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Implementation of Six Sigma For Minimizing The Defects Rate At A Yarn Manufacturing Company

Neha Gupta
Department of Mechanical Engineering
Integral University
Lucknow, India

Dr. P. K. Bharti
Department of Mechanical Engineering
Integral University
Lucknow, India

Abstract

This article presents a quality improvement study applied at a yarn manufacturing company based on six sigma methodologies. More specifically, the DMAIC (Define, Measure, Analyze, Improve, and Control) project management-methodology & various tools are utilized to streamline processes & enhance productivity. Defects rate of textile product in the yarn manufacturing process is so important in industry point of view. It plays a very important rate for the improvement of yield & financial conditions of any company. Actually defects rate causes a direct effect on the profit margin of the product & decrease the quality cost during the manufacturing of the product. By checking & inspection of defects of product at different point in production where more defects are likely to happen. A thousand defects opportunities create in the final package of yarn. That's why it is decided to do work & implement DMAIC methodology in winding departments where the final package of yarn is make.

Keywords-Six Sigma; DMAIC; Lean manufacturing; Yarn manufacturing.

I. Introduction and Background

Organizations look for ways to improve their production and management processes in order to remain competitive in the market. This calls for ways to reduce production cost, enhance productivity and improve product quality. Therefore, organizations must utilize all the available resources efficiently and effectively in order to cater their customers with high quality products at a low price. For these reasons, researchers all over the world proposed several improvement strategies and tools to satisfy organization's needs. Such initiatives include Total Quality Management, Quality Awards, Total Preventive Maintenance (TPM), Lean and Six Sigma. The lean concept, which was initially referred to as the Toyota Production system, concentrates on the flow of the entire processes rather than on the optimization of individual operations [13]. Womack (2002) specified the main components of lean management system as follows:

- Identify process value from the customer perspective.
- Identify the value stream for each product and eliminate all types of wastes currently imbedded within the production process.
- Try to develop a continuous production process.
- Develop the pull management technique within the production lines.
- Manage toward perfection.

The main thing of Six Sigma is to taking the existing product, process and improves them in a better way. It is a very powerful approach to achieve the financial goals for the organization and improving the company's value by the following:

- Data driven
- Project based
- Disciplined and systematic
- Customers focused (internal & external)

Success of every organization is dependent on, how to introduce and implement Six Sigma in the organization. For clear understanding, "Six Sigma Onion" is a best example for showing the process of implement Six Sigma in the organization [30].

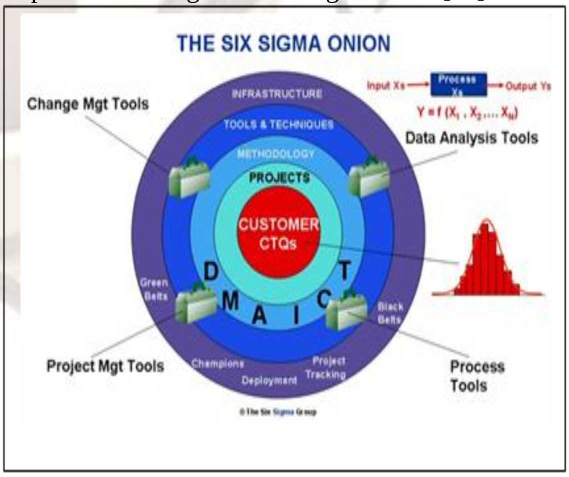


Figure 1. Six Sigma Onion

Six Sigma, on the other hand, is a data driven methodology used to identify root causes for variations in a production processes in order to achieve organizational excellence. Six Sigma management strategies require process improvement through identifying problem, root causes, process redesign and reengineering, and process management. Six Sigma follows a model known as DMAIC (Define, Measure, Analyze, Improve, and Control). Therefore, Six Sigma starts by analyzing defects and lean initial focus is on customer, process flow, and waste identifications [23]. However, using one of these tools has limitations. Since lean eliminates the use of Six Sigma's DMAIC cycle as a management structure to define required process capabilities to be truly lean. On the other hand, Six Sigma eliminates defects but does not address how to optimize the process flow. Hence, applying both Six Sigma and Lean tools sets results in far better improvements than could be achieved with either one method alone [16].

