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Dmaic Approach for Process Improvement: Improving Fabric Width Shrinkage of Basic T Shirt

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ABSTRACT

This paper represents the effectiveness of DMAIC approach for process improvement, which is a structured methodology of Six Sigma that is proven to be a dynamic approach for defect identification, problem solving and future prevention by the support of different statistical tools. In this paper, the major problem was negative shrinkage of garment width which was not within the UCL and LCL. Consequently, the overall AQL of finished product on customer end reached to 7.50%, where the standard allowable shrinkage is ±5.5 cm and standard AQL is 1.5%. Therefore, after identifying the root-cause the DMAIC was used for process improvement and solving the issue. In an overview, DMAIC is one of the most authoritative approaches in Six Sigma problem solving process. This is the short form of Define-Measure-Analyze-Improve –Control. DMAIC is one of the most widely practiced tools to ensure and lead towards maximum quality level that absolutely fulfill the SIX SIGMA methodology. And, this result comes by following the steps of process improvement that includes not only determining existing system but also bringing up new possible process changes to improve quality, process efficiency, productivity and reduce cost. Throughout these steps different supporting tools such as project charter, Pareto chart, process map, CTQ parameter identification, data collection, cause and effect diagram, check list etc. has been used and also form which final corrective actions and preventive actions (CAPA) has been attained to gain the ultimate progress. The progress in any of the mentioned areas is considered to be a catalyst towards the process improvement.

The main objective of this study is meet the voice of customer (VOC) that is AQL% level up to 1.5%, in other words improve the overall width shrinkage %. Though, primarily the root cause of high percent defective was identified by 80/20 rule by using the complaint data received from the customer, later by implementing corrective and preventive action the AQL% was controlled up to 1.15% which is 84.67% improvement of the overall quality level.

Keywords: DMAIC, Width Shrinkage%, CTQ, AQL, CAPA

1. Introduction

It is not unknown that at present time considering the Bangladesh ready-made garments manufacturing industries, it is a rising demand to establish an organized practice of process improvement is required to meet the biggest challenges. This can include defect reduction, downtime reduction, efficiency improvement, cost reduction etc. And, for this kind of process improvement DMAIC (Define-Measure-Analyze-Improve-Control) is a very effective tool- one of the most frequently used approach of Six Sigma.

Six-Sigma methodology was originally developed by Motorola in 1980s and it targeted a difficult goal of 3.4 parts per million defects. Six Sigma was initially introduced on manufacturing processes; today however, marketing, purchasing, billing, invoicing, insurance, human resource and customer call answering functions are also implementing the Six Sigma methodology with the aim of continuously reducing defects throughout the organizations processes [1]. A study by Antony et al. indicates Six Sigma as a more advanced level of quality, which will certainly implement those organizations that tend to business excellence after QMS certification per ISO 9000 series [2].

Six-sigma strategy has four aspects that are not emphasized in other business improvement methodologies and total quality management (TQM). First of all, Six Sigma places a clear focus on bottom-line savings. Second, Six Sigma has been very successful in integrating both human aspects (culture change, training, customer focus etc.) and process aspects (process stability, variation reduction, capability etc.) of continuous improvement. Third, Six Sigma methodology (DMAIC) links the tools and techniques in a sequential manner. Finally, Six Sigma creates a powerful infrastructure for training of champions, master black belts, black belts, green belts, and yellow belts [3].

DMAIC Methodology and DMADV Methodology, both inspired by Deming‘s Plan-Do-Check-Act Cycle. Where, DMAIC is used to improve the existing business process and DMADV (Define-Measure-Analyze-Design-Verify) is used to create new product or process design. [4]. There are several example of using DMAIC for such process improvement. For example, by Sharma and Rao, an engine crankshaft manufacturing process had been improved by reducing deviation of dimensional measurement data of the CTQ characteristics using DMAIC [5]. Again, by Gupta, for increasing yarn quality in a yarn manufacturing industry DMAIC methodology

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had been used, by reducing defects and quality cost from input-process up to packaging final product [6].

