Total Quality Control for Manufacturing of Plastic Woven Laminated Bags Using Six Sigma

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Abstract - This paper has focused on the quality improvement of major defects of plastic woven laminated bags production and assembly line in a plastic woven bags manufacturing company. The objectives of this thesis were to identify current quality problem and to improve major quality problem in the plastic woven laminated bags production department using Six-Sigma DMAIC methodology. The main defects in the assembly line determined and proper tool is used to analyze the quality problem. Major defects were highlighted and analyzed. Root causes for the problems were determined and suggestions for improvement were suggested. One of major defect in production line is marked as tape breakage. After the improvement stage, suggestions for control the quality also were suggested.

Key Words: Total Quality Control, Plastic Woven Bags, Six Sigma, Tape Breakage

INTRODUCTION

Quality has become one of the most important competitive strategic tools which many organizations have realized it as a key to develop products and services in supporting continuing success. Quality system is designed to set a clear view for organization to follow enabling understanding and involvement of employees proceeding towards common goal. Quality control is a very important parameter in any organization. Quality control is done by many measures, six sigma is one of them.

Six sigma today has evolved from merely a measurement of quality to an overall business improvement strategy for a large number of companies around the world. The concept of six sigma was introduced by Bill Smith in 1986, a senior engineer and scientist within Motorola's communication Division, in response to problems associated with high warranty claims. Six sigma focuses on the reduction and removal of variation by the application of an extensive set of statistical tools and supporting software.

Six Sigma's methods include many of the statistical tools that were employed in other quality movements, Six-Sigma is employed in a systematic project-oriented fashion through define, measure, analyze, improve, and control (DMAIC) cycle.

Define (D)

The purpose of the Define phase is to clearly identify the problem, the requirements of the project and the objectives of the project. The objectives of the project should focus on critical issues, which are aligned with the company's business strategy and the customer's requirements.

Measure (M)

The purpose of the Measure phase is to fully understand the current performance by identifying how to best measure current performance and to start measuring it. The measurements used should be useful and relevant to identifying and measuring the source of variation.

Analyze (A)

In the Analyze phase, the measurements collected in the Measure phase are analyzed so that hypotheses about the root causes of variations in the measurements can be generated and the hypothesis subsequently validated. It is at this stage that practical business problems are turned into statistical problems and analyzed as statistical problems.

Improve (I)

The Improve phase focuses on developing ideas to remove root causes of variation, testing and standardizing those solutions.

Control (C)

The Control phase aims to establish standard measures to maintain performance and to correct problems as needed, including problems with the measurement system.

COMPANY PROFILE

XXX Pvt. Ltd. is one of the leading manufacturers, suppliers and exporters of HDPE/PP Woven Fabrics Laminated / Unlaminated, HDPE/PP Woven Sacks / Bags & Multicolour Printed BOPP Laminated PP Woven Sacks and Bags for the last 30 years.

They offered PP/ HDPE woven bags / sacks are used for the purpose of making bags for cement bags, fertilizers, and food grains like rice, wheat, chemical and flower. Their PP/HDPE tarpaulin are used in various industries and covering road transport vehicles, boats, ferries, swimming pools, shops, houses, at all festive occasions and these are also used as monsoon sheds.

4.5.1 Manufacturing Process

PP Woven Sacks are generally manufactured and printed as per the Customer's demands or needs. The end users adopt different kinds of color combinations and Designs in the Printing of these Sacks to convey the massage(s), characteristic(s), quantity & quality related details and handling instructions etc. For some kinds of specific applications like filling of Hydroscopic Materials e.g. Chemicals, Fertilizers, Food Products etc. these Woven Sacks are laminated also. The Process of manufacturing PP Woven Sacks involves following three steps:

- Manufacturing of tape
- Extrusion of film
- Quenching of film
- Slitting of film
- Orientation of tapes
- Annealing of tapes
- Winding

Extrusion

The process of manufacturing PP woven bags involves mixing raw materials starting with PP or HDPE pellets and other additives, extruding the raw materials into a yarn PP resin is heated with feeler of CaCo3 and pigment, melted and extruded as a flat film. It is then slit into tape yarn by the slitting unit and stretched and annealed. Next, a take-up winder winds the heat oriented tape yarn onto a bobbin.

