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Research Article

In-Depth Analysis and Defect Reduction for Ethiopian Cotton Spinning Industry Based on TQM Approach

Abdella Simegnaw Ahmmed and Million Ayele

Bahir Dar University, Ethiopian Institute of Textile and Fashion Technology (EITEX), P.O. Box 1037, Bahir Dar 6000, Ethiopia

Correspondence should be addressed to Abdella Simegnaw Ahmmed; abda0515@gmail.com

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Competition is truly global. Higher product quality is required for a company to become more competitive both locally and in international markets. Any textile company basically competes on its reputation for quality, reliability, and capability of processes and costs of quality and delivery. Currently, most of textile industries in Ethiopia are suffering from quality-related problems due to high process variations. These problems include poor performance of manufacturing products in the export market, insufficient qualitative raw material supply, customer dissatisfaction, low productivity, and poor utilization of the resources. These problems led to the manufacturing of low-quality products with a high cost, and because of this, most of the Ethiopian textile companies in the country are not competitive and profitable. The main objective of this study is to examine the existing traditional models of quality and to introduce an improved and emerged quality measuring system based on a methodological approach by using six sigma total quality management tools and analyzed by STATA 14.0 software. The analytical findings show that the application of total quality management (TQM) programs, tools, and techniques has been expanded beyond the traditional quality concepts and has improved the acceptable quality level of the product by 57.96% with a low cost.

1. Introduction

The Ethiopia textile industry is prominently the oldest manufacturing sector; it has a very important place in building the economy of the country by contributing to industrial output, employment generation, and earning the foreign revenue [1].There are 56 textile factories [2], and there is an opportunity to export textile goods to the global market created through initiatives by the African Growth and Opportunity Act, the Common Market of Eastern and Southern Africa, and bilateral trade agreements established with Western countries [3]. But, the Ethiopian Textile Industry Development Institute stated that the country's textile exports for the year 2009/10-2015/16 are lagging behind the plan which are only 46.4%, 73.2%, 49.4%, and 70% of the plan [4].

Currently, most of textile industries in Ethiopia are suffering from production and quality-related problems [5] due to higher challenges, i.e., low efficiency of 40 to 45% in production as compared to other countries, and the production in Ethiopia takes about 45 to 60 days longer [6]. And the smallest variation in the quality of raw material, production conditions, and operator behaviour can result in a cumulative variation (defects) in the quality of the finished product on the spinning stage. So, there are many strategies which have evolved over the last several decades to improve the quality of manufacturing of an item [7, 8], process, or a system. And the industries are under increasing pressure to improve quality of products by reducing variation. To overcome the above quality-related problem, the Ethiopian textile industries could be shifted from their traditional quality concepts of total quality management (TQM) by effective implementation of the program, tools, and techniques [9, 10], although the traditional quality tools [11] are no longer sufficient to handle emerging challenges due to customized products, low production runs, and high quality cost.

TQM refers to a management process and set of disciplines that are coordinated to ensure that the organization consistently meets and exceeds customer requirements. The goal is to deliver the highest value for the customer at the lowest cost while achieving sustained profit and economic stability for the company [12].

Besterfield defined TQM as both a philosophy and a set of guiding principles that represent the foundation of a continuously improving organization. It integrates fundamental management techniques, existing improvement efforts, and technical tools under a disciplined approach [13].

In a study conducted by Scheuermann et al., the tools, classified as qualitative tools, include flowcharts, cause-and-effect diagrams, multivoting, affinity diagram, process action teams, brainstorming, election grids, and task list, whereas quantitative tools include Shewhart cycle (PDCA), Pareto charts, control chart, histogram, run chart, and sampling [14]. Nowadays, the use of TQM tools and techniques [15, 16] such as Six Sigma [17–20], total preventive maintenance, business process re-engineering, lean Six Sigma [21], quality function deployment (QFD), Poka Yoke, and bench mark (BM) [22, 23], is improved textile process diagnosis.

The Six Sigma DAMIC [24] is a closed-loop process [25] which has different features [26], and the methodology approach includes many of the statistical tools at where they are employed by other quality movements [27] for improving any product manufacturing industry performance [28] by tackling the process variability [29, 30] as well as it is problem solving. This improvement methodology can be applied to every type of process to eliminate the root cause of defects [31–49] and minimize reworks [50].

The Six Sigma approach focuses on the critical characteristics that are relevant to the customers [51]. Based on these characteristics, Six Sigma identifies and eliminates defects, mistakes, or failures that may affect the final product, processes, or systems. And it is a project-driven management approach to improve the organization's products, services, systems, and processes by continually reducing the defects in the organization [35, 52, 53], promoting customer satisfaction [54], and also improving complaint handling [55].