Therefore, DMAIC is generally used for data driven problems where risk is high and impact is crucial in business or manufacturing processes. In other words, for quantitative analysis rather than general qualitative analysis, it requires ample data for statistical analysis to reduce process variation. And, there is no alternate to DMAIC since this problem solving approach is the back bone to take initiative for improvement. For this reason, in this study this Six Sigma methodology (DMAIC) is used for the fabric width shrinkage problem that is caused by variations in the process.

2. Background

This Study has been performed on a customer complaint data of a 100% export oriented ready-made knitwear industry, a leading manufacturing organization in Bangladesh. The problem is specifically found in tubular basic T Shirt Styles rather than side seam basic T shirts. Where, the chest measurement of the garments were found smaller or in other words tubular fabric width was shorter against standard measurement set by customer. Table 1 shows the list of tubular basic t shirt models which are frequently found out of tolerance.

Table 1 Types of defective Basic T

Styles	% defective
BT 76000	76.23%
BT 64000	21.51%
BT 41000	2.26%

The width shrinkage (%) is one of the three major parameter of dimensional stability which is determined as per AATCC 135, test method that is intended for the determination of dimensional changes of fabrics after 3HL home laundering [7].This is a very important basic CTQ characteristic for dyed knitted fabric that is needed to be evaluated before going for bulk production. Therefore, in this study this test has been used as key feature to monitor the overall performance of the fabric.

The data used here, is a consolidation of about six months report (June, 2017 to December, 2017) containing the quantity of 'unit inspected' and 'unit defective' and a details of number of defects for each defect type. Therefore, a Pareto Analysis has been performed initially.Afterwards, DMAIC has been performed accordingly.

3. Methodology

The methodology is a complete set of actions that provides the ultimate results. Figure 1, represents the overall approach step by step: 3.1, 3.2, 3.3, 3.4 and 4.1 respectively.

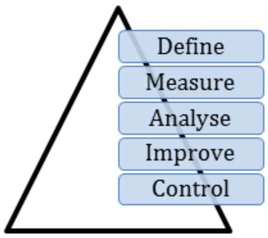

Fig.1 Flow diagram of DMAIC

3.1 Define

The problem defined bellow satisfies SMART (Specific, Measurable, Achievable, Relevant and Time-Bound).

3.1.1 Project Charter

Firstly, a project charter has been developed for the team.

Table 2 Project Charter of the Team Project

Project Charter												
Project Leader: Vice President, Black Belt	Team Member: Engineer, Dept. of Quality Assurance; Engineer, Dept. of Process Improvement											
Starting Date: January, 2018; Completion Date: May, 2018	Project Location: A 100% export oriented ready-made garments manufacturing facility, Savar, Dhaka, Bangladesh.											
Business Case: Identify root-cause of top defect and come up with a solution to improve process to reach standard quality level (AQL%) to satisfy customer, which will improve quality and reduce cost accordingly.												
Project title:	Reduce customer complaint of 'X' customer by											
Stakeholders:	Employees of Quality Assurnce & Process											
Subject Matter Experts:	Black Belt of team and Process Owners- Textile and Sewing Manufacturing Facility											
Project milestone:	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Define Phase: 01 June, 2017 to 31 December, 2017												
Measure Phase: 01 January, 2018 to 15 January, 2018												
Analyze Phase: 16 January, 2018 to 15 February, 2018												
Improve Phase: 16 February, 2018 to 15 April, 2018												
Control Phase: 16 April, 2018 to 31 May, 2018												

3.1.2 Process Map

The given process map in Figure 3 is prepared to learn the overall process and QC check points from which we can extract data later.

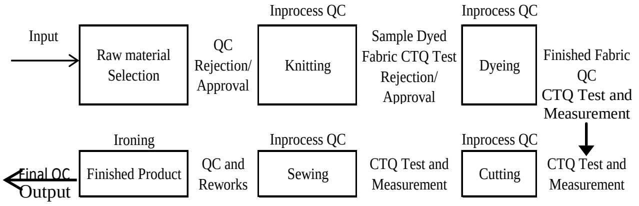

Fig.2 Process Map (Raw material input to finished product)

From the process map it can be determined that, CTQ test data can be collected from dyed fabric after knitting process is done and critical measurement can be done after dyeing process up to the finished final product.