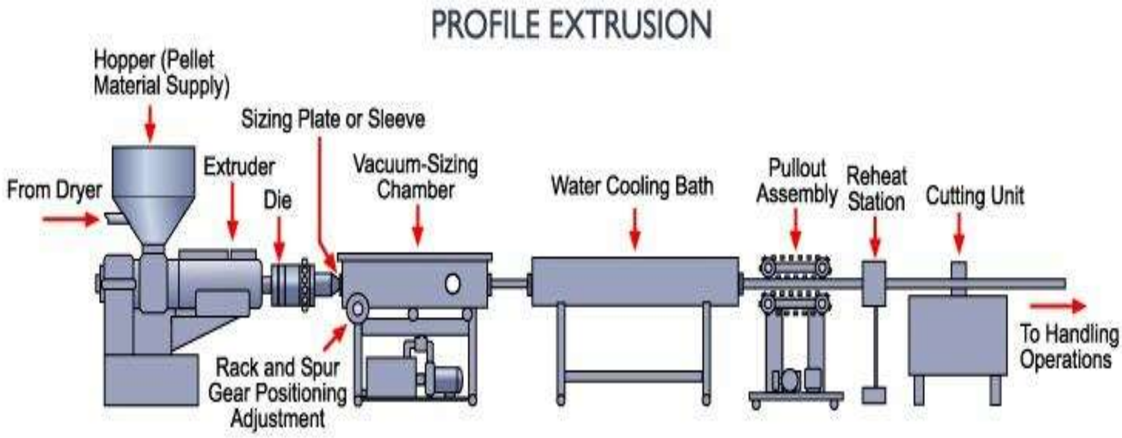


Figure 1 Extrusion process of woven bag manufacturing

Weaving

Weaving the yarn into a fabric is a process similar to the weaving of textiles. These flat tapes are then woven into circular fabric by Circular weaving machine. Thus woven circular fabric is then cut in to required dimension. Thread from the bobbin in the circular loom's creel stand is woven into tubular cloth The Weaving of Raffia Tapes into Cloths is carried out in Circular Looms, which produce Circular Cloth of desired Width. The process of Weaving is Automatic and Continuous in nature. Numbers of Circular Looms are installed so as to match the Effective Output of the Raffia Tape manufacturing Plant. The Cloth produced by each Loom is continuously wound on Rotating Pipes.

Figure 2 wrapping of thread in waving process

4 Finishing & Stitching

The Rolls of Woven Cloth are carried out to the Finishing & Stitching Section of the Unit. The Cloth is cut into desired size and the printed. After printing the cut pieces are sent for stitching. Prior to the stitching of the Cloth, a valve is made in one corner of the cut piece, as per the Customers specification. The Woven Sacks passed through the Quality Control Test are bundled in 500 or 1000 Nos. and pressed on a Bailing Press. The pressed Woven Sacks are wrapped, bundled, packed and dispatched. The Quality Control checks are carried out at each and every step to avoid rejections. The parameters pertaining to the Weight, Denier, Bursting Strength etc. are strictly adhered to.

LITERATURE SURVEY

As per [Hikmet Erbiyik, Muhsine Saru, 2015] In recent years one of the outstanding issues with regard to quality is six sigma.Six sigma can be defined as the process quality management that leads us to excellent quality level via continual improvement of processes.(TekinM,2013,p.459). Six sigma is also a quality management model that ensures the elimination of mistakes by focusing on the mistakes in processes. (TekinM,2013,p.459). According to six sigma approach while the sigma level increases the quality level also increases accordingly. The base of the six sigma is related to statistics. The sigma(σ) is the symbol of standard deviation. Standard deviation is a measurement unit for statistical dispersion and spreading.

$$\sigma = \frac{|\bar{X}-\mu|}{z}$$

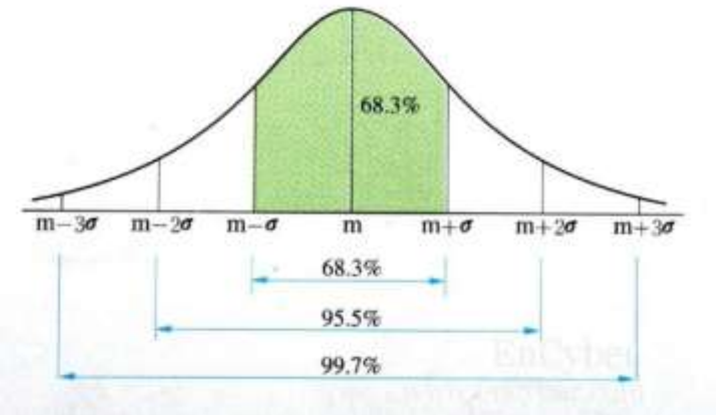


Figure 3 Percentage distribution of six sigma

As per [Hacer Canatan, 2015,ELSEVIER] Six Sigma's methods include many of the statistical tools that were employed in other quality movements, Six-Sigma is employed in a systematic project-oriented fashion through define, measure, analyze, improve, and control (DMAIC) cycle. The DMAIC cycle is a more detailed version of the Deming PDCA cycles, which consists of four steps Plan, Do, Check, and Act within continuous improvement.

The method and the tools of six-sigma approach can be summarized as below (Pande,P.Neuman,R&Cavanagh,R.2000)

- Process design
- Change analysis
- Balanced test systems
- The voice of the consumer
- Creative Thought
- Experiment design
- Process management
- Statistical Process Design
- Continuous improvement

The indicator concerning the statistical measurement aspect of six-sigma method is the normal distribution curve. The distribution curve demonstrate show the process operates well , indeed ,it emerge show the next outcome of the process will take place. In statistics, the probability is of the distribution curve is grouped by separating into pieces and it is labelled as "standard" deviation from the mean". The objective of six-sigma is to narrow the standard deviation of the variability within the specified limits in the directions of the consumer demands.

RESULT AND DISCUSSION

The methodology adapted for this study is done by applying the Fu-Kwun Wang approach. They are the Define, Measure, Analyze, Improve and Control (DMAIC) methodology. The application of Six-Sigma methodology is a statistical analysis approach to quality management. In this chapter the rejection ratio of plastic weaving process department was analyzed statistically using DMAIC methodology and suggestions for quality improvement will be made to the department.

