Improving quality of plastic woven laminated bags manufacturing by minimizing defects using six sigma

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Abstract

The six sigma methodology have an important place for developing and reducing the defects which occur during weaving of plastic bags in the firms. The aim of six sigma is defining, analyzing, correcting and improving the variables, which affect the quality of weaving process in order to decrease the number of defects and the failures and to propose the improvement means for the processes. In this study general structure of six sigma is explained with regard to 'how to define the complex problems which are encountered in the manufacturing of woven bags along with the relevant knowledge and comments for statistical methods that are utilized in measurement and quality improvement of the process.

Six Sigma is an optimization technique and its largest difference is to be a flexible system aiming to optimize both the performance and the managerial skill. The primary objection of Six Sigma is to minimize the errors and to actualize a quality level in the groove and its philosophy consists of the aims of reducing costs, increasing customer satisfaction, actualizing the optimization of business processes and increasing the efficiency of the employees. Six Sigma approach, with the most areas of application is observed in production sector is combined of the junction of the best and most successful sides of the previous methods.

Key words: six sigma, quality control, statistical approach

INTRODUCTION

The companies have to analyze, monitor and make improvements of their existing status in order to comply with the market competition and stay in the market under the ever changing world competition and market conditions. In this regard the six sigma is a methodology that enables the firms to review their existing status and guide them in making improvements by analyzing their status via statistical methods. Six sigma applies DMAIC approach to improve the quality and control the defects.

In Six Sigma Approach of DMAIC (Define, Measure, Analysis, Improve, Control)[Hikmet Erbiyik, Muhsine Saru,2015]

Define: In the first step of six sigma studies, what is source of problems causing to failure? What are the relations between cause and effect of problem? By searching the answers for above questions the relevant problem is defined.

The aim of this stage is to define the objective and scope of the problem. The important points that have to be taken into account;

- The suitability of the selected project to your capability and opportunity
- Creating a higher quality level and the high probability of cost reduction.
- Defining problems clearly and as much possible as numerical

Measure: In this stage relevant information that defines the existing status by all means is gathered. Unless valid and true measurements are made, it is not possible to define the existing performance and effects of the realized improvement of the processes. The most critical factor in this stage is true definition that what items to be measured. In the measurement stage, measurement work of the failures that causes the problem is made. In terms of the measurement work, number and ratio of failures are defined and possible consequences are evaluated.

Analysis: Kinds of defects and volume of defects are revealed as numerically. If we may respond that when, where and how the defects are emerged , then we presume that we have the sufficient information for the concerned development issue. In the analysis stage the causes of defects that yields to poor quality are investigated and relevant factors examined in detail.

Improve: These stages, is the one that the defects are eliminated or their effects will be mitigated. In the improvement stage, necessary works are done in order to eliminate the causes of defects that yield to poor quality.

Control: In the last stage, control work is made. Control work is made to eliminate the causes of defects that yield to poor quality and to maintain the continuity in process improvement. Additionally control works are so important to realize that verifies the compliance of planned and realized quality objectives.

Control stage is the most important stage in six sigma methodology. In this stage;

- The reduced defects in the first four stages are defined.
- It is decided that how the defects will be kept under control.
- Even the least successes are ensured to be lasting with the aid of six sigma's powerful tools.

MANUFACTURING PROCESS

The particular weaving processes of the plastic woven bags are described in figure 5.1.It shows the process flow for plastic woven bags manufacturing and production line.