3.2 Measure

This phase represents, the Pareto Analysis, CTQ parameters, data collection, evaluation of existing system, current level of quality etc.

3.2.1 Pareto Chart

To identify the root-cause, the top defect has been determined from the data of customer by using Pareto Analysis. Figure 2, indicates the Pareto Chart where we can see that apart from smaller chest measurement issue (73%) there are also other sewing and textile defects available in minor percentage (%):Untrimmed thread 12%, Uneven Top Stitch 9%, Bigger Chest 3%, Stain 2%, others 1% respectively.

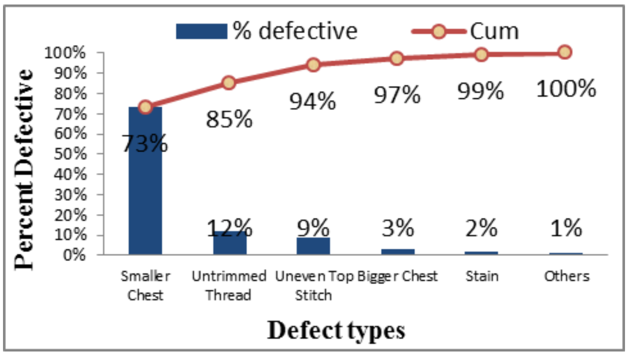

Fig.3 Pareto Chart

3.2.2 Pareto Analysis

From June, 2017 to December, 2017 total 9840 pieces of garments were inspected in total and out of them 7.5% was found defective. And, one defect (16.67%) is the cause of 73% of the bad quality.

3.2.3 Project Objective

1. Meet customer requirement (VOC) and reduce overall AQL%
2. Improve width shrinkage (%) through corrective and preventive action.

3.2.4 CTQ Parameter and Measurement

Based on the process study, following CTQ parameter and measurement point has been selected to monitor the overall process performance.

1. Follow up Sample fabric width shrinkage before bulk production in dyeing.
2. Take measurement of diameter of the tubular fabric after dyeing process and after 24 hour relax of the fabric in dyeing area.
3. Take measurement of diameter of finished garment before and after ironing.

Since, Cotton and cotton/polyester blended knitted fabrics are prone to shrinkage during finishing processes and customer usage.Knit loop formation is defined in each relaxation stage from dry relaxed to fully relaxed [8].

3.2.5 Data Collection

The data of fabric width shrinkage% has been collected from the QC Test Laboratory where the AATCC 135 test method has been followed for 3HL. Equation (1) has been used to calculate the required parameter.

Fabric Width shrinkage %, DC = 100 (B-A)/A (1)

Where, DC = Average Dimensional change
A = Average Original Dimension
B = Average Dimension after Laundering

According to Table 1, BT 76000 is found the highest defective model of Basic T Shirt. Therefore, further investigation has been narrowed down to BT 76000 MD (medium) and LG (large) sized garments which are the 76.23% of the total smaller chest defect.

Figure 4 and figure 5 illustrates the existing results of average width shrinkage % for BT 76000 MD and LG sized garments from January to December, 2017.