DMAIC – Define stage

Define the process

Before the process can be investigated, all circumstances have to be defined. Such circumstances are often described as SIPOC (Suppliers, Inputs, Process, Outputs and Customers or Consumer). The circumstances around the woven plastic bag manufacturing are listed in chronological order below.

- Suppliers - Material supplier, DuPont
- Inputs - Material, ABS
- Process - Receive HDPE and load into hopper
  Dry HDPE
  Woven making
  Tape Making
  Deliver cover to assembly stations
- Outputs – Bags
- Customers - assembly stations / external customers

DMAIC- Measure stage

Data was collected for 12 weeks continuously from February to April 2007 for output line reject that occurred in the plastic woven bags manufacturing and assembly line that focused on the production of part named case A to track down the problem encountered by this particular part. Since there are five machines producing the same part, the reject data were collected for each machine. A fish bone was created to measure and investigate the causes of defects.

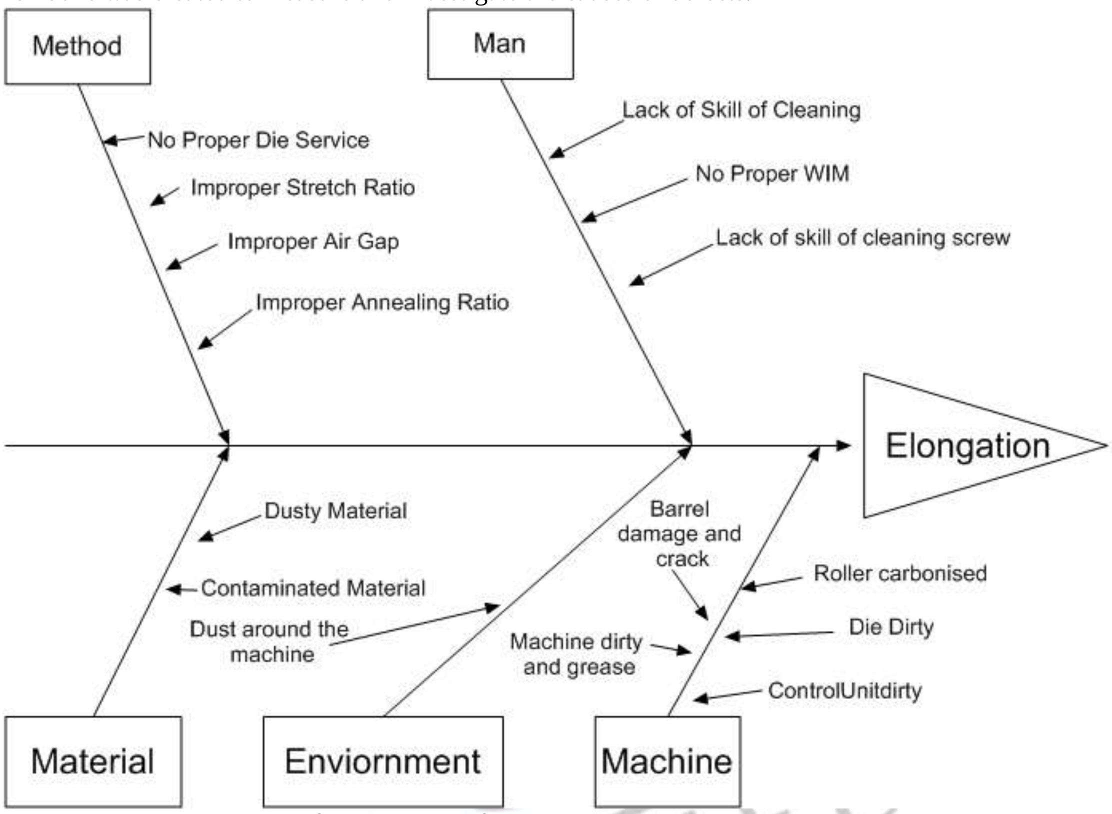


Figure 4 Root cause analysis for puncture in film

There were four machines selected for this study named as: M1, M2, M3, M4.

To calculate the DPMO and sigma level equation (1) and (2) were used. In equation 1, DR stands for Defected Result, NO stands for Number of opportunity and NU stands for number of units. For this particular study the value for NU is equal to one.

These data were used to calculate defect per million opportunities (DPMO) for each weeks. Table 4 shows the total output, reject quantity, DPMO and sigma level for each week.

$$\text{DPMO} = \frac{\text{DR}}{\text{NO} \times \text{NU}} 10^6 \quad (1)$$

$$\text{Sigma Level} = 0.8406 + \sqrt{(29.37 - 2.221 \times \ln \text{DPMO})} \quad (2)$$

Product	Inline Rejection Unit	Inline (K-Unit)	Percentage	Acc.
Product A	4567	4.567	33.25	33.25082
Product B	2067	2.067	15.05	48.29996
Product C	1789	1.789	13.03	61.32508
Product D	741	0.741	5.39	66.72006
Product E	675	0.675	4.91	71.63451