DMAIC is a systematic six-sigma project management practice inspired by Deming's PDCA (Plan, Do, Check, and Act) Cycle. The process consists of the five phases called Define, Measure, Analyze, Improve and control. The Define phase concentrates on forming the team, defining the project's goals, mapping the process, identifying customers, and identifying the high impact characteristics or the CTQs (Critical to Quality). The Measure phase consists of defining and executing a systematic data collection plan for the key measures (CTQs) for the targeted process. Data collected in the Measure phase are analyzed in the Analyze phase to identify the root causes behind the gap between the current performance and the goals identified in the first phase by defining the main type of wastes embedded within the production processes and the root causes for these wastes. The Improve phase focuses on identifying expected solutions, suggest set of alternative solutions to enhance performance, and implement some of these solutions according to the available budget and the expected cost for each alternative. The Control phase concentrates on creating and implementing monitoring and response plans for sustaining improvements, spread out the outcome and the methodology for the whole organization, insure the establishment of a new culture within the organization. Moreover, operating standards and procedures are documented and published in the Control phase.

Lean and Six Sigma have been implemented successfully in the manufacturing and service sectors to optimize different performance measures. Both lean and Six Sigma methodologies have proven over that last twenty years that it is possible to achieve dramatic improvements in cost, quality, and production time by focusing on process performance. Linderman et al. (2003) pointed out that Six Sigma could be implemented to the processes of producing manufacturing goods, business trade, executive management, and services. Recent research papers include improving operational safety [5], reducing amount of waste [8], improving quality for surveillance cameras to diminish related excess costs [10], enhancing the assembly efficiency of military products [4], increasing customer loyalty in the banking sector for Bank of America and Citigroup [21, 22], reducing patients' waiting time and length of stay [3, 17, 29], reducing length of stay for Ophthalmology Day Case Surgery [16], reducing lead-time [1], enhancing staff satisfaction [7], reducing clinical errors [20], process improvement for both the radiology department and medication administration process [15], and process design of compressor-housing machining process [25]. Others include [2, 6, 11, 12, 18, 19, 24, 26, 28, 29].

As a summary, both lean and six sigma methodologies have proven over that last twenty years that it is possible to achieve dramatic improvements in cost, quality, and production time by focusing on process performance. In this paper, a customized lean Six Sigma methodology is deployed at a local paper manufacturing company to increase production rate, minimize waste and increase Overall Equipment Effectiveness (OEE). The two tools have been used as complementary to each other, wherein DMAIC's roadmap has been used as a general framework for process improvement and lean tools have been embedded within these phases. Furthermore, the research focuses on employee involvement and motivation that are imperative to advance a new culture [9].

Sigma value increases the process performance in a better way. Another way of measure the process capability and performance by the statistical measurements like Cp, Cpk, Pp and Ppk. The Six Sigma means a 3.4 % defects part per million or yield of 99.9997% (perfect parts). Following is the table 1 of comparison of different Sigma values at different defects part per million and capability of process here [31].

TABLE I. THE COMPARISON OF DIFFERENT SIGMA VALUES

SIGMA	DPMO	COPQ	CAPABILITY
6 Sigma	3.4	<10% of sales	World Class
5 Sigma	230	10 to 15% of sales	
4 Sigma	6200	15 to 20% of sales	Industry Average
3 Sigma	67000	20 to 30% of sales	
2 Sigma	310,000	30 to 40% of sales	Noncompetitive
1 Sigma			

II. PROBLEM STATEMENT

This paper is related to textile industry especially to Yarn manufacturing process. This paper identifies the different problems occurring during manufacturing of yarn in the last process (winding), DMAIC tool is applied by the practical examples which was applied in practical field. It is very complicated and important process and it's difficult to achieve the quality throughout the process.

The main reason is the raw material, which do not possess good properties such as maturity, degree of reflectance, impurity and fiber strength and shade variation from bale to bale. The main thing in this paper is to reduce the defects rate and also reduce fault opportunities in the final yarn, As in Six Sigma methodology, if we decrease the opportunities in the final product then we can increase the Sigma value which shows that the process improvement. We have also applied a basic tool of Six Sigma like DMAIC which highlighted the different phases of tool with respect to process behavior and importance in the manufacturing of yarn. Winding department where we have applied DMAIC tool is critical as compared to other departments in the process as it cause an increase defects rate percentage in the final product of yarn.

In winding department, there is an Auto cone machine which winds the yarn on the cone and makes a final package for the end customers. It's better to implement DMAIC tool to eliminate or reduce the defects at the last section of the department. After this section, we can't improve the quality or reduce the defects in the final product.

III. RESEARCH METHODOLOGY

During production of different processes in the yarn manufacturing process, there are failures at many stages. All such failures are recorded in the manufacturing plant. It was observed that worst defects % is at winding stage. So it was decided to implement DMAIC tool in this process to eliminate a large variation in it. During this it was focused in all three departments such as Quality, Maintenance and Production. I followed all the standards which play important role for the satisfaction of the customer needs and expectations.