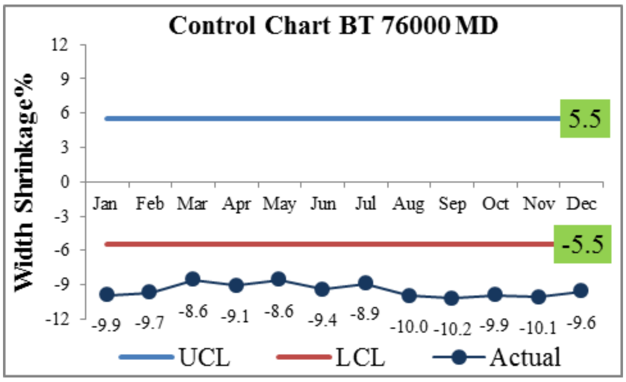

Fig.4 Average Width Shrinkage (MD) of for FY 2017

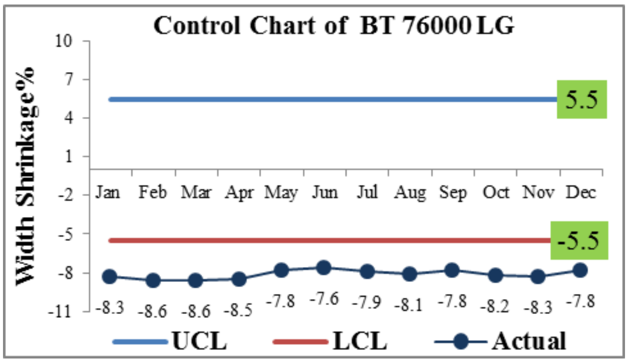

Fig.5 Average Width Shrinkage (LG) of for FY 2017

Hence, the above figures indicate that the existing system is not working properly and the measurements in QC points of the whole process could not detect the issue.

3.3 Analyze

In Analysis phase usually the potential causes are identified which has primary role on the occurrence of the defect and also on the inability to detect the defect in process before sending it on the hand of customer receiving complaint.

3.3.1 Cause and Effect Diagram

In figure 6, all the possible causes have been identified because of which the issue may have risen. However, the top strongest and direct 6 reasons have been encircled which need to be verified and also need to take proper corrective and preventive action if required.

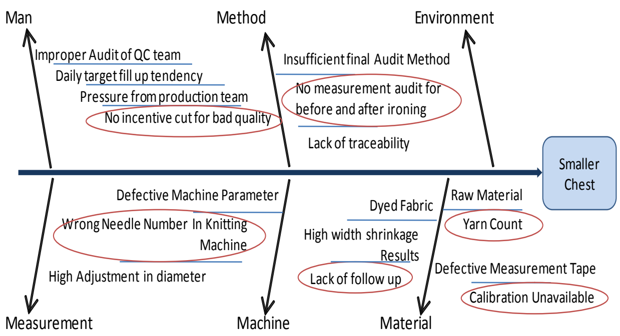

Fig.6 Cause and Effect Diagram for smaller chest of BT 76000 model of Basic T Shirt

3.3.2 Checklist

The top 6 reasons as per figure 5 are-

1. Wrong yarn counts, which should be 24 counts.
2. Lack of follow up or strictness on quality test results especially on shrinkage results.
3. Wrong needle number in knitting machine which impacts on the diameter.
4. No calibration of fiber measurement tapes which are expandable due to high temperature in dyeing area where the average temperature is 35ºC to 40ºC.
5. No Measurement audit for before and after ironing, this may cause shrinkage.
6. No impact on incentives of production team due to bad quality.

Therefore, the following checklist in table 3 has been prepared where the above mentioned 1 to 6 causes have been verified which indicates the opportunity of improvement.

Table 3 Checklist

Scope	Yes	No	Remarks
Standard Yarn Count 24 is being followed	X		Need further investigation
All QC Tests are performed	X		Need further investigation
CTQ test results are ok of the produced fabric		X	**Some batches' shrinkage has failed**
Action Taken for QC failed batches		X	**Batches passed for next process by management decision for BT 76000, 64000 and 41000.**
Measurements are done properly		X	**Defective measurement tapes are found**
Calibration of Measurement Equipments		X	**Measurement Tapes are not calibrated**
Critical measurement points are checked in all process		X	**Not done before and after ironing of final product**
Final Auditors are checking all bundles	X		
Defects are properly identified		X	Need monthly or quarterly training about defects and customer requirements
Incentive is based on Quality		X	Incentives are based on first quality production but no action is taken if any major complaint is received

3.4 Improve

In this phase, based on the measure and analyze phase outcome corrective and preventive actions are set and feasibility of those actions are also verified based on time, efficiency, cost and many other driving factors.

Based on the root-cause analysis and overall verification by the check list two main reasons have been identified for the high width shrinkage. And, by solving any one of those issues the desired results can be achieved and this problem can be solved. Figure 7 is indicating both plans A and B any of which must be implemented.

