DOI: 10.7763/IPEDR. 2013. V59. 38

Integrating Advanced Quality Techniques to Improve the Quality of Glass Tubes: A Case Study

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Abstract. Total quality or continuous improvement is a consensus theme used by many industries for improving product quality and service. In the last decade newer quality techniques have become well established in many companies such as six sigma, lean manufacturing, and total quality management. The significant difference between TQM, Six-sigma and lean methodologies from the existing traditional quality philosophies is that they promote a stronger emphasis on monitoring production yield and manufacturing costs associated with any quality improvement effort. TQM is an approach that seeks to improve quality and performance which will meet or exceed customer expectations. The significant contribution that "Six Sigma" makes to the quality movement is the detailed structure for continuous improvement and the step-by-step statistical methodology. Lean is a generic process management that centers on preserving value with less work through the elimination of different types of wastes.

The aim of this paper is to integrate the main concepts of these three methodologies for the purpose of improving quality by reducing rejection rates, reducing cycle time and reducing cost in a medium sized manufacturing plant producing fluorescent glass tubes.

Keywords: Integrated Quality Systems, Lean Philosophy, Six Sigma, TQM.

1. Introduction

In manufacturing industries it is commonly stated that "Quality drives productivity." Improved productivity is a source of greater revenues, employment opportunities and technological advances (Godfrey, J. M.1998). Achieving manufacturing excellence is seen as essential to survival and economic growth for any country in this age of globalization (Singh and Khanduja, 2010). These global challenges are forcing companies to implement various quality improvement efforts to meet the needs of ever-changing customer and market demand. In order to survive industries have to improve productivity by utilizing resources like machinery, men, and material as optimally as possible (Kaur, Singh, and Ahuja, 2012).

In the past, when quality was to be improved, typically defined as producing fewer defective parts, they did so at the expense of increased cost, increased task time, longer cycle time, etc.. However, when modern quality techniques are applied correctly to business, engineering, manufacturing or assembly processes, all aspects of quality - customer satisfaction and fewer defects/errors and cycle time and task time/productivity and total cost, etc. - must all improve or, if one of these aspects does not improve, it must at least stay stable and not decline. The most progressive view of quality is that it is defined entirely by the customer or end user. The customer experience is the aggregate of all the touch points that customers have with the company's product and services, and is by definition a combination of these.

There are many quality techniques and terms such as: six sigma, lean manufacturing, zero defects, statistical process control, and total quality management; integrating such techniques gives us what we are looking for improving, developing, reducing cost and other industrial requirements (Pyzdek, T. 2003)). The integration of Lean and Six Sigma allows an organization to incorporate the problem-solving and analysis tools that make the most sense within their organization, while creating an infrastructure that supports and encourages a process improvement focus throughout the organization (Maleyeff, Edward and Venkateswaran, 2012).

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This paper deals with the implementation of a proposed technique that integrates different quality techniques in a glass manufacturing factory that produces fluorescent glass tubes. It is organized as follows: section 2 introduces the glass tube manufacturing process and the plant where the case study was executed. Section 3 presents the total quality management approach and how it was implemented in the factory. Section 4 introduces the six sigma methodology and its implementation phases throughout the end forming process. In section 5, the Lean philosophy is presented through the application of the 5s technique, while section 6 concludes the general findings of the study.

2. Factory Case Study

Glass manufacturing is considered a complicated process because of its diverse inputs and controllers that have to be adjusted carefully to achieve the required glass properties. The production steps at the factory under study can be summarized through five main departments: the batch department, the furnace, the ST line, the end forming line, and the laboratory (El Araby, 2010).

The first step in implementing the proposed integrated system was to determine the key ingredient (KI) that the company considers important. In this study the KI was the low quality and high production cost of the tube manufacturing which is mainly produced in the end forming line. The main objective of this process is to have the final shape of the product where the tube length and diameter are adjusted and the ends take the collar shape with its standard dimensions. This is the last process before packing so exploring glass defects inherent in the end forming process, reduces the cost of tube manufacturing. The next step was to form a multidisciplinary team, which was the basis for the success of the project.