Product F	477	0.477	3.47	75.10739
Product G	461	0.461	3.36	78.46378
Product H	403	0.403	2.93	81.39789
Product I	372	0.372	2.71	84.10630
Product J	353	0.353	2.57	86.67637
Product K	350	0.35	2.55	89.22461
Product L	349	0.349	2.54	91.76556
Product M	184	0.184	1.34	93.10521
Product N	167	0.167	1.22	94.32108
Others	780	0.78	5.68	100
Total	13735			

Figure 5 In-line rejection based on part produced

There were different types of bags manufacturing in company. Table 4 shows the rejection data for woven plastic bag manufacturing and assembly line for the weeks of average of March. All the products from product A to Product N are plastic woven bags that have different sizes and film thickness. This data shows the highest rejection ratio compared to the previous months rejection data. The result shows that, part named case-A has the highest rejection rate for the weeks which is 4567 units and contributes 33.25 % of the total rejection rate. Since the part has the highest rejection rate it has been taken as the studying element for the research.

Week	Output	Machine rejection Unit				Total reject per week	DPMO	SIGMA
		M01	M02	M03	M04			
I	74880	30	468	455	203	1388	18536	3.5870
II	74880	32	470	450	195	1375	18363	3.5908
III	74880	28	472	430	204	1358	18136	3.5958
IV	74880	26	468	445	208	1378	18403	3.5899
V	74880	34	464	460	194	1382	18456	3.5888
VI	74880	37	464	465	202	1402	18723	3.5830
VII	74880	28	469	471	199	1401	18709	3.5833
VII	74880	34	463	460	209	1398	18669	3.5841
VIII	74880	37	472	441	197	1376	18376	3.5905
IX	74880	32	461	468	199	1392	18589	3.5859
X	74880	27	457	462	205	1382	18456	3.5888
XI	74880	30	461	442	192	1348	18002	3.5988
XII	74880	28	463	455	205	1378	18402	3.5900
Total	973440	403	6052	5904	2612	14971		

Figure 6 DPMO and sigma level for all weeks

A bar graph was constructed as in Figure 5, for each month based on reject quantity. Figure 5 shows that the highest rejection rate was identified in the week VI, meanwhile for other weeks the data collected shows small variations.

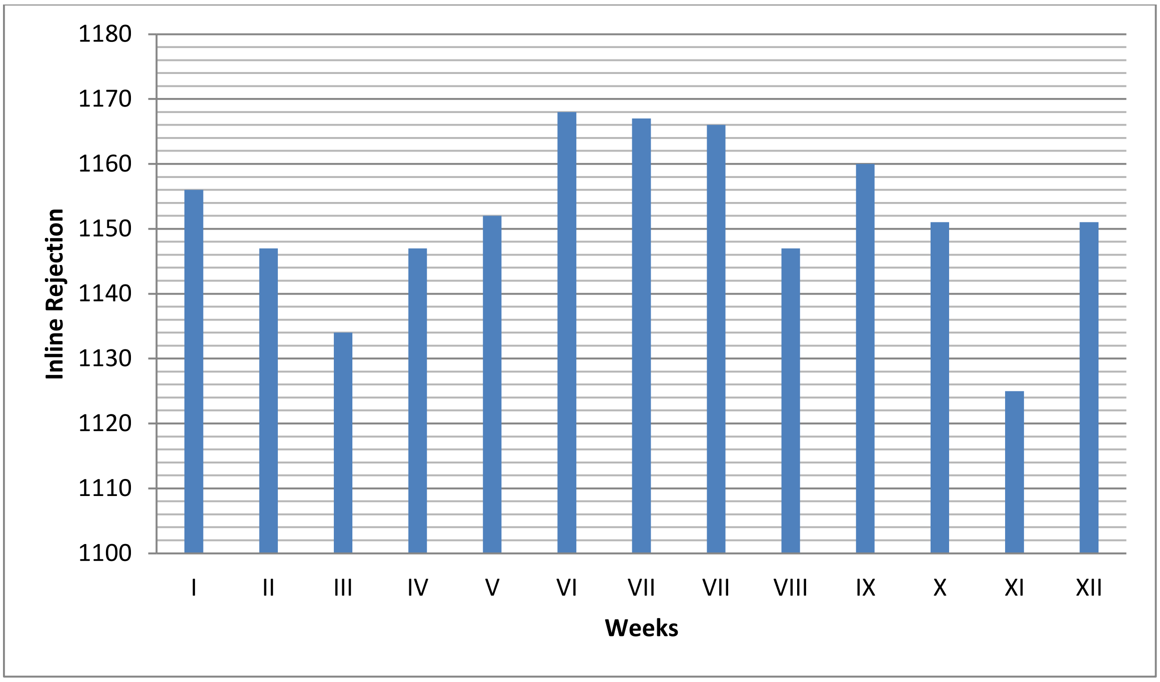


Figure 7 In-line rejection from week I to XII

Based on the data in table 4, the sigma level for the process were calculated and illustrated as in figure 6. The figure 6 reveals that the sigma level from the weeks is vary 3.5830 to 3.5988. This shows the average sigma level for the whole process is 3.5890. The lowest sigma level was recorded for the VI week and the highest sigma level was recorded on the XI week. Since the sigma level for the week VI has the lowest sigma level, the studies or research will be focused on the week VI. This data will used to track down the problem that contributes to highest reject on the part.