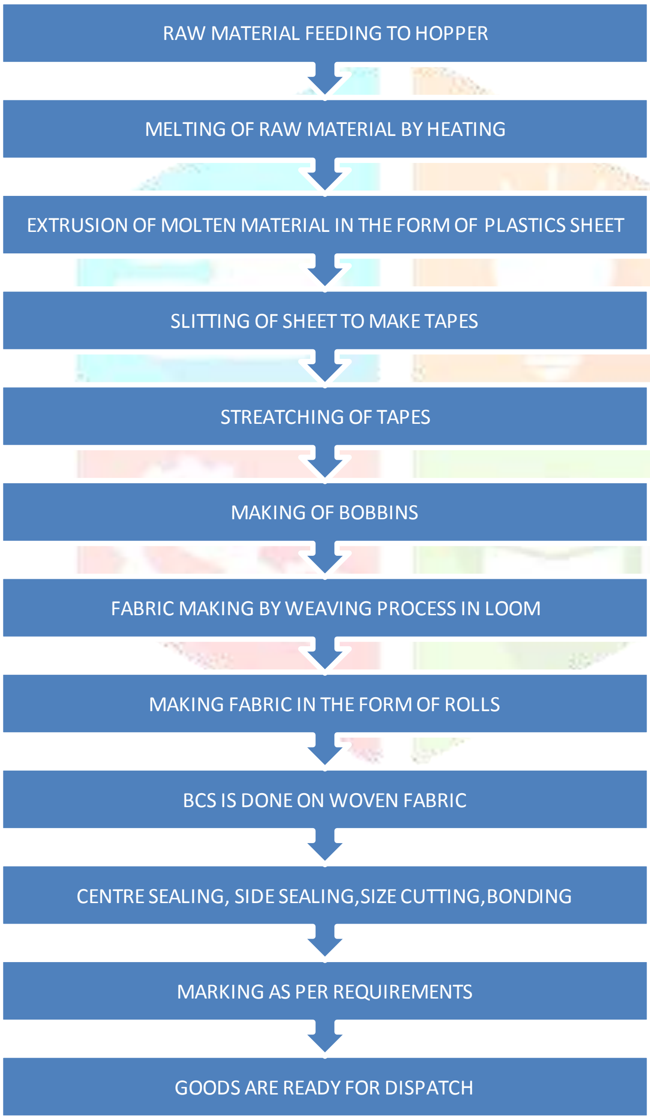

Figure 1 The process flow chart of woven plastic bags manufacturing process.

This Manufacturing produces polyethylene bags through a blown-film extrusion process. In the blown-film extrusion process, small plastic pellets (called resin) are melted down under controlled conditions so that they become molten and pliable. They are then pressed (extruded) through a circular die gap to form a continuous tube of plastic. While it is still in this molten state, the tube is pinched off at one end and then inflated and stretched to the size and thickness of the desired finished product. The inflated bubble of plastic is drawn vertically up a tower so that it has a chance to cool before it is flattened out and wound onto a roll.

After the plastic is on a roll, it can be cut to form tubing, single-wound sheeting, or centrefold sheeting. Most often, we transform the plastic into poly bags.

Polyethylene bags are made by heat sealing and cutting rolls of film. Rolls of tubing or sheeting are fed through a machine that draws material out to the proper length. The machine then cycles to place a seal on the material and then cut it off to make an individual bag. In some cases, with small bags, machine cycle speeds may produce up to 70,000 bags per hour. In other instances, a large bag may run as slowly as 2,000 bags per hour.

The secret to producing high quality film is having good equipment that maintains a consistent flow of material throughout the process.

PROBLEM STATEMENT

A plastic woven bag manufacturing company, specialized in manufacturing of woven bags is going through rejection problem due the defects caused in the products and the quality issues. The XXX plastics Pvt. Limited manufactures,

- High density polyethylene (HDPE) woven fabric,
- polypropylene (PP) woven fabric,
- HDPE/PP un-laminated woven Fabric,

This case study was focused on PP and HDPE woven bags production.The objectives of this thesis are:

- To utilize six sigma methodology in performing the study.
- To study the "**DEFECTS**" rejects utilizing QC tools at the identified assembly lines.
- To identify the root causes of the rejects

- To recommend actions to improve the quality and sigma level.

RESEARCH 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.

The DMAIC Six Sigma methodology applied to manufacturing process

1 Define the process (Define stage)

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). In this stage the whole manufacturing process was studied and well defined to know the flaws at every step of the process. To study the processes in detail, use of flow charts, petro charts, and manuals was used. The analysis was focused on the production line providing tapes for manufacturing of woven bags.