Maintenance play important role in every field. It play very important role regarding to quality. Because of proper maintenance, quality of product will be better. So it was focus on maintenance department as well. Winding section is a very critical department in yarn manufacturing process.

In this department there are a lot of chances of defects opportunities in the final yarn. It is the last section of manufacturing process where defects can be minimized or eliminated. After manufacturing of yarn from deferent departments in the preparatory process and ring department it is ready to make a shape into final cone form so that it can be shipped to customer for use. During winding process of yarn following objectives are met.

- **Scanning and faults removing**

Electric Scanners (uster) is used for checking and elimination of yarn faults during winding process. This process is called Usterization of yarn. Such faults are called scan-cuts.

- **Splicing of broken or cut yarn**

Auto splicing is done for broken yarn pieces to eliminate yarn knots and bad piecing.

- **Bigger package** Conversion of yarn from small ring bobbins to bigger yarn cones of different international standard or as per requirement of customer.

During achieving above objectives or making of winding cones some faults are created during the process. These faults need to be controlled through monitoring and continuous study. Most of the winding faults are very dangerous for the next subsequent process which can be warping or knitting or doubling. We can face complains from customer of breakage of yarn during unwinding process.

The following subsections illustrate how the DMAIC cycle is used to increase the quality and reduce the defects rate in the yarn manufacturing company.

A. Define Phase:

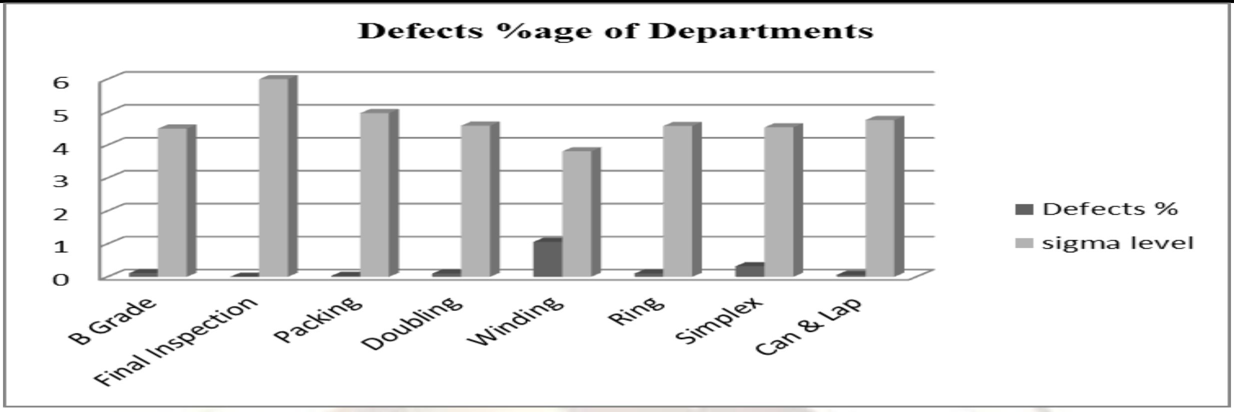
In this phase, define the process at different angles with the help of tools like Pareto chart, XY matrix and cause and effect diagram. First of all there is a comparison of rejection rate of different departments given below.

1) Rate of Rejection of Departments:

TABLE II. COMPARISON OF REJECTION RATE OF DIFFERENT DEPARTMENTS

Area	Defects	Production	Defects %	DPMO	Sigma level
B Grade	5303	4684800	0.11	1132	4.5
Final Inspection	0	4684800	0.00	0	6
Packing	1227	4684800	0.03	262	4.97
Doubling	494	494700	0.10	999	4.59

Winding	**49752**	**4684800**	**1.06**	**10620**	**3.81**
Ring	4852	4684800	0.10	1036	4.58
Simplex	14795	4684800	0.32	3158	4.54
Can & Lap	2660	4684800	0.06	568	4.76



	Defects%	Sigma level
B Grade	0.11	4.5
Final Inspection	0.00	6
Packing	0.03	4.97
Doubling	0.10	4.59
Winding	1.06	3.81
Ring	0.10	4.58
Simplex	0.32	4.54
Can & Lap	0.06	4.76

Figure 2. Defects% age of Departments

2) SIPOC Diagram:

As it is decided to work and analysis the defects in winding section, following SIPOC diagram is used to understanding the clear relationship between customer and supplier relationship.