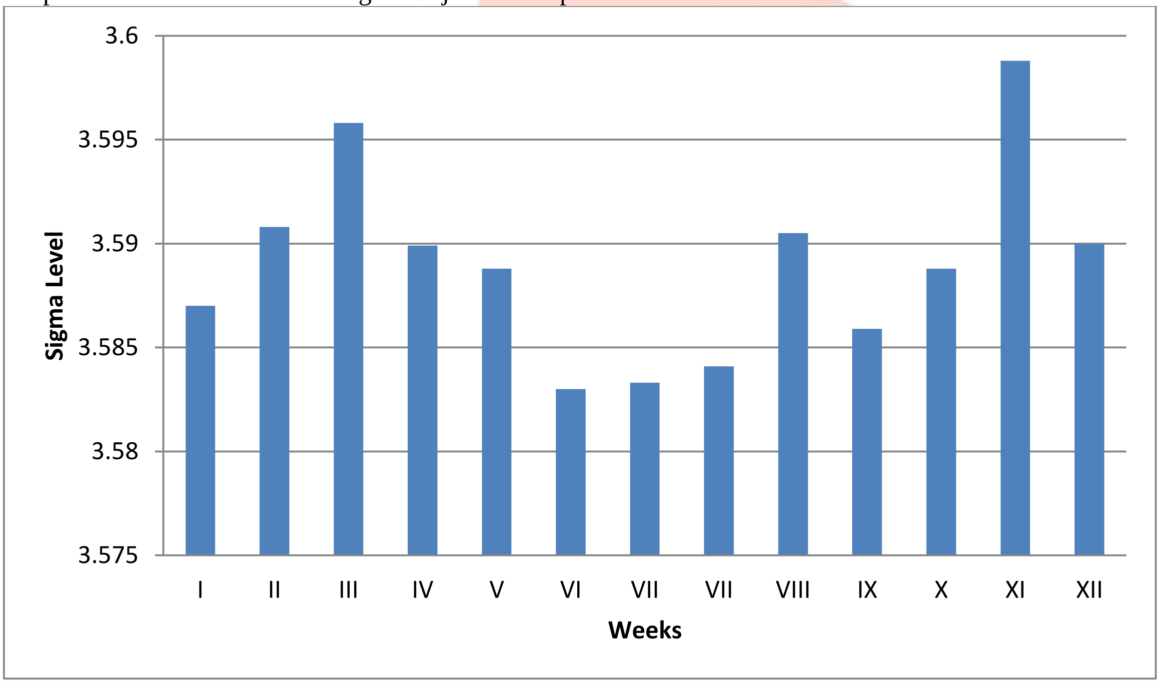


Figure 8 Sigma level from week I to XII

DMAIC- Analyze stage

Table 7 shows the most common types of defects that occurred data for the VI week and number of defects as particular defects. This table also shows the percentage and accumulated percentage of defects. Figure 5.6 illustrate the Pareto diagram for this particular data. As mentioned before, there are four machines (M01, M02, M03, M04) which produce the same part which known as case A and the data for defects were collected based on machines. This is to identify the machine which contributes to the highest rejection rate. The defects which are recorded in Table 5.3, are the common types of defects which normally occurs on plastic woven parts which produced by using tape laminated process.

Figure 7 explains that tape breakage defects are the major contributor for the rejection rate for the week VI which contributes almost 41% of the total rejects compared to other defects. If defect data compared by each machine, still black dot contributes the highest defects compared to others and for the machines, machine M03 contributes to highest tape breakage defect compared to other machines. As a measure to track down the problem machine M03 will be used to analyze the root cause for the tape breakage defects since it shows the highest rejection rate and the analyze data will be used as references for other machines.

Defects	Machine No.				Sub Total	Percentage	Acc.
	M01	M02	M03	M04			
Tape Breakage	77	694	545	536	1852	40.10	40.10
High Elongation	4	608	490	188	1290	27.93	68.03
Roughness in the film	0	320	330	43	693	15.00	83.03
Puncture in the film	0	0	235	0	235	5.09	88.12
Denier variation	28	86	100	17	231	5.00	93.12
Low Tenacity	4	128	20	5	157	3.40	96.52
Residual shrinkage	4	17	84	15	120	2.60	99.12
Screen Chocking	2	17	10	0	29	0.63	99.75
Fibrillation	0	0	0	6	6	0.13	99.88
Color Variation	0	0	5	0	5	0.11	99.98
Decreasing Density	1	0	0	0	1	0.02	100.00
Weld Line	0	0	0	0	0	0.00	100.00
Others	0	0	0	0	0	0.00	100.00

Figure 9 Reject data based on the defect type for average of weeks

Figure 7 shows the potential causes for high defects occurred in part for case A. Analyzing the rejects based on models indicates that the highest percentage of defects occurred in model of case A. The number of defects is high when there are new models being introduced. It may be due to the operators not given enough training or no special training for the operator to understand the correct method to produce the part.

Besides that the method or standard operation principles also can lead to high defects.