2. Methodology

The methodological approach of this research is applied in the TQM Six Sigma approach based on the DMAIC (Define, Measure, Analyze, Improve, and Control) principals for selected three best spinning industries in Ethiopia, which suffer the common quality-related problem in 40 Ne carded yarn manufacturing and apply in five different phases. The first phase, the Define phase, will identify the highest level of process variation in spinning stages. During the Measure phase, the relevant data were collected from the three spinning industries, and the average data were used. Then, the magnitude of the problems was described and measured by using a pie chart. In the Analyze phase, identification of the potential root causes and severity of the defects have been done by the fishbone diagram and Pareto analysis; also, the existing process performance was evaluated by the capability study. In the Improve phase, the best solution was determined, and by applying this pilot solution in the process, the solution was evaluated. Finally, in the Control phase, the mistake proofing, monitoring, and response plan and visual controlling were made.

Mistake proofing by using DAMIC, monitoring, and response plan and visual control will be done.

The key process input variables which affect the key process output variables will be identified, and the solution will be proposed, as well as the key process input variables will be optimized, and remaining actions will be implemented.

Assessing the design process, process performance is evaluated, and the defective process is analyzed by using Pareto chart and fishbone diagram.

Data collection and planning and quantitative measurements of the magnitude of defective items in each spinning section from blow room to ring spinning will be done.

Define the customer voice based on international standards, and examine the defect found in each individual stage in the process. Clearly define the problem statement through customer analysis (Figure 1).

3. Results and Discussion

3.1. Define Phase. In this phase, it is required to identify the chronic problem with higher potential for contribution to performance improvement in the spinning process. Since quality plays a pivotal role in all aspects of life, reducing the number of defects, wastes, and lead time in the textile industry is an important function. Various defects are generated in cotton spinning mills due to small variations which are arising in the process.

The first section in spinning is blowing room, and the cause of blow room defects is mostly waste generation, NEP formation, low cleaning efficiency, high variation in the chute, and excessive lint loss which are impacts on the quality of the final yarn product in spinning. The second section is carding process, and it is the heart of the spinning process, and in this process, also arise defects such as NEP formation in cards, high waste generation, and high card sliver variation, and impurities in sliver are found. The third section is roving frames, and there are also potential defects occurring in the draw frame; also, the results of the defects in the next process of the speed frame include roller lapping in the draw frame, end breaks in drawing, impurities in sliver, and high drawing sliver count variation.

Most of the time, the causes of ring spinning defects are arising due to variation in the roving frame process, i.e., high count variation in roving, slobs in roving, high breakage in roving, and roving laps on the drafting zone.

The various types of defects in ring yarn processed at ring spinning, particularly arising due to variation occurred in raw material, improper process parameters, poor maintenance, and the condition of the machines, i.e., uneven yarn, count variation between cops, crackers in the yarn, thick and thin places in yarn, end breaks in ring spinning, and slub problems are found.

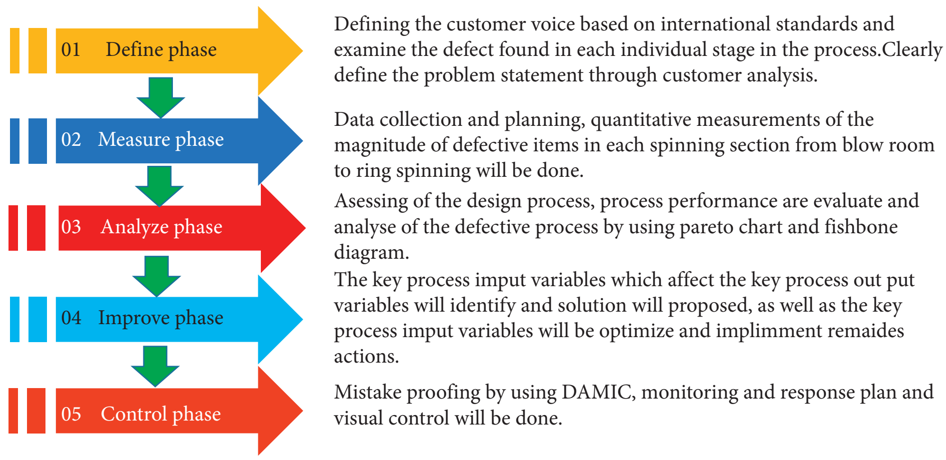

Figure 1: Methodological approach of the research.