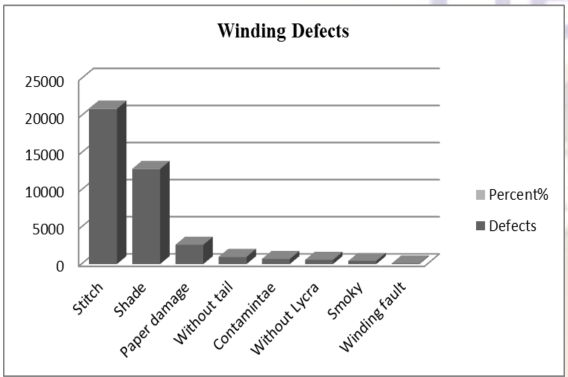
TABLE III. SIPOC (SUPPLIER, INPUT, PROCESS, OUTPUT, CUSTOMER) DIAGRAM

Supplier	Input	Process	Output	Customer
Roving Department	Roving Bobbin	Spinning	Ring Yarn Bobbin	Preparatory of Winding Machine
Preparatory of Winding Machine	Ring Yarn Bobbin	End Finder	Bobbin with end at top	Winding Spindle
Winding Spindle	Bobbin With end at top	Winding	Wound cone	Auto doffer
Auto doffer	Wound cone	Auto doffing	Doffed Cone	Inspection Department
Inspection Department	Doffed Cone	Inspection	Inspected Cone	Packing
Inspection Department	Inspected Cone	Pallet Formation	Cone on Pallet	Packing
Packing	Cone on Pallet	Steaming	Steamed Cone	Packing
Packing	Steamed Cone	Repacking & Inspection	Packed Cone on Pallet	Packing and Quality Control

Packing	Packed Cone on Pallet	Shrink Wrapping	Packed Pallets	Logistic, Quality Control
Logistic	Packed Pallets	Yarn Storage	Ready for Storage	Marketing, Quality Control
Logistic	Stored Yarn	Final Inspection	Pass Pallets	Marketing, Customer
Logistic, Marketing	Pass Pallets	Delivery to customer	Delivered Pallets	Customer

3) Winding Defects:

There are many defects which are produced in winding section and show them in bar graph here.



	Percentage%	Defects
Stitch	53.3	20899
Shade	32.7	12807
Paper Damage	6.6	2604
Without tail	2.5	981
Contamintae	1.8	689
Without Lycra	1.5	569
Smoky	1.1	428
Winding fault	0.2	82

Figure 3. Bar graph of Winding Defects

B. Measure Phase:

To start the measurement phase a standard from has been designed and distributed to the DMAIC team, from contain the necessary information that should be gathered to be analyzed at the next phase, these information comprise from product type, raw materials type, machine parameters, type of wastes combined with general comments. Measure the performance of the process by collecting the data and also write down the importance of different critical defects regarding to customer value. In this phase there is different data analysis here

- Cause and Effect Analysis
- Data Collection Plan
- Measurement system analysis

1) *Cause & Effect Analysis:*

Rating Scale 1~9 (1 being lowest and 9 being highest)

			1	2	3	4	5	6	7	8	
Rating of Importance to Customer			10	6	6	1	8	8	9	7	
Key Process Outputs			Defect Rate	Rework	B Grade Yarn	Hard Waste	Customer Complain	Customer Return	Customer Claims	Final Inspection Failures	
	Process Step	**Process Input**									**Total**
1	Winding Machine	Guide	9	9	1	3	3	3	3	1	**235**
		Gas Kit	9	9	1	1	1	3	3	1	**217**
		Disk	9	9	1	1	3	3	3	1	**233**
2	Personals	Cradle Gauge	9	9	1	3	9	3	3	1	**283**
		Suction mouth gauge	9	9	1	9	9	6	6	1	**340**

		Over Hauling	3	3	3	6	1	1	1	3	**118**
		Inspection	9	9	1	6	9	9	9	1	**388**
3	Material	Scan Cuts	9	9	9	9	9	9	3	6	**420**
4	Environment	Temperature	3	3	3	6	3	3	3	3	**168**
		Humidity	3	3	3	3	1	1	1	1	**101**
5	Product plan	Yarn Type	3	3	3	3	1	1	1	1	**101**
		Count	6	6	6	6	1	1	1	3	**184**
		Speed	9	9	6	9	9	6	6	6	**305**
		Machine Change	3	3	1	3	3	1	1	1	**105**
	Total		**930**	**558**	**240**	**68**	**496**	**400**	**396**	**210**	