Analysis

In order to determine the exact and most likely causes of major defects, a brainstorming section was carried out with the Quality Assurance Engineer (QAE) in production and assembly line operation. Although the brainstorming section, all possible causes including major and minor causes were listed in the cause and effect in diagram. Following section will discuss on the root causes for tape breakage defects.

Machines are one of the factors that we must be given consideration. So the machine contribute a lot of possibilities to tape breakage rejection defect. For an example, without proper parameter setting it will result to a carbonized roller. Aging machines also can lead to defects. When an operator does not have enough experience and skill, it is quite obvious that the operator will produces more defects than the others.

Maintenance also plays and important part because, without proper maintenance the performance of machine will be affected and the desired output could not been achieved.

Some defects might occur when jobs carried out without proper guidance of leader or without any instruction. And another reason is that the number of defects will increase when untrained operator or new operators are assigned to do the job.

It was found that the operator did not know the correct method set the machine and the parameters but only followed the instructions without knowing the correct method. The work method is another major cause of the problems. As a result the operator can lead to tape breakage defect or other rejection.

Summary on the analysis

Conclusion for the analysis stage, defines as the major defect found was tape breakage and several problems were identified as the main problems causes high defects woven bag manufacturing production line. The major problem identified from the analyze section is the machine this due to the data which was collected indicates that the major problem for most of machines are the Tape breakage. This shows that the major defect might cause by the fault of machine. Although there are other several factors affecting that causes problems, the main consideration has given to the machine factors. The next section of this thesis will be discussed about suggestions for improvement.

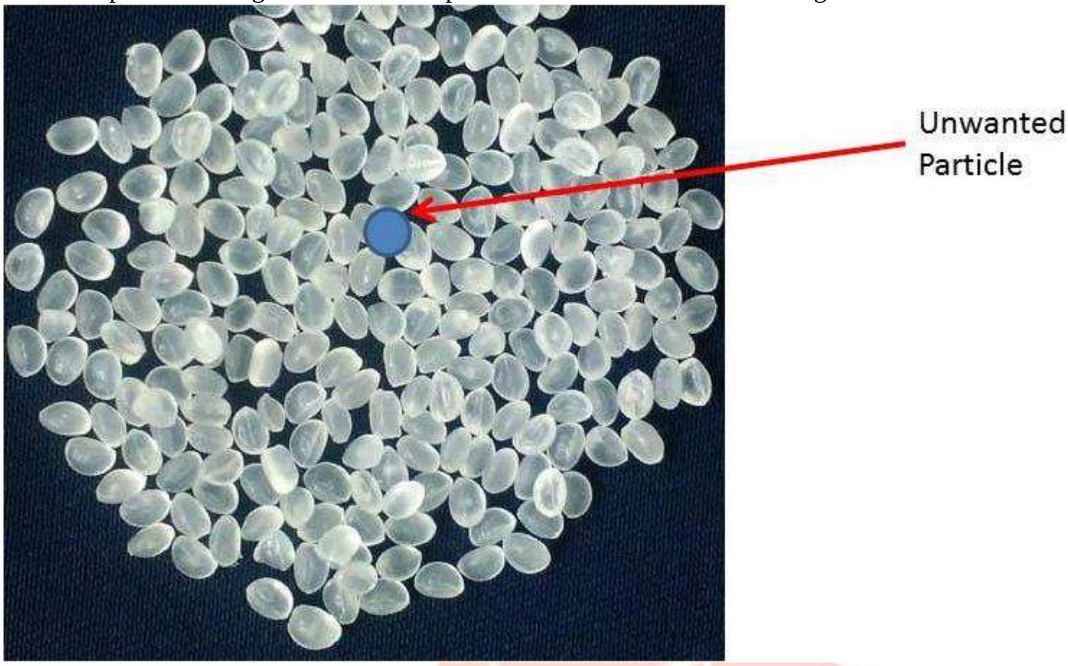
Improve stage

After collecting and analyze the data, the most identified defect was the tape breakage defect which caused major quality problem in the woven bags manufacturing production line. Cause and effect diagram was also drawn to identify the causes of major defects. From here seven suggestions was recommended to reduce the defects. The suggestions were:

1. Reduction of particles in Raw Material
2. Maintaining of moisture content in environment
3. Reduction in Stretch Ratio

Reduction of particles in raw material

If there are any external particles in raw material causes the tape breakage because of improper adhesion with base material. So the reduction in external particle in the raw material reduces the tape breakage defect in woven bags manufacturing production line. An image was captured from a normal purpose microscope. Figure shows the particles available in raw material. The image is magnified to 100 times. It was completely visual parameter to control the defects. A person is assigned to check the particles in the raw material. Though this case is no occurs for most of the time.