Product	Inline Rejection Unit	Inline (K-Unit)	Percentage	Acc.
Product A	1789	1.789	39.71	39.71143
Product B	675	0.675	14.98	54.69143
Product C	461	0.461	10.23	64.92143
Product D	372	0.37	8.26	73.18143
Product E	353	0.35	7.84	81.02143
Product F	350	0.35	7.77	86.67637
Product G	184	0.18	4.08	92.87143
Product H	144	0.14	3.20	96.07143
Product I	100	0.10	2.22	98.29143
Others	77	0.08	1.71	100
Total	4505			

Figure 2 In-line rejection based on part produced

The table shows the no of products produced in the company with the rejection data for woven plastic bag manufacturing and assembly line for the weeks of one month. All the products from A to I are plastic woven bags that have different sizes and film thickness name. The result shows that, part named case-A has the highest rejection rate for the weeks which is 1789 units and contributes 33.71 % of the total rejection rate. Since the part has the highest rejection rate it has been taken as the studying element for the research.

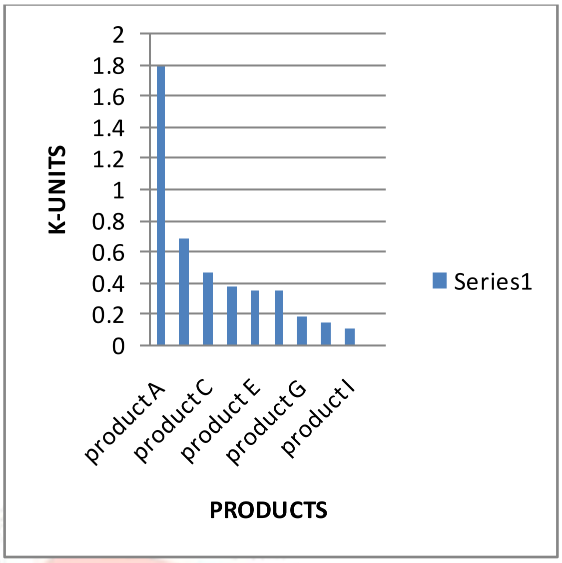

Figure 3 K-Unit for In-line rejection of products

The above given Fig shows the Pareto diagram for the particular part rejects based on the code name. This data has been collected for the whole month on weekly bases.

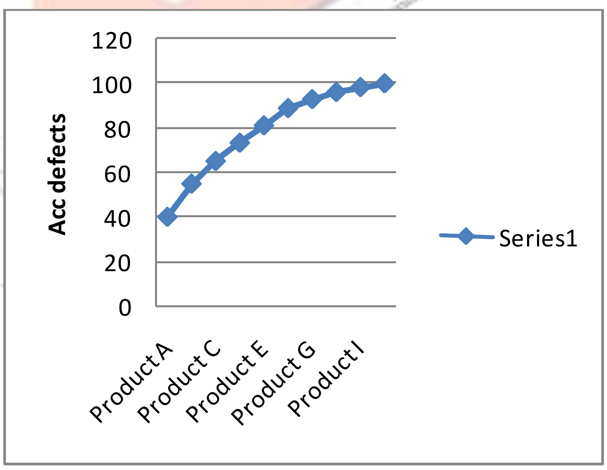

Figure 4 Accumulated defects for Inline Rejection of products

DMAIC -Measure Phase

In this stage, focus is on data collected for 11 weeks for the rejection rate in 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. Data was collected from 4 machines which produce the same product for analysis of the major defects.

The Measure includes

- Matrics and sample determination
- Data gathering plan
- Processes data gathering
- Sigma level calculation
- Target definition

To calculate the DPMO and sigma level equation (1) and 2) [Alexender tenera,2014] were used. In these equation 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 5.2 shows the total output, reject quantity, DPMO and sigma level for each week.