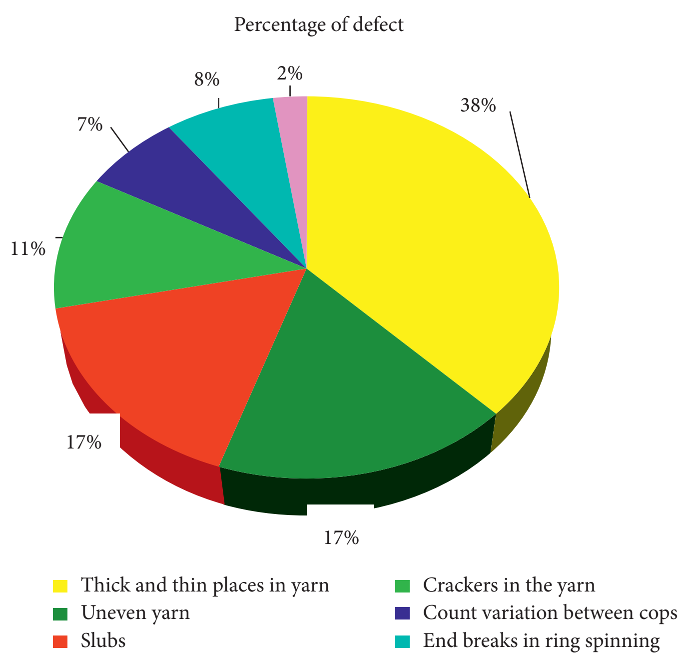

Figure 2: Defects frequently occurring in ring spinning yarn.

3.2. Measure Phase. The Measure phase is used to assess the existing performance of the process and identifies the percentage of defective and its severity of the product. It also gathers valid baseline information about the process and is used to establish the improvement goals. The defect which is generated in the ring spinning process has been identified and plotted by a pie chart. The defects found in the process are shown Figure 2.

3.3. Analyze Phase. In Analyze phase, it is the process to determine root causes of variation and poor performance (defects). Analysis of the reasons of the poor quality indicator is carried out in a number of steps. To analyze the input variables or factors that might affect the ring spinning yarn quality, the potential defects and their root causes were detected and analyzed from blow room to ring spinning process, and the identification of potential root causes of the specific defect was analyzed by Pareto charts as shown in Figure 2. And the root cause of the problems for ring spinning yarn was also analyzed by Ishikawa or fishbone diagram, as shown in Figure 3.

From Figure 3, the results show that 20% of few root causes are the result of 80% of defects occurring in the carded yarn spinning process. In ring spinning machine, the major defects such as thick and thin place, unevenness, slubs, and crackers are found. In roving frame machine, roller lap on the drafting zone, slubs, and high breakage rate are also found. Also, the foremost defects exist from draw frame machine are draw frame roller lapping and end breaks. High waste generation, NEP formations in cards, and card sliver variation are also the main problems which occur in carding machine, and high waste generation and NEP formation are

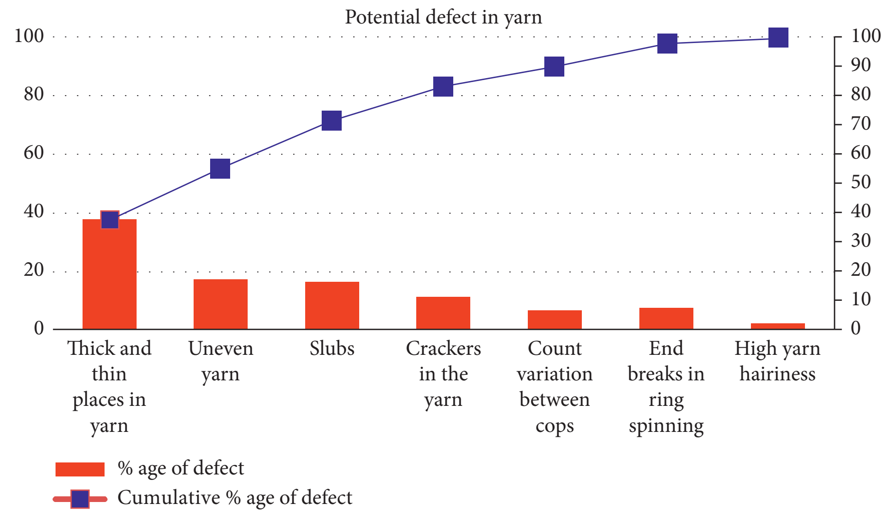

Figure 3: Potential defects in ring spinning yarn.