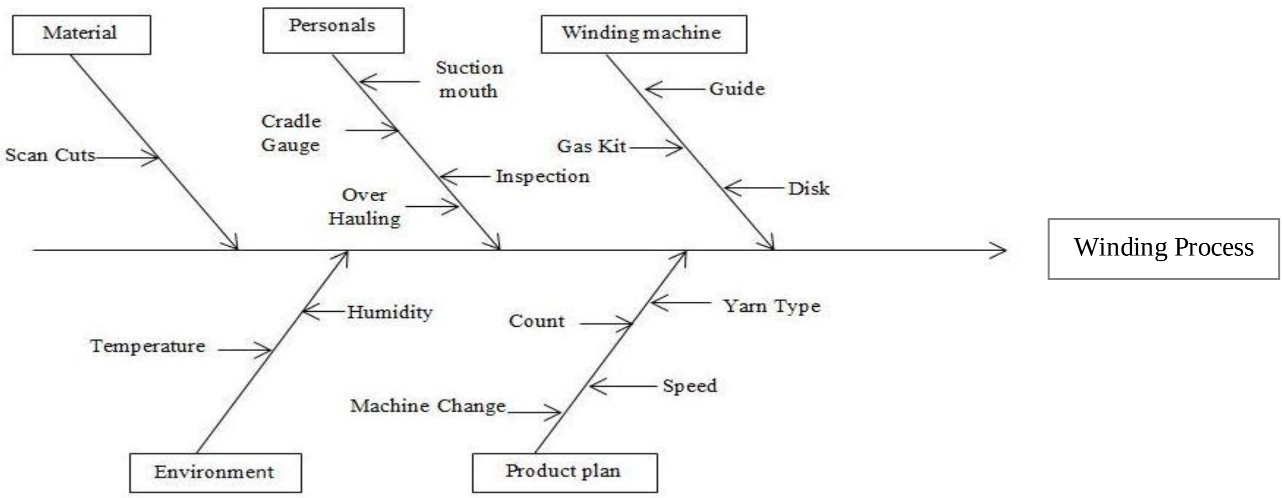


Figure 4. Cause & Effect Daigram

2) Data Collection Plan:

There is different way where the data collect of the yarn manufacturing process. Following are the different types of data which is collected from different source.

For identify the problem of cross stitch, there is data collected here.

- The system in a manufacturing plant is to collect a lot of data from department is already established.
- Date and month, Yarn type, Operator and his experience, yarn count, Shift, production, Machine type and machine number, our hauling, scan cuts, Speed of machine, Temperature and humidity.
- Responsibilities of person is shown in data to highlight the clear understanding regarding to process data and also take a data collection source like production and maintenance rejection report.

It is an especially design experiment to identify the variation in the measuring components. A measurement system analysis considers the following things related to the process.

- Selection of correct measurement system and approach.
- Capability and assessing the measuring device.
- Assessing of operators and procedures implement in a process.
- Calculating the uncertainty in the measurement.

3) Measurement system analysis for Defective Yarn cones:

At winding section, inspection of yarn cone is done manually and conducts a MSA of attribute data.

Sample Selection-

Sample Size = 50 cones
Pass cones = 20
Fail Cones = 20
Borderline cones = 10
Number of operators=3
Number of trials / operator = 2
Overall %age appraiser = 82 %
Overall %age attribute= 76 %

- Appraiser %age of this sample selection shows that it should be needed to retrain the inspectors to reduce the error.

- Attribute %age of this sample shows that it should be needed to improve the existing system and redefine the defects parameters of winding section.

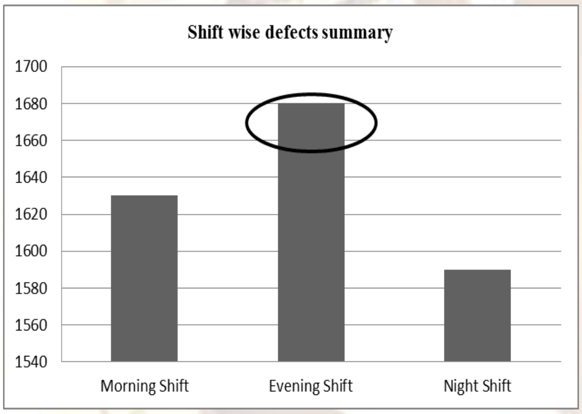
C. Analysis Phase:

The analysis phase deals with identifying the root causes of the process whether it can be improved or redesigned the process. To understand the defects stitch following studies & charts were produced to analyze this problem from different angles.

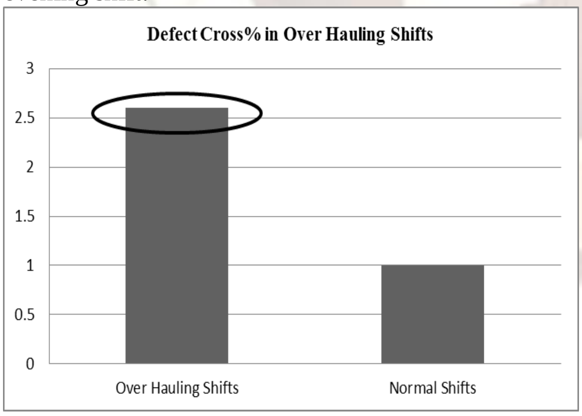
1) Effect of over hauling, product change and shift on Stitch defect:

Data shows that Evening shift has more defects as compared to morning and night shift. The night shift has minimum defects during manufacturing process.