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

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

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 5 DPMO and sigma level for all weeks

A bar graph was constructed as in Figure 6, for each month based on reject quantity. Figure 5.4 shows that the highest rejection rate was identified in the week VI, meanwhile for other weeks the data collected shows small variations.

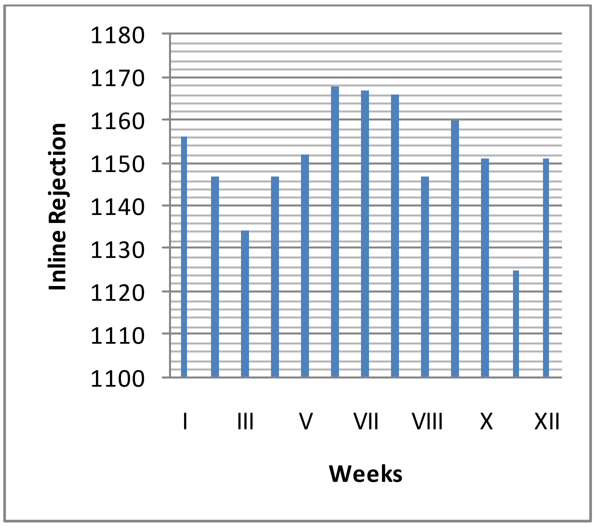

Figure 6 In-line rejection from week I to XII

Based on the data in table 5, the sigma level for the process were calculated and illustrated as in figure 5. Calculations for the DPMO (defects per million opportunities) and sigma level are attached in fig 6.1 and 6.2. The figure 7 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 6.1 Over all calculations for DPMO for all weeks

Week	Output	TRPW	DPMO = $\frac{Total\ Rejection}{NU \times Total\ Output} \times 10^6$	DPMO
I	74880	1388	$\frac{1388}{1 \times 74880} \times 10^6$	18536
II	74880	1375	$\frac{1375}{1 \times 74880} \times 10^6$	18363
III	74880	1358	$\frac{1358}{1 \times 74880} \times 10^6$	18136
IV	74880	1378	$\frac{1378}{1 \times 74880} \times 10^6$	18403
V	74880	1382	$\frac{1382}{1 \times 74880} \times 10^6$	18456
VI	74880	1402	$\frac{1402}{1 \times 74880} \times 10^6$	18723
VII	74880	1401	$\frac{1401}{1 \times 74880} \times 10^6$	18709
VII	74880	1398	$\frac{1398}{1 \times 74880} \times 10^6$	18669
VIII	74880	1376	$\frac{1376}{1 \times 74880} \times 10^6$	18376
IX	74880	1392	$\frac{1392}{1 \times 74880} \times 10^6$	18589
X	74880	1382	$\frac{1382}{1 \times 74880} \times 10^6$	18456
XI	74880	1348	$\frac{1348}{1 \times 74880} \times 10^6$	18002
XII	74880	1378	$\frac{1378}{1 \times 74880} \times 10^6$	18402

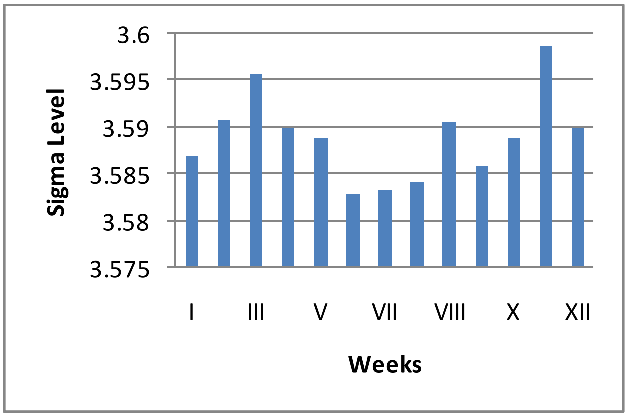

Figure 7 Sigma level from week I to XII

Defects	Machine No.				Sub Total	Percent age	Acc.
	M01	M02	M03	M04			
Puncture in film	76	236	529	625	1466	51.35	51.25
Low tenacity	10	205	309	108	632	22.14	73.49
Color variation	0	0	235	80	315	11.03	84.52
Roughness in film	60	43	16	0	119	4.17	88.69
Shrinkage	12	14	26	50	102	3.57	92.26
Dirt patches	16	52	21	0	89	3.12	95.38
Scratches	10	10	10	21	51	1.79	97.17
Burr	19	0	0	30	49	1.72	98.89
Greece marks	0	20	0	12	32	1.12	100.00
Others	0	0	0	0	0	0.00	100.00