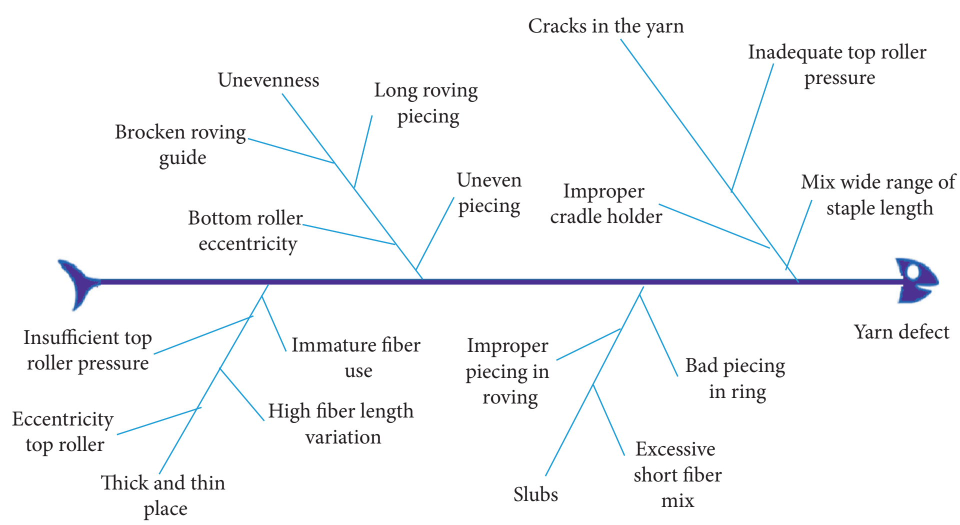

Figure 4: Cause and effect (fishbone) diagram of ring yarn.

found in blow room machines. The cause and effects of the potential defects are described by the fishbone diagram shown in Figure 4.

3.4. Improve Phase. After the root causes have been identified, the DMAIC's improve phase aims to determine the solutions to reduce and tackle them. A major component in successful quality improvement is driving the use of the proper statistics and engineering tools into the right places in the textile mill. The key process input variables based on the Pareto chart were identified, and the solution of the problem action plan was proposed. Table 1 shows the potential defects and their remedies for improving the overall quality in the spinning process.

3.5. Control Phase. After implementation of the solutions, the progressive outcomes were documented and shared with everybody in the spinning mill from top managements to workers. The defects are identified and reduced. For this purpose, a control plan is prepared as shown in Table 2.

3.6. Result and Evaluating Performance of the Process. After the implementation of the action plan proposed based on Six Sigma, the reduction of defects and significant improvements have been observed in the process, and the effects of TQM tools and techniques of the DMAIC approach on reduction and elimination of process variation are analyzed by the box plot as shown in Figure 5.

Figure 4 shows that the percentage of defects which were occurring in the process is reduced after TQM Six Sigma DMAIC tools are introduced to the process. Since the potential cause of the defect and its root cause are analyzed, so, by formulating preventive action like adjusting mechanical root cause problems and by minimizing and rejecting raw material faults and environmental variation, it can reduce and also eliminate 80% of the

Table 1: Root causes and their remedies in carded yarn process.

No.	Section	Defect	Root causes	Action (remedies)
1	Ring spinning	Thick and thin place	Immature fibers	Use mature fiber
			High fiber length variation	Properly mix
			Eccentric top and bottom rollers	Change eccentric top roller
			Insufficient pressure on top rollers	Apply required pressure on top roller
		Unevenness yarn	Uneven roving	Control short term autoleveller
			Bottom roller eccentric	Change eccentric bottom roller
			Long roving piecing	Give training to operators
			Broken or damaged roving guide	Change damage roving guide
		Slubs	Excessive short fibers in the mixing	Properly mix
			Improper piecing in roving	Give training to operators
			Bad piecing	Give training to operators
			Improper cradle holders	Change cardle holders
2	Roving	Roller lap	Improper ambient conditions in the department	Use required RH% and temperature
			Damaged surface in the top roller cots	Change top rollers
			Improper use of spacers	Change spacers
	Slubs on roving	Excessive end breaks.	Use adequate top roller pressure	
		Waste accumulation at creels	Clean the creel periodically	
		Damage on roller cloth	Change top roller clothing	
		Improper handling in transport	Properly transport the roving	
3	Draw frame	Roller lap in drafting zone	Improper humidity	Use required RH% and temperature
			Excessive top roller pressure	Use required RH% and temperature
			Inadequate suction in the pneumatic duct	Use required amount of suction air
			Excessive trash in the feed material	Use clean raw material
		High breakage rate	Improper pressure on top rollers	Apply required pressure on top roller
			Variation in top roller coating	Change top roller or grinding top roller coats
			Worn top roller end bushes	Change or grinding top roller coats
4	Carding	High waste generation	High short fiber in the raw material	Properly mix
			High trash content in the raw material	Use clean raw material
		Nep formation	High licker in speeds	Adjust licker in speed
			Uneven flat setting	Adjust flat to cylinder setting
			Rough surface in front and back plate.	Grind the wire
			Lunt licker in wire or dull flats	Grind or change licker in wire
		Card sliver variation	Bent/damaged back and front plate	Change front plate wire
			Feed roller weighting not acting properly.	Control short and long term autoleveller
5	Blow room	High waste generation	Use of excessive soft waste in the mixing	Reduce soft waste use in blow room
			Uneven mixing of soft waste	Properly mix
			Extreme variation in the ambient condition in the department	Use required RH% and temperature
		Nep formation in blow room	Cottons with too low moisture	Use required RH% and temperature
			Extremely fine cottons with high trash content	Completely rejects fine cotton with high trash content

