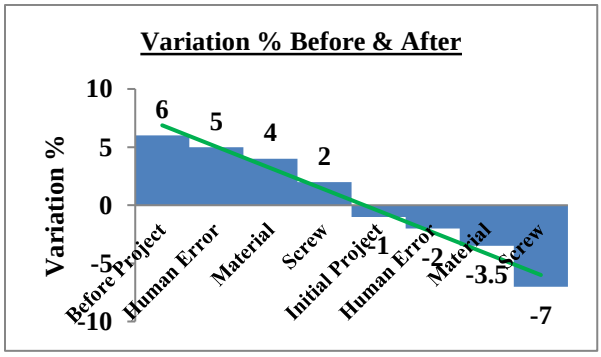

Table 7. Weight and Profit Gain

Month	Weight (MT.)		Diff. (%)	Diff. (MT)	Cost (Rupees)
	Reqd.	Act.			
Oct-21	1155	1137.5	-1.5	-17.3	17,32,500
Nov-21	1220	1204	-1.3	-15.9	15,86,000
Dec-21	1242	1215.9	-2.1	-26.1	26,08,200

CONCLUSION

Human error, machine error & material error in the workplace is a common phenomenon. The pareto analysis is a fundamental tool to identify the major head of business loss. It helps us to eliminate the damaging factor one by one. In this study we conclude the three factors which were the reason for the excess dispatch of material. There are human errors, material property problem & machine parts problems. Due to combine effect of these three factors, there was always excess weight material was producing. We study and analyse the key factors and eliminate them. We achieved the desired result and produced the product with excess weight without affecting the quality.

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