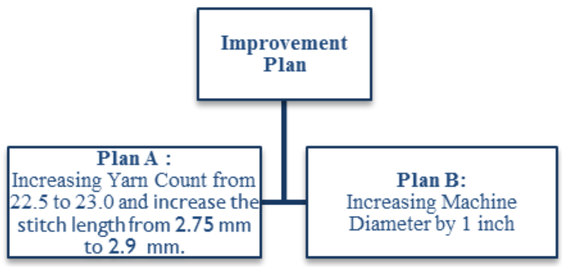

Fig.7 Improvement Plan A and Plan B

3.4.1 Experimental special batches

To identify which plan is more feasible special batches has been produced considering plan A and plan B separately.

Plan A

For Plan A, 4 batches are produced. Two of them are normal batches and other two are special batches of BT 76000, MD size and LG size. Where, three significant measurements are taken:

(1) Measurement of diameter after 6 hours of relaxes after compacting before going to cutting.

(2) Measurement of diameter after ironing.

(3) Variation between the measurements.

Measurement results are given in fig. 8 and Table 4 for MD size and fig.9 and Table 5 for LG size respectively.

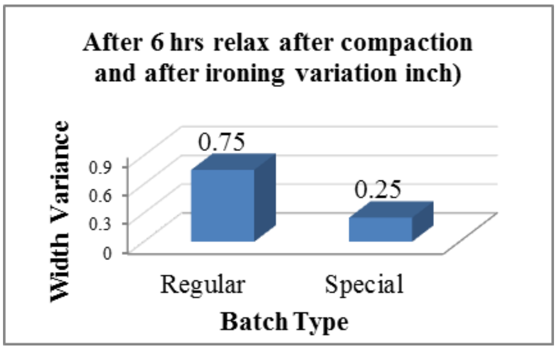

Fig.8MD size: Regular vs. Special

Table 4 Variation (inch) MD

After 6hrs relax in dyeing and After ironing variation(inch)			
Regular	20.5	19.75	0.75
Special	20.5	20.25	0.25

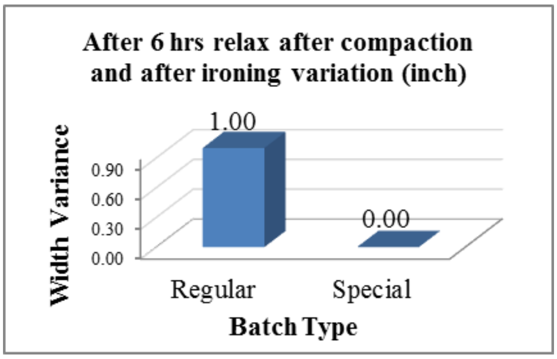

Fig.9LG size: Regular vs. Special

Table 5 Variation (inch) LG

After 6hrs relax in dyeing and After ironing variation(inch)			
Regular	21.5	20.5	1.0
Special	21.5	21.5	0

Both MD and LG size of BT 76000 special batches have satisfactory results.

Plan B

For Plan B, same parameters have been checked as Plan A for all sizes XS (extra small), SM (small), MD (medium), LG (large), XL (extra large), 2XL (double extra large) and 3XL (triple extra large). And, the results for this plan are also satisfactory but the only impact on the fabric is that the GSM has fallen out of the allowable limit which is 175±5, figure 10.

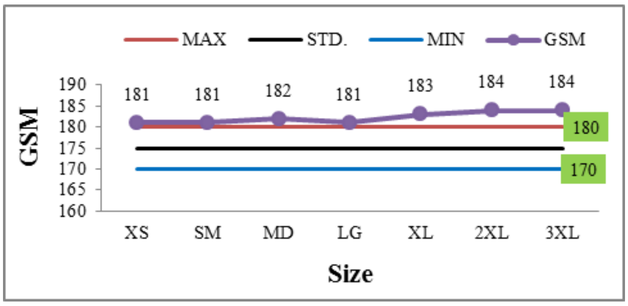

Fig.10GSM of Plan B Special Batches

Therefore, plan A is the best solution to implement for the improvement of the overall process. Since, plan B will increase the fabric consumption thus increase overall cost of production plan A has to be implemented.

3.4.2 Opportunity of Improvement

Table 6, indicates the corrective and preventive action that are taken by quarter 2, May 2018 to ensure the control of the full process.