Table 2: Control plan.

Responsible body	Action plan
Top management	Management review could be adapted by organization to check the current capacity of DMAIC being implemented. Top management could commit to applying TQM programs. Management review could be adapted by organization to check the current capacity of DMAIC being implemented.
Employee	Everyone in the company views the organization as an internal system with common aims. Everyone in the company could do for improving the quality. Everyone in the company could take training for improving the productivity. Everyone in the company could apply continuous improvement tolls in the production area rather than stability seeking. Everyone in the company could be aware of the costs of quality. Everyone in the company could solve the problem at root causes.
Higher institution	Researcher and top managements in the university have to support textile industries by doing applied problem solving researches in the industry.

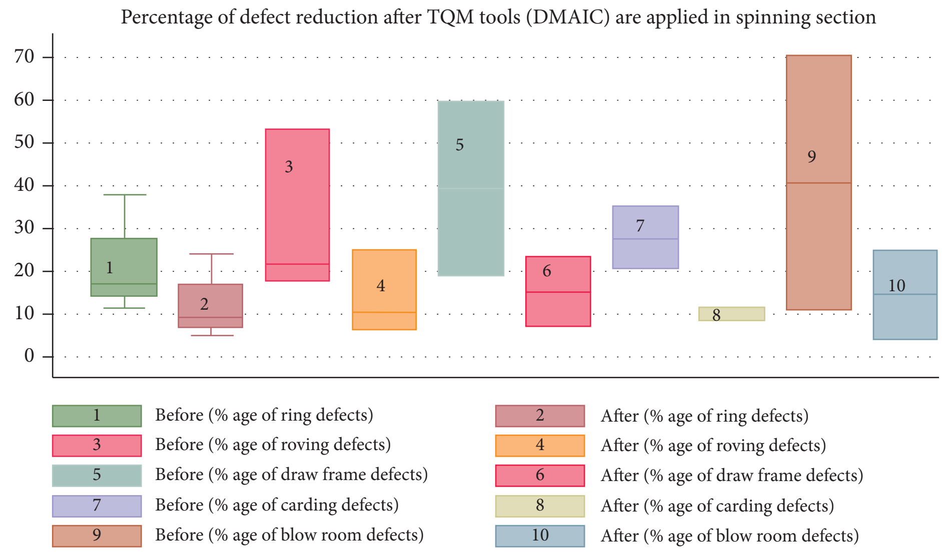

FIGURE 5: Percentage of defect reduction after preventive action is applied.

defects by eliminating 20% of root cause occurring in spinning mills.

4. Conclusion

The Measurement phase shows that the textile industry only performs based on the traditional quality control system, and the systems are no longer sufficient to handle emerging challenges due to low production runs and high quality cost. But, this is not the right way to minimize the causes of nonconforming or defective in the process.

This case study describes the reduction of defects in cotton spinning based on Six Sigma for improvement of the analysis process of defective products in each spinning stage from blow room to ring spinning. The key process input variables and the root causes of low-quality products were identified, and the solutions for improvements and action plans were also proposed. Since the Six Sigma methodology is a defect reduction approach, by decreasing the opportunities of defect arise in the overall stage of the process, we can increase the Sigma level or value of the process which shows the process improvement.

The analytical findings show that the application of total quality management programs, tools, and techniques of Six Sigma DMAIC approach has been expanded beyond the traditional quality concepts and has improved process performance by 57.96% and decreased the percentage of defects generated in the ring spinning, roving frame, draw frame, carding sliver, and blow room by 53.39%, 43.47%, 38.56%, 38.2%, and 36.45%, respectively.

Data Availability

The primary data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Supplementary Materials

The actual production and quality data in the manufacturing of ring yarn, from blow room to ring spinning process, are available and attached. (*Supplementary Materials*)

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