Figure 8 Reject data based on the defect type for average of weeks

DMAIC- ANALYSE PHASE

This phase is about analyzing the root causes o defects occurring during the process. Table 8 shows the most common types of defects that occurred and number of defects as particular defects. This table also shows the percentage and accumulated percentage of defects. Figure 8.1 illustrate the Pareto diagram for this particular data. Figure 8 explains that puncture in film defects are the major contributor for the rejection rate which contributes almost 51% of the total rejects compared to other defects. If defect data compared by each machine, still punctured film contributes the highest defects compared to others and for the machines, machine M04 contributes to highest tape breakage defect compared to other machines. As a measure to track down the problem machine M04 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.

Summary on the analysis

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 is puncture in films. 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 work will discuss about suggestions for improvement.

Week	Temperature (℃)		Remark
	Mean	Tolerance	
I	220 – 280	Not Applicable	Old
II	220 – 280	Not Applicable	Old
III	220	± 2℃	New
IV	230	± 2℃	New
V	240	± 2℃	New
VI	260	± 2℃	New
VII	280	± 2℃	New
VIII	230	± 2℃	New
IX	230	± 2℃	New
X	230	± 2℃	New
XI	230	± 2℃	New
XII	230	± 2℃	New

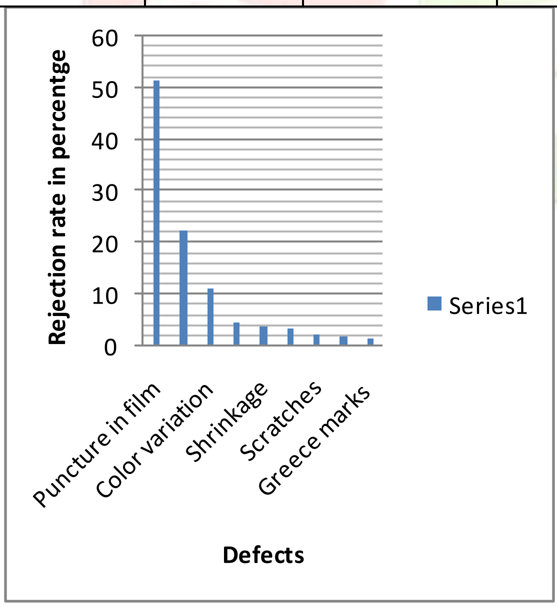

Figure 8.1 Reject data based on the defect type

DMAIC- Improve stage

Introduction

After collecting and analyze the data, the most identified defect was the puncture in film 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. Setting proper Temperature(setting-Barrel, Die, Quench water, Oven)
2. Reduction in Denier Variation
3. Variation in Godet speeds.
4. Checking for mechanical damage of tapes.

Setting proper Temperature

Extrusion temperature i.e. the temperature profile on the extruder affects the melt temperature and extruder output. There were four temperatures plays crucial role in plastic bags manufacturing and production line. These are:

1. Barrel Temperature
2. Die Temperature
3. Quench Temperature
4. Oven Temperature

Barrel Temperature

Thermistor type temperature sensor is used to measure the barrel temperature. Thermistor probe is attached to barrel of machine. There were three temperature probe used to measure the temperature. All three temperature sensor have temperature difference about 2℃. For present work the mean value of three temperatures were used to study. Before this study the operators were not interested in checking or controlling the temperature barrel. Our inspection shows that the temperature varies from 220 ℃ to 280 ℃. When the temperature is not proper set, this condition will lead to a situation where the foreign materials or scrap material will mixed original material and at the same time leads to tape breakage and other defects. Table 5.5.1 shows the setting of temperature for different weeks.