By deeply analyzing this problem, whenever change the product at machine or run the machine after overhauling changes of Stitch defects increases in first shift. Up till second shift things get normalized.



All overhauling is done mostly in morning shift by the maintenance team and restart the machine in evening shift.



The same case product change case, mostly product change in morning and evening shift. Top management are absent in night shift and extra are avoided in night time

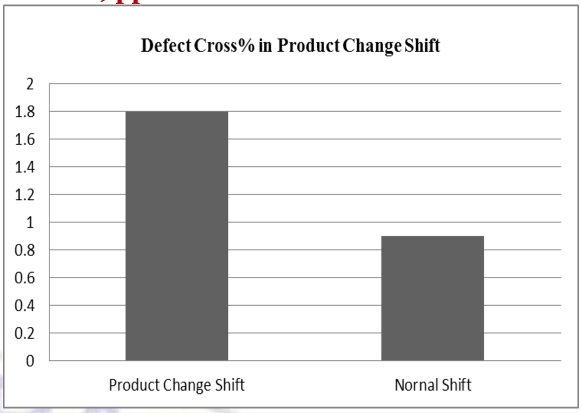


Figure 5. Bar Graph of Shifts data

2) Effect of yarn type on Defect Stitch:

In the yarn type, there are three types of yarn in relation to its end use.

- Weaving Yarn
- Knitting Yarn
- Stretch Yarn (Lycra Yarn)

According to different type of yarn, it is clear that the weaving yarn has more defect Stitch and then comes Knitting and Lycra yarn.

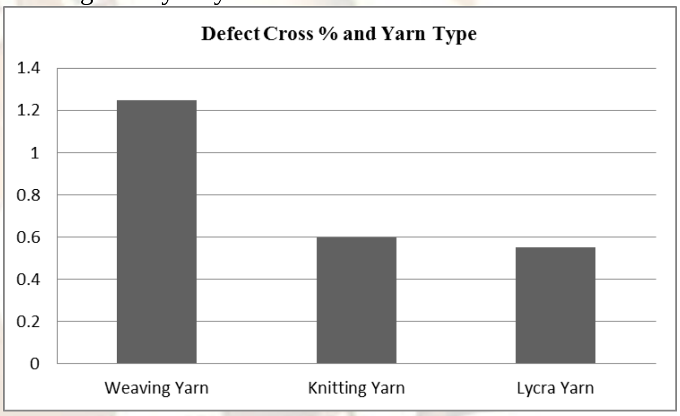
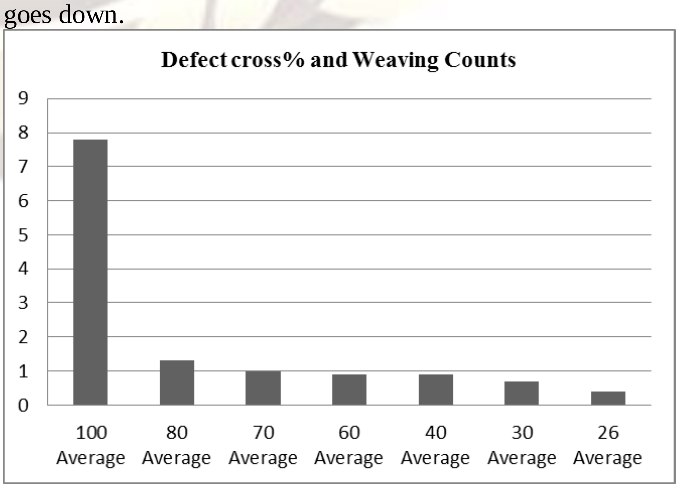
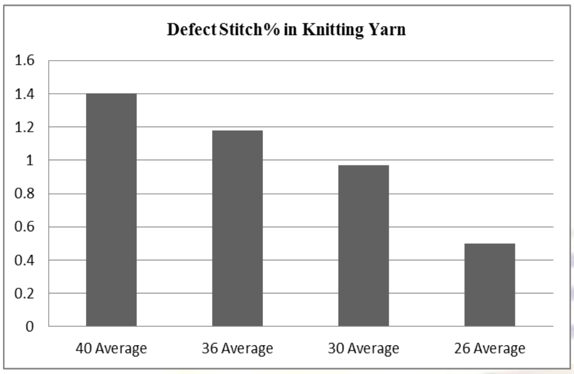


Figure 6. Defects in Yarn Type

Data shows that the fine count like 100s has high defects rate than the course count like 26s. As the count is going from fine to course, the defects rate goes down.