Maintaining moisture content in environment

There are two cases of moisture content first is moisture present in raw material (Plastic) and other case is high relative humidity in air. Both two cases cause the tape breakage defect. The remedy of this problem is seasoning of raw material. This test is done by an instrument name as DSC 71P Moisture Analyzer machine. If the moisture content is less than 0.01% by mass then the material is good for the processing. Because of the rainy weather and storage environment the most of samples have shown the moisture content more than 0.01 percent by weight. This raw material was reheated in oven before using

Reduction in Stretch Ratio

Draw stretch ratio is one of important process parameter for quality of plastic woven bags manufacturing. As the draw ratio increase tenacity increase and percentage of elongation decreases. To obtain a tape with good combination of mechanical properties, non-fibrillation and curl free tapes. The stretch ratio is also determining initial cross section of the slit strip/non filaments which is required for obtaining final width of the tape or size of monofilaments. However draw ratio increase the alignment of the polymer molecules. For this study a special team was established to check the stretch ratio. The company was using stretch ratio of 3:1 to 5:1. This stretch ratio was completely manipulated with new feed back Table 5.4 shows the different stretch ratio for different weeks. For our study we have changed the stretch ratio 3:1 to 7:1 and get the results. After getting optimum result a standard stretch ratio was set to the machines. For this study the machine no. M03 was selected, and after optimizing results we have set this stretch ratio to all for machine, that was selected for this study. Figure 8 shows the defects for every weeks and stretch ratio. First four weeks were the stretch ratio implemented for optimizing effects on defects. The figure 8 shows that the third week has the stretch ratio 5:1 to 6:1 and it has the minimum defects. This stretch ratio (5:1 to 6:1) was implemented for all the weeks and all the machines.

Week	Stretch ratio		Machine No.
	From	To	
I	3:1	4:1	M03
II	4:1	5:1	M03
III	5:1	6:1	M03
IV	6:1	7:1	M03
V	5:1	6:1	M01, M02, M03, M04
VI	5:1	6:1	M01, M02, M03, M04
VII	5:1	6:1	M01, M02, M03, M04
VIII	5:1	6:1	M01, M02, M03, M04

IX	5:1	6:1	M01, M02, M03, M04
X	5:1	6:1	M01, M02, M03, M04
XI	5:1	6:1	M01, M02, M03, M04
XII	5:1	6:1	M01, M02, M03, M04

Figure 10 Stretch ratio for different weeks and Machines

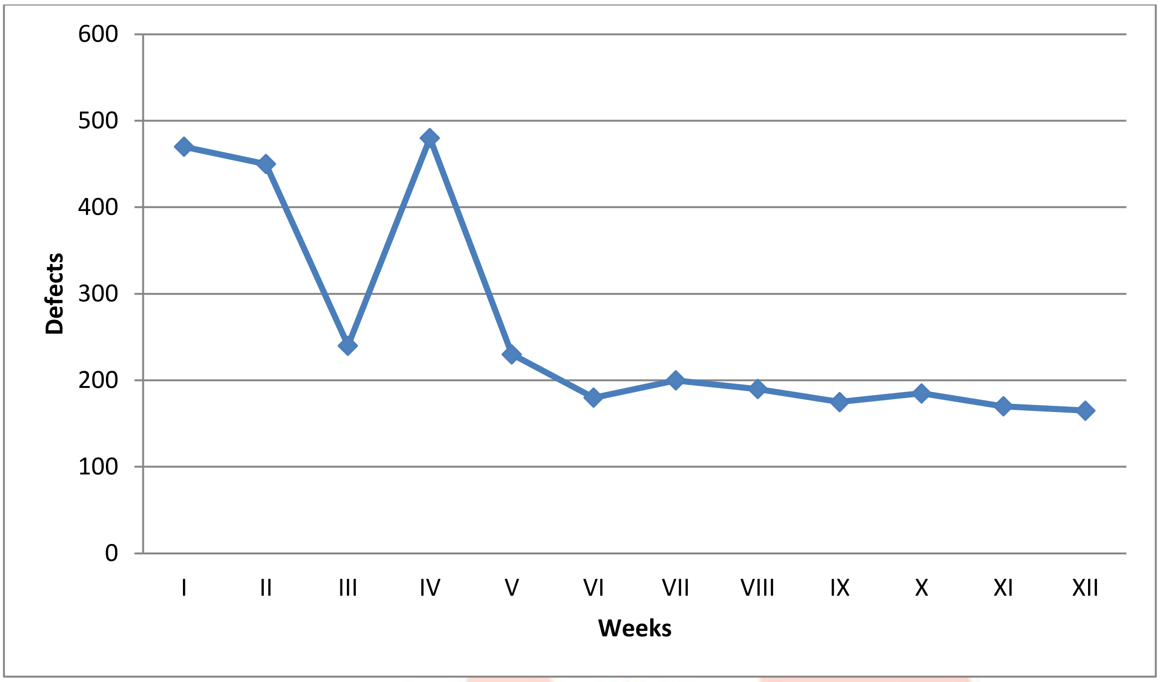


Figure 11 Defects for different stretch ratio for weeks

Five day Production

To achieve sigma level up to value six, a special five day program is conducted. Every expert engineer, quality person and operator was present there. Every optimum process parameter is selected. The set parameters were as: barrel temperature is set to 110℃, Die temperature is set to 140℃, quench temperature of water is set to 35℃, and stretch ratio set to 5:1. Due to policy of company other few parameters were not shown. A combined effect of defects is shown by figure 11. From this figure the week VIIth have the minimum defects.