Figure 9 temperature set for different weeks.

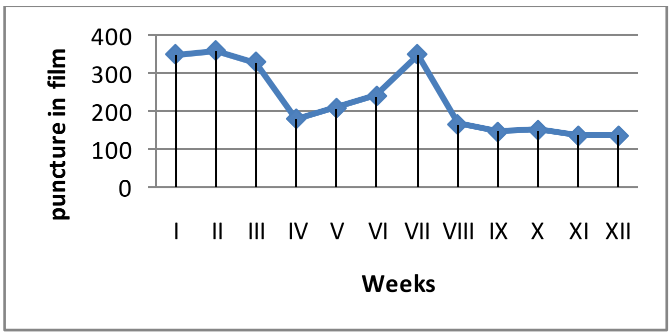

Figure 9.1 Defects of tape breakage after setting temperature of barrel

Die Temperature

Die temperature is another crucial parameter for quality of plastic woven bags manufacturing. Because of die temperature is quite sensitive to measure so thermal couple type of temperature gauge is used to measure the die temperature. Some times for quality purpose an IR temperature sensor is also used to ensure the die temperature. It is non-contact type temperature meter. Figure 5.13 shows the image of non-contact IR thermometer. The old temperature for die was set to 120 ℃ For this study the die temperature is set 100 – 150 ℃ The figure 5.12 shows the effect of die temperature on defects of woven plastic bags manufacturing. Week I[st] (Die temperature is 100 ℃) shows the highest defects. While the week V[th] (Die temperature is 140 ℃) shows minimum defects. So the die temperature 140 ℃ is set for rest of weeks.

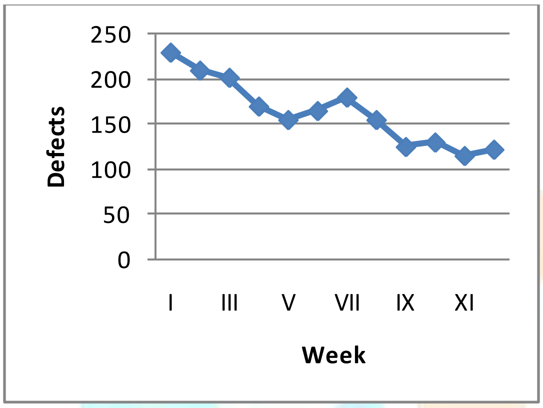

Figure 9.2 The defects after changing die temperature

. Quenching Temperature

Quenching temperature is also another crucial variable as the rate of the cooling has a significant effect on the strength and characteristic of the products. Proper quench temperature is also fewer tendencies to fibrillation. Water was the quenching media that is stored in an open tank.In the stretched tape process rapid cooling with low quench temperature product a film of higher crystallinity which results in poor orientation.

Figure 9.3 Table for months and quench temperatures

Figure 10, shows the defects due to temperature variation a combined temperature guide. In this scenario the overall defects were count due to temperature change, the barrel temperature is set to 100 ℃, die temperature is set to 140 ℃ and quench water temperature is set to 35 ℃ This reveals that the defects were minimized for week V to XII.