The same case in knitting yarn, knitting yarn of fine count has high defects rate than course counts and it is gradually decreases from 40s to 26s count.



In lycra yarn, the same situation is also here but little bit difference because of lycra %age of different yarn as per customer requirement.

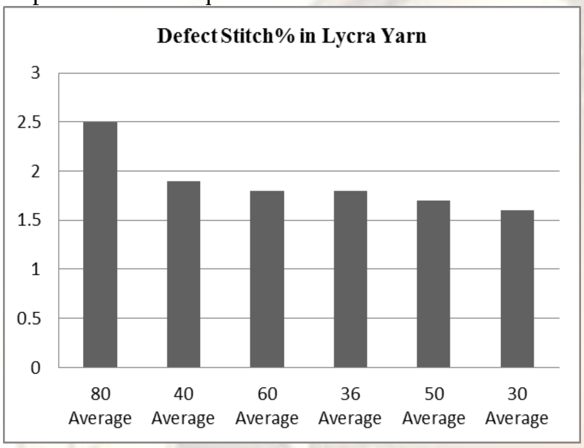


Figure 7. Defects in Yarn Count

In all types of yarn Weaving, Knitting and Lycra have more defects percentage in finer and lower as it goes towards course count. It is due to the finer count cone has more stay time on machine as compared to course counts. So opportunities of having stitch defects in finer counts cone is more as compared to courser counts cone. Whenever machine stopped for readjustment, overhauling and restarted it, then coming shift is critical to stitch defects.

D. *Improve Phase:*

The improvement of process is calculated by the help of Design of Experiment. In order to improve the process, some settings are change which are the sever effect on the defects of final product.

In this normal plot, some significant factors are shown which causes major effects on the defects on the product in the winding process.

- Scan cuts
- Speed of winding machine
- Disk of machine
- Suction mouth gauge

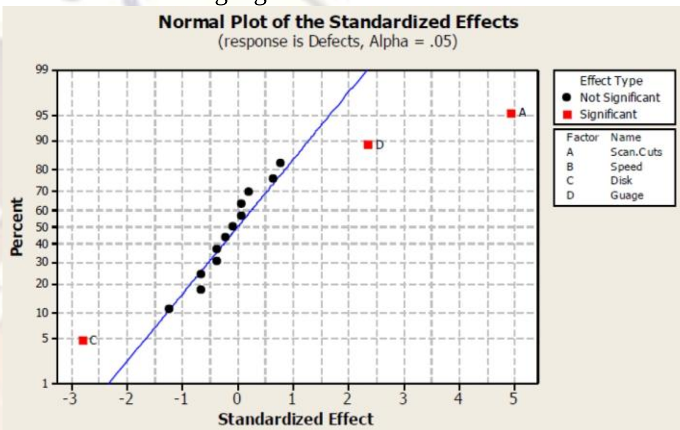


Figure 8. Normal plot of the standardized effects

1) Parameters:

Speed is already slow so no big influence on defect. Scan-Cuts and Disk life are most important factors. They need to be controlled to achieve optimum results best Scan-Cuts are below 40. Condition of Disk should be good always and the suction mouth gauge should be less than 6 mm.

TABLE IV. RESPONSE TABLE FOR DEFECTS

Level	Value	Scan Cuts	Speed	Disk	Gauge
Initial	1.0	37.00	700.00	1 (Good)	-1 (< 6mm)
Optimal	1.0	37.00	700.00	1 (Good)	-1 (< 6mm)
1	1.0	40.2089	700.00	1 (Good)	-1 (< 6mm)