Day	**Output**	**Rejection**	**DPMO**	**Sigma Level**
Day 1	10698	3	28.0426	5.5527
Day 2	10698	4	37.3900	5.4612
Day 3	10698	2	18.6950	5.6224
Day 4	10698	3	28.0426	5.5527
Day 5	10698	3	28.0426	5.5527

Figure 12 DPMO and sigma level for five day production

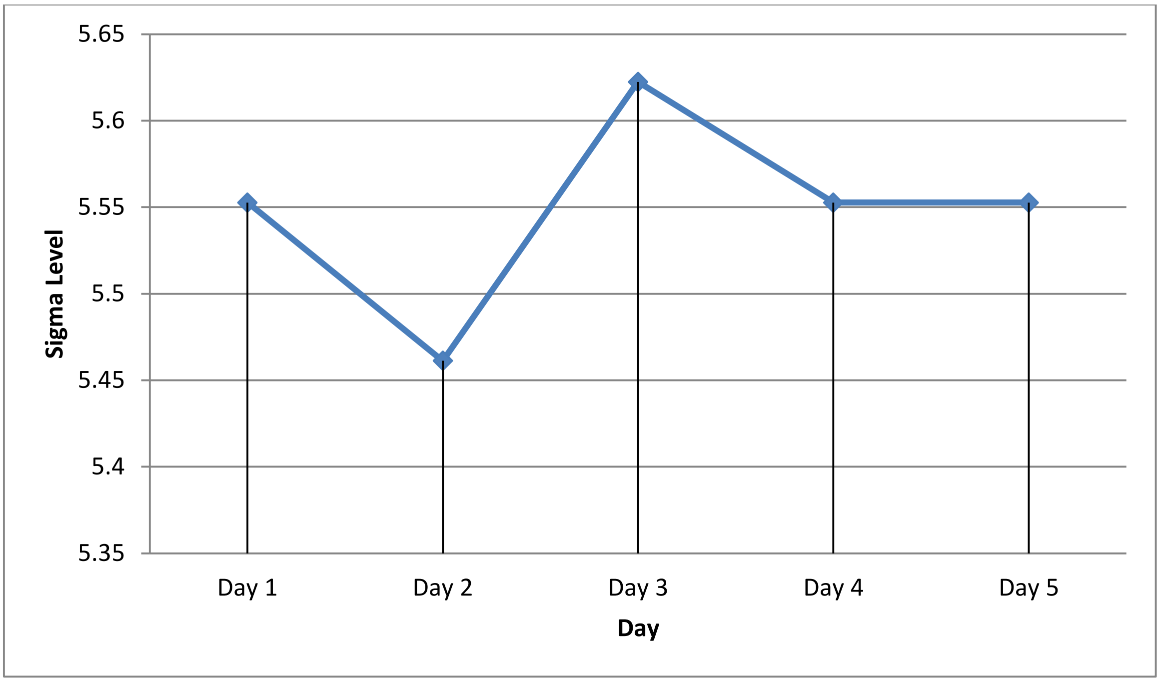


Figure 13 Sigma level for five day study

Summary on improve stage

Based on the given suggestions, the product rejection rate can be reduce and at the same time the sigma level can be improve since the defect per unit will be much more smaller than the previous situation.

Control stage

Control stage is another important stage before completing DMAIC methodologies. This chapter will describe the step taken to quality control. Control chart is the type of quality tool that is used as comment in this study.

1 Control chart

Control chart is one of popular statistical process control tools which will be used in this stage because control chart can detect abnormal variation in the process parameters. Control chart will be used in this assembly operation is c-chart because c-chart can monitors the number of defects per inspection unit and is based on the Poisson model of distribution. Besides that c-chart also will monitor multiple types of quality in a product manufacturing.

chart

C-chart note occurrences of every defect found in the production line and chart the number of defects per product unit or good. In general, the opportunities for nonconformities or defect may be numerous, even though the chances of nonconformity occurring in any location on a product are relatively very small. The Poisson model is an appropriate model in this case and serves as a basic for the c-chart. It is also important to note that the area of opportunity for defects to occur must be constant from sample to sample when applying the c-chart model.

1. Determine C-bar.

$$cbar = \frac{1}{k \sum c(i)}$$

There are k inspection unit and c (i) is the number of nonconformities in the i^{th} sample.

2. Since the mean and variance of the underlying Poisson distribution are equal,

$$\sigma^2 = cbar$$

Thus,

$$\sigma = \sqrt{cbar}$$

And the UCL and LCL are;

$$UCL = cbar + 3.\sqrt{cbar}$$

$$LCL = cbar - 3.\sqrt{cbar}$$

3. Plot the centre line cbar, the LCL and UCL, and the process measurements c(i).
4. Interpret the control chart.

Cbar : the populations mean number of defects per inspection unit
c(i): the number of defects observed in sample i
LCL, UCL: the lower, upper control limits for the c-chart
i: the samples index

Once the c-chart is set up using the computed control limits and center line, plot the c (i) values. Next, connect the points with a solid line and use the chat to monitor the process. Here, c (i) is the observed number of defects on the (1) inspection unit.

Summery

As a conclusion for this chapter, the major defect in the plastic woven bags manufacturing unit were identified using the statistical process control tools and the cause and effect diagram were used to identified the root cause for major defect parameters. In the improvement stage the analysis suggestion was proposed. Besides that, suggestion to control the quality level in the production and assembly line also was proposed in the control stage.

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