3. Total Quality Management

Many literatures pointed out that the key concept of Six Sigma has inspired by TQM, and the two methodologies have many common principles (Ji Hyun Cho, Jae Hoon Lee, Dong Geun Ahn, Joong Soon Jang, 2011).TQM is basically a strategy that integrates all organizational functions and organizational objectives in a focus on meeting customer needs (Kumar et al., 2008). It emphasizes the role of internal and external customers and suppliers, and the involvement of employees in a quest for continuous improvement. TQM allows firms to obtain a high degree of differentiation, satisfying customers' needs and strengthening brand image, and, to reduce costs by preventing mistakes and wasted time and by making improvements in the corporation's processes. TQM training, so vital for the success of a TQM program, is usually a much neglected action item (Kumar and Garg, 2011). In the factory under study, one of the initial and essential steps that were implemented was top management education and training about the quality improvement process. This training allowed the management to provide good leadership means, have close involvement in implementation process to maintain the thrust of employees towards customer satisfaction.

4. Application of the Six Sigma Methodology

Improving the end forming process will adopt the six sigma DMAIC approach. The DMAIC roadmap consists of five basic steps: Define, Measure, Analyze, Improve, and Control.

4.1. Define

The define phase determines the whole process; process flowchart, boundaries, and controllers. A SIPOC diagram of the end forming process is shown in (figure1). The diagram was drawn using the "quality companion" software. SIPOC is a high-level process map that defines the scope of a process and its principle inputs, outputs, suppliers, and customers. SIPOC means **S**upplier > **I**nputs > **P**rocess > **O**utputs > **C**ustomer (ASQ, 2010).

SIPOC

Suppliers	Inputs	
	Description	Requirements
batch department	batch	batch calculation, mixing
furnace	molten glass	furnace adjustment
S/T line	straight glass tubes	good storage

Process
heating
forming
cutting
glazing
inspection
packing

Outputs		Customers
Description	Requirements	
End formed glass tubes	high quality, dimensional accuracy	lamps factory

Fig.1: End forming SIPOC

A detailed definition of the processes is as follows:

(1) Operation number and name; (2) Production and measuring tools; (3) Referring standards; (4)Operation type and working procedures; (5) Product specifications and limitations related to the operation; (6)Operation specifications and limitations; (7)The sampling plan; (8)Controllers ; (9) The control points.

4.2. Measure

The defects that occurred in the end forming line through the study period were summed in (table 1). The defected bulb is totally rejected regardless the type of defect, so the cost of defects is equal to the cost of one bulb (0.68 LE). To reduce such numbers, further measurements were required to predict the causes of these defects and their locations. Predictable areas of improvement will be within one of the main parameters of the glass bulb: 1. Overall length, 2. Base length, 3. Fixed collar inside diameter, 4. Moving collar inside diameter, 5. Fixed collar length, 6. Moving collar length, 7. Fixed flatness, 8. Moving flatness.

Measuring these parameters and analyzing them can give us the solution to improve the situation (table 2).

Table 1: Defects cost analysis of end forming line

	flatness	length	crack		inside dia						
Day	G00A13	G00A11	G00A3	Crush	G00A17	No Cut	No Glazing	Other	Crush F M/C	inside dia %	Crush F M/C %
May-08	1946	25	506	4131	15396	3219	0	2217	9012	0.6%	0.3%
Jun-08	2584	0	581	3382	19294	2660	266	1495	7034	0.7%	0.3%
Jul-08											
Aug-08	12	777	11	3273	34231	2019	0	1346	7450	1.2%	0.3%
Sep-08	403	398	57	2651	9702	1345	140	710	6755	0.4%	0.3%
Oct-08	403	398	57	2651	9702	1345	140	710	6755	0.4%	0.3%
Nov-08	0	22	159	2653	17773	2107	139	902	7442	0.7%	0.3%
Dec-08	0	97	3	1585	9358	428	0	414	11607	0.4%	0.5%
Jan-09	0	27	71	2358	11368	490	0	1626	14607	0.4%	0.6%
Feb-09	160	0	135	1501	15739	1192	0	342	14239	0.6%	0.6%
Mar-09	740	520	0	1364	10523	605	0	281	13958	0.4%	0.5%
total	6,248	2,264	1,580	25,549	153,086	15,410	685	10,043	98,859	0.6%	0.4%
التكلفه بالجنيه المصري	4,186	1,517	1,059	17,118	102,568	10,325	459	6,729	66,236		