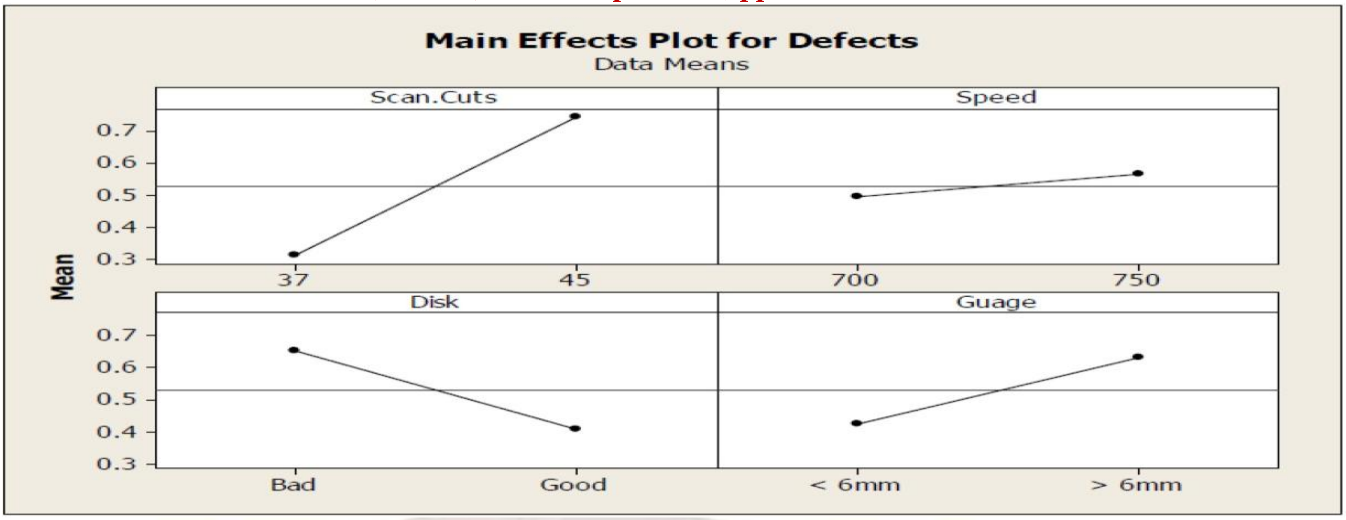


Figure 9. Normal plot of Design of Experiment

E. Control Phase:

In control phase, the process will be check by applying the control charts whether it is control or not. Variation of whole process should be in control limits for control process.

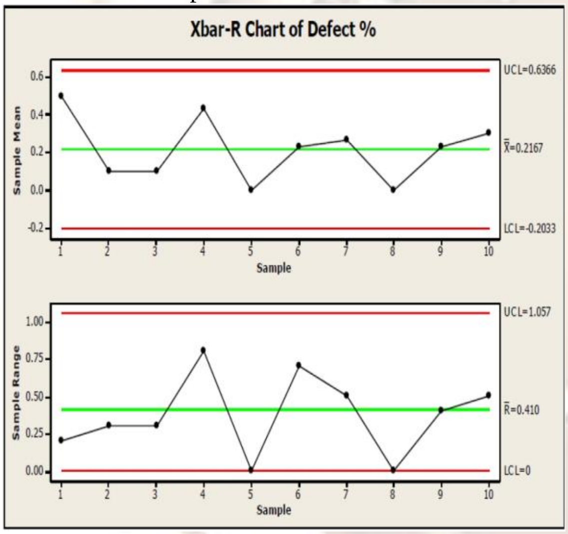


Figure 10. X bar- R chart

1) Statistical process control:

Statistical process control is used to monitoring the consistency of process and makes the process is under control. Data of defects %age shows that the process is under control and there is not any point in this graph which is out of control limits.

2) Design the speed limits:

Speed of different yarn count on winding machine should be designed in different standard. The training of operators should also conduct for the understanding of speed limits of different product.

3) Inspection procedure*:*

Inspection procedure of maintenance department improved and checking of suction mouth gauge and tension disk on daily basis and make the part of daily checking sheet form. For the improvement of measurement system analysis following steps have been taken.

After categorization the stitch fault in the cone, it is included in the SOP as it was a great confusion among operators to detect a stitch cone fault. All operators were trained according to the new portion of SOP. After one month training of operators according to new portion of SOP, Measurement system analysis was conducted of attribute data.

Sample Selection-

Total Sample size = 50 cones
Pass cones = 22
Fail cones = 22
Borderlines cones = 6
No of Operators = 3
No of trials/ operator = 2
Overall appraiser %age = 94%
Overall attribute %age = 90%

IV. Conclusion

In this paper, we have achieved a lot of results regarding to process problems during manufacturing of yarn in different departments. The main thing in our paper is to reduce the defects rate and also reduce fault opportunities in the final yarn; we have worked in every department to reduce these opportunities and gave a solution in the form of preventive action. As in Six Sigma methodology, if we decrease the opportunities in the final product then we can increase the Sigma value which shows that the process improvement. We have also applied a basic tool of Six Sigma like DMAIC in our thesis in which highlighted the different phases of tool with respect to process behavior and importance in the manufacturing of yarn. Winding department where we have applied DMAIC tool is critical as compared to other departments in the process as it cause an increase defects rate percentage in the final product of yarn. In winding department, there is an Auto cone machine which winds the yarn on the cone and makes a final package for the end customers. It's better to implement DMAIC tool to eliminate or reduce the defects at the last section of the department. After this section, we can't improve the quality or reduce the defects in the final product.

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