Table 6 Corrective Action and Preventive Action (CAPA)

What	Where	When	Who	Required Results
Corrective Actions:				
Change the 24 yarn count to 22.56 count and increase the stitch length from 2.75 mm to 2.9 mm.	Knitting Process	By, Quarter 2, May 2018	Knitting process owner	Improved width shrinkage.
Release batches based on CTQ test results.	Quality Assurance Process	By, Quarter 2, May 2018	Quality Assurance Process Owner	Improved Quality Control
Remove defective measurement tapes immediately after detection and monthly calibration of all measurement tapes	Quality Assurance Process	By Quarter 2, May 2018 As per ISO 9001	Quality Assurance Process Owner	Accurate QC inspection data
Preventive Actions:				
Check all critical measurement points before and after ironing of final products.	Sewing Quality Inspection Process	By, Quarter 2, May 2018	Sewing Process Owner	Ensuring that the overall process is working
Improve traceability and incentive cutting policy for customer complaints	Sewing and Quality Assurance Process	By, Quarter 2, May 2018	Sewing and Quality Assurance Process Owner	Improved Quality Production mind set
Continuous Awareness Program	Quality Assurance Process	By, Quarter 2, May 2018	Quality Assurance Process Owner	Awareness of customer requirement (VOC)

4. Results

In this section, the control phase has been discussed because control phase represents the overall plan implementation verification and derived results meeting the overall objective.

4.1 Control

All the corrective and preventive actions have been implemented accordingly by the end of May 2018, quarter 2. The results obtained for all models and sizes are satisfactory. Figure 11 represents the results of BT 76000 for all sizes.

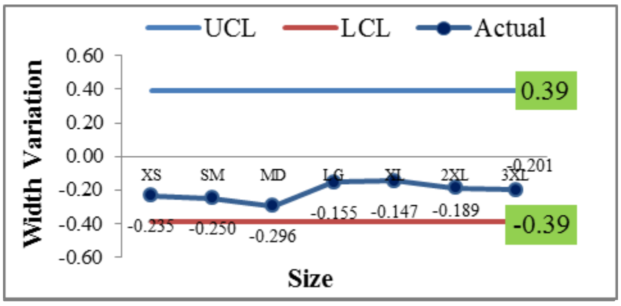

Fig.11 Width variation after implementing Plan A

Hence, by implementing corrective and preventive action the AQL% is controlled up to 1.15%. The overall result has been accepted by the six sigma Black belt, project team member and stakeholders. And, all the changes that have been taken through plan A has been approved in formal documents and distributed to the process owner and related area responsible for proper execution and continuation of the actions for desired results of the improved process. So, this study has derived a controlled plan which needs to be taken as biggest challenge in order to sustain the improvements and make the process continuously improving.

5. Conclusion

Export oriented garment industries are the biggest source of economy of Bangladesh. And, day by day the demands are increasing; facilities are expanding to meet the demands. Therefore, the challenges are becoming greater to meet the goals, keeping all the processes working smoothly. The benchmark of quality is also becoming crucial and even better quality is expected. So, old standards need to be revised or new standards need to be implemented to meet the customer requirement for better quality products as well as sustaining good impression in the market which impacts on the sales tremendously.

The customer provided data has helped immensely the team to extract the top defect smaller chest (73.00%), to set objectives, to identify important parameters. And, later through the cause-and-effect diagram and checklist the existing process was possible to verify and two significant plans A and B was determined to solve the issue. Later, where we have concluded to the point that changing the 24 yarn count to 22.56 count and increase the stitch length from 2.75 mm to 2.9 mm is the most feasible solution based the special batch experiment results.

After getting the satisfactory experiment results, opportunity has been derived from the overall approach which has been implemented by quarter 2, May 2018 to establish complete control on the processes. Finally, improved results have been gained in the final product of all sizes and by the end of this project AQL% is reduced up to 1.15% which is 84.67% improvement of the overall quality level. Since, the sustainment of the improved quality is a part of continuous process. Proper follow up is a mandatory part of DMAIC Six Sigma Methodology.

NOMENCLATURE

CTQ : *Critical to Quality*
AQL : *Allowable Quality Level*
CAPA : *Corrective and Preventive Action*
DC : *Width Shrinkage, %*
AATCC: American Association of Textile Chemists and colorists

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