Table 2: Experimental data

Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6	C7	C8
	Overall Length	Base Length	fixed Collar Inside Dia.	Moving Collar Inside Dia.	Fixed Collar Length	Moving Collar Length	Fixed Flatness	Moving Flatness
728	1187.90	1178.10	22.500	22.10	5.3	5.0	0.3	0.3
729	1188.05	1178.30	22.500	22.00	5.0	5.1	0.3	0.3
730	1188.00	1178.10	22.500	22.10	5.1	5.1	0.3	0.3
731	1188.00	1178.10	22.550	22.10	5.1	5.1	0.2	0.2
732	1188.05	1178.00	22.510	22.10	5.2	5.0	0.2	0.3
733	1187.90	1178.10	22.650	22.00	5.2	5.2	0.3	0.3
734	1188.10	1178.20	22.450	22.12	5.2	5.0	0.3	0.3
735	1188.00	1178.20	22.500	22.30	5.1	5.1	0.3	0.4
736	1188.25	1178.40	22.530	22.30	5.2	5.0	0.5	0.3
737	1188.00	1178.20	22.550	22.10	5.1	4.9	0.3	0.2
738	1188.07	1178.40	22.410	22.30	5.1	4.8	0.3	0.2

4.3. Analyze

In the analysis phase, examine the data collected in order to generate a prioritized list of sources of variation. Process capability analysis (figure 3) was performed to find out actual state of the process. A brain storming session was held and a cause and effect analysis (figure 4) was applied to determine the root causes of such problems in the machine capability. X-bar and s charts were also used to visualize performance and determine variations in the process (figure 5).

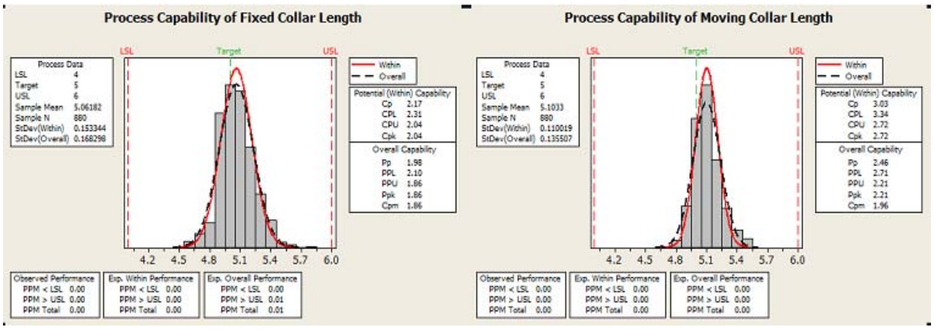

Fig. 3: Process capability analysis;Before improvement

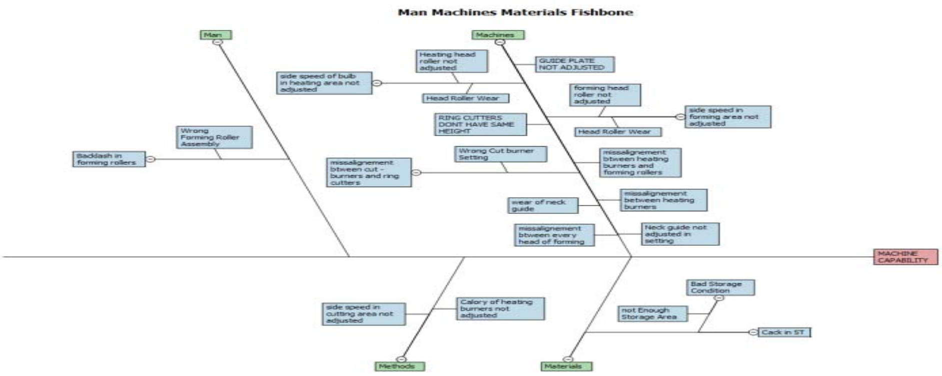

Fig. 4: The fish bone analysis

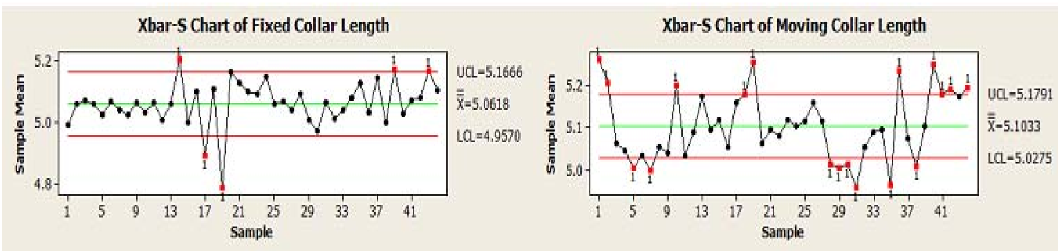

Fig.5: Minitab Results: Xbar-S Chart of some parameters

Analyzing the data was performed using the mini-tab software (Minitab Inc., 2010). It took couple of weeks to get 900 readings. A sample of data gathered and results are shown in the next figures. Mini-tab results for the machine capability of the glass tube dimensions resulted in hunting points out of the control limits, and analyzing the causes of variation, several reasons were discovered, some of which are:

- The maladjustment of heating burners and forming heads
- Misalignment of forming rollers and the heating and cutting burners
- Instability of the heating temperatures
- Forming rollers and the neck guide are subjected to wear and corrosion

Further process capability analysis (Cm & Cmk) was also applied on the end forming process resulting in the following data shown in table 3. Causes of variation were categorized by the method of fixing them as: machine initial setting, maintenance, and inventory. A Pareto chart was formed for the number of their repetitions (figure 6):

Table 3: Capability values and comments

Glass tube parameters	C_m & C_{mk} values	Comments
Overall length	C_m= 2.84	Accepted value but need to be increased and increasing the overall length control
	C_{mk}= 2.76	The points are trended to the lower side and this is not good since the customer needs them to the upper side
Base length	C_m= 1.25	Unaccepted low value and this indicates bad control. This value has to be raised
	C_{mk}= 0.95	Very low value and the process is trended to the upper limit, and this is totally not accepted especially for the collar length

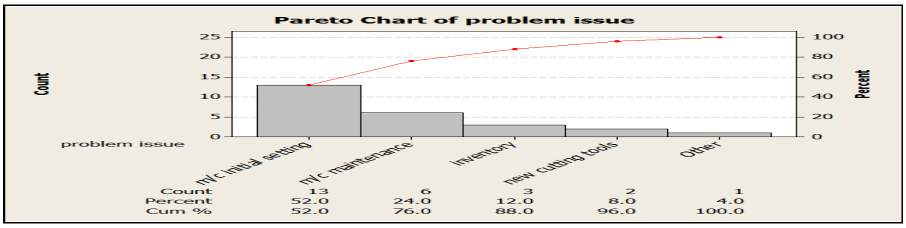

Fig. 6: Pareto chart for categorized possible causes

4.4. Improve

Therefore, the machine initial setting was chosen for analysis to demonstrate in details the appropriate improvement procedure. The initial setting procedures can be simply stated as follows:

(1)Guide plate initial setting, (2)Head roller initial setting, (3)Heating burner initial setting, (4)Hold roller initial setting, (5)Forming roller initial setting, (6)Transfer home position initial setting, (7)Neck guide initial setting, (8)Cutting burner initial setting.

Some improvement applications for this process are:

- Replacing the neck guide with other one of higher quality and of harder material
- Giving more restrictions of applying the control limits (check sheet & line check) and the working procedures in general
- High adjustment of the forming rollers and the temperature of the glazing

4.5. Control

In control phase, x-bar and s control chart was drawn to visualize the improvement that took place in the process after implementing the changes in factors proposed.

To control the achieved measurements the following recommendations are required:

- Changing the neck guide every 3 months.
- Performing the initial setting operation every 3 months.
- Performing the periodic maintenance especially for the air valves in the glazing operation since they affects the inner diameter directly.
- Adjusting the line speed before working every week (when the line stops) especially in the forming and cutting areas since the line stops one day per week.

4.6. Six Sigma Results and Conclusion

The proposed improvement recommendations were introduced as previously mentioned. According to these recommendations improvement plans were designed and implemented. After the initial setting improvement process was implemented readings were taken and analyzed resulting in the following output (figures 7 and 8). Figure 7 shows that the process is closer to the upper limit resulting in low glazing values and this is mainly due to need of maintaining and regularly checking the air valves.

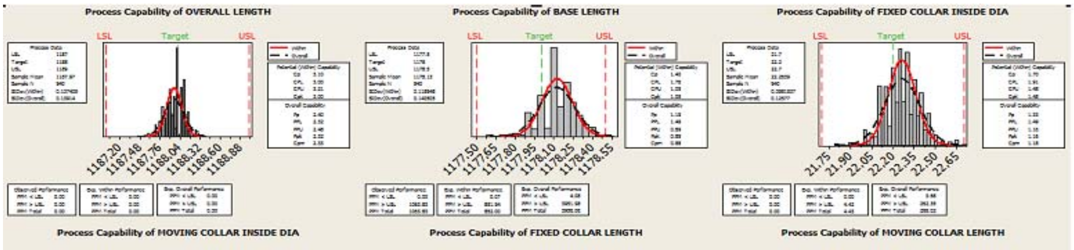

Fig. 7: Process capability after improvement.