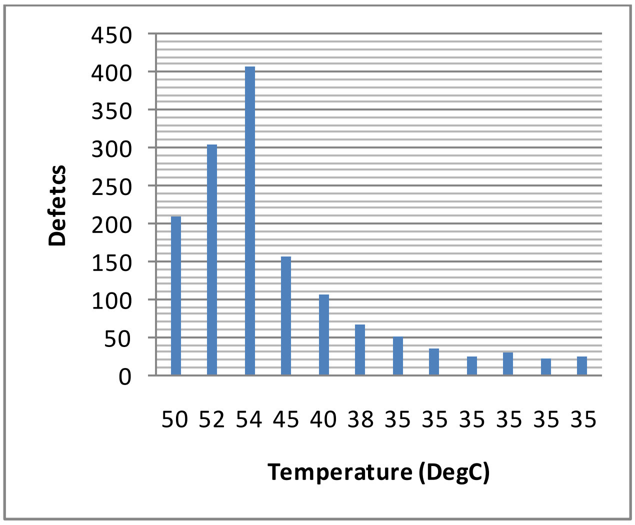

Figure 9.4Number of defects with respect to quench temperature

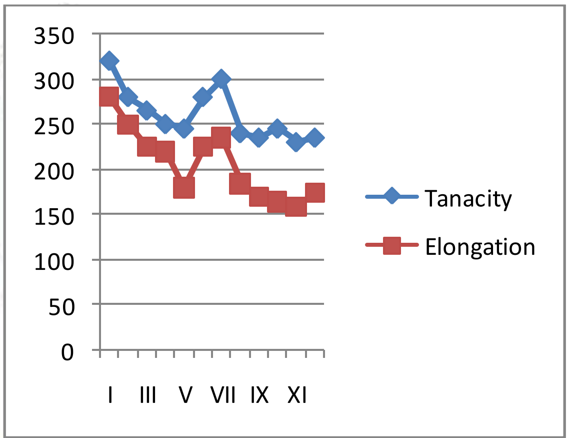

Figure 9.5 Quench temperature and tenacity and elongation

Week	Temperature (℃)		Machine
	Quench	Die	
I	50	100	M02
II	52	110	M02
III	54	120	M02
IV	45	130	M02
V	40	140	M02
VI	38	145	M02
VII	35	150	M02
VIII	35	140	M01, M02, M03, M04
IX	35	140	M01, M02, M03, M04
X	35	140	M01, M02, M03, M04
XI	35	140	M01, M02, M03, M04
XII	35	140	M01, M02, M03, M04

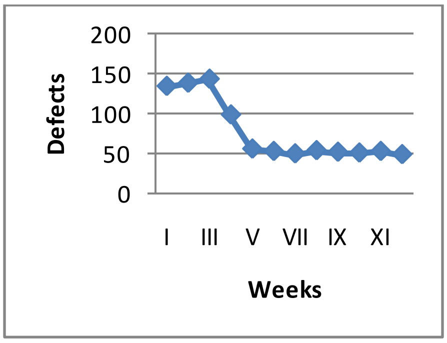

Figure 10 Defects due to temperature variation a combined temperature guide.

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. Table 11 shows the parameters and their set vale. A combined effect of defects is shown by figure 11.1

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 11 DPMO and sigma level for five day production

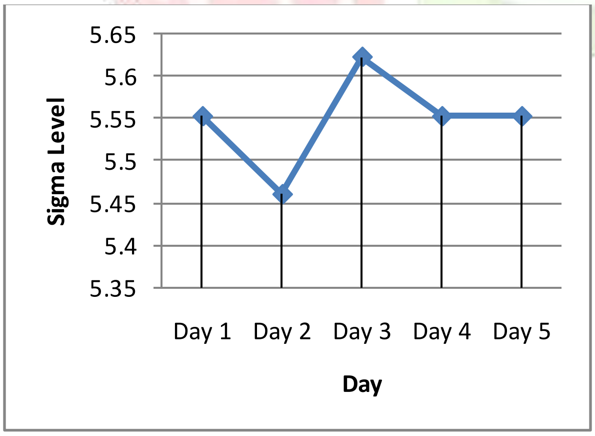

Figure 11.1 Sigma level for five day study

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.

CONCLUSION

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.The root cause for the puncturing of film defect has been successfully determined. Corrective option to overcome this quality problem has been suggested. Lowering the water quench temperature minimized the defects. The optimum water quench temperature was found 35 ℃. The implementation of the proposed corrective action needs commitment from the management of the company. The finding from this project can be used as a guide to improve other quality problems. It is hoped that the company can take up the suggestion given in this study to be implemented.

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