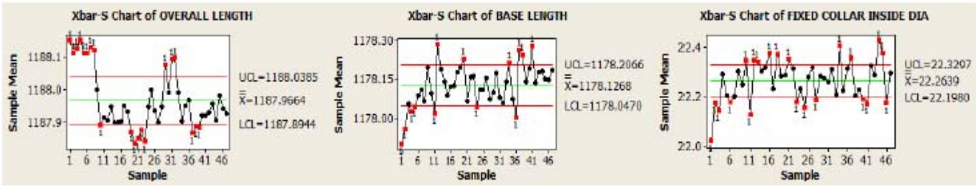

Fig. 8: Sample of Xbar-S chart of glass tube parameters.

As shown in table 4, all Cm & Cmk values are raised for all parameters except for the inside diameter and this is due to the glazing instability of the fixed and moving sides.

Table 4: Capability Analysis

Variable	Overall length	Base length	F.C.inside diameter	M.C.inside diameter	F.C.length	M.C. length	Fixed flatness	Moving flatness
Cm Before	2.84	1.25	1.85	1.92	2.17	3.03		
Cm After	3.1	1.4	1.7	1.57	2.45	3.35		
Cmk Before	2.76	0.95	1.61	1.73	2.04	2.76	2.06	2.76
Cmk After	3	1.05	1.48	1.33	2.11	2.92	2.3	2.92

The overall length is improved and slightly moved closer to the lower limit but still close to the target, the collar length is enhanced and approached the upper limit as the customer recommends. As for the flatness a great improvement need to be controlled, while slight improvement for the base length took place and the process approached the upper limit this is because it is affected by the inner diameter. The application of project recommendations succeeded in improving quality, customer satisfaction and the cost of one bulb reached L.E. 0.55.

5. The 5s Application and Results

Lean principle is a generic process management philosophy that centers on preserving value with less work. This involves the endless pursuit for eliminating several types of wastes to optimize the flow of resources at the processes (Womack and Jones, 2003). Lean is also a method of economizing resources. Good Housekeeping is of great importance to a lean organization's success: what we assume as "little things" does count in making the processes work better (Henderson, 2010).

Of relevance is 5S Job cycle i.e. removing unnecessary items from work area (Sort), arranging work tools in right place (Set-in-order), cleaning area and equipment (Shine), developing checklists, standards and instructions to keep things in order (Standardize) and maintaining to improve the efforts (Sustain); as much as 50 percent of the organization's overheads could be reduced in this way (Amit Kheradia, 2011). In the glass bulb manufacturing plant another major problem was the unorganized floor area. The 5S tool was used as the most suitable tool to overcome such a problem. The 5S team applied the methodology in the whole factory and also in the end forming process these results are listed:

- To standardize working processes a system for labeling the factory documents in the library (archive) was performed, determining the job descriptions that have the right to use these documents, also adjusting the duration of keeping these documents in their positions, and finally preparing a listing all documents. This facilitated the use of data available in such documents. It can be also considered the first step in designing and constructing a computerized quality information system.

- Organizing needed tools for production and maintenance. They were firstly classified, then cleaned and organized in all factory departments. This was done to protect the tools and keep them clean and available all the time.
- Painting floors and stairs for making the plant ready for hosting visitors or even customers at any time, and to recapture valuable floor space by determining storage areas and passages areas.

A serious problem was the increase of temperature around the furnace that reaches 54˚C, this affects the workers safety and performance on the long run. As an immediate solution, a shield was built around the furnace area. This action resulted in temperature reduction to 33˚C. However, there was excess heat inside the furnace area; consequently, openings were designed and implemented to permit air flow, thus, improving environmental conditions in the work area.

6. Conclusion

The success of TQM, Six Sigma and Lean application in this case study can definitely encourage other manufacturing units and medium sized enterprises to use these quality techniques as a quality tool to reduce the losses in their processes and harvest unlimited benefits from it. The application of project recommendations succeeded in improving quality, customer satisfaction and the cost of one bulb was reduced from L.E0.68 to L.E.0.55.

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