Investigating the Application of Six Sigma Methodology and Quality Control Tools and Techniques in Sepanhan Oil Company

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Abstract

In developing new products and services, quality is critically important, not only to satisfy clients, but also to help organizations to stand out from their competitors. Continuous quality improvement process demands that the team of quality initiatives as well as company leadership actively use quality tools and techniques in their improvement activities and decision making process. Quality tools and techniques can be used in all phases of production process, from the beginning of product development up to product marketing and customer support. Statistical Process Control (SPC) includes seven approaches: Pareto diagram, Cause and Effect diagram, Check sheets, Process Flow diagram, Scatter diagram, Histogram and Control charts. The primary objective of this paper is to show how quality can be enhanced in the oil industry by Six Sigma methodology and selected SPC tools and techniques. Respectively, potential causes of failures in the Sepahan Oil Company have been found, analyzed and improved. For this purpose, the four liter production line of the company has been selected for investigation. The findings imply that the application of SPC tools has reduced the scraps from 50,000 to 5,000 ppm and has resulted in a 0.92% decrease of the oil waste.

Key Words: Six Sigma, Statistical Process Control, Quality Management, Sepahan Oil Co., Waste

Introduction

Quality management has been an important management strategy for achieving competitive advantages and improvements. The concept of quality management (QM) is quite old and was first originated in Japan after the Second World War with emphasis on improving quality and using quality control tools in the manufacturing sector (Talib, et al., 2010). Numerous approaches of QM were suggested, in order to help industries improve efficiency and competitiveness through improvement of quality. One of the most popular and often recommended approaches is the philosophy of Total Quality Management (TQM) and Six Sigma that seeks to integrate all organizational functions to focus on meeting and surpassing customers' requirements and organizational objectives. TQM and Six Sigma methodology, Quantitative Tools ensures better decision-making, better solutions to problems, and even improvement of quality and productivity for products (Hekmatpanah, 2011). Six Sigma, as a concept gains more and more attention and importance because of its comprehensive approach for company development and performance improvement of both products and processes. Nevertheless, Six Sigma is recognized for its complicated statistical and non-statistical tool-sets for reducing operational deviation (Lee and Wong, 2011).

Method and Material

Quality Management System

In successful application of quality tools the implemented quality management system is an advantage. The quality management principles are a starting point for company's management striving for continuous efficiency improvement in long periods of time and customer satisfaction (Paliska, 2007). Quality management system is based on integrity of all production and support resources of certain companies. It enables faultless process flow in meeting related contracts, standards and market quality requirements. Implementation of quality management system is always a part of a company development process, Fig. 1 (Johanson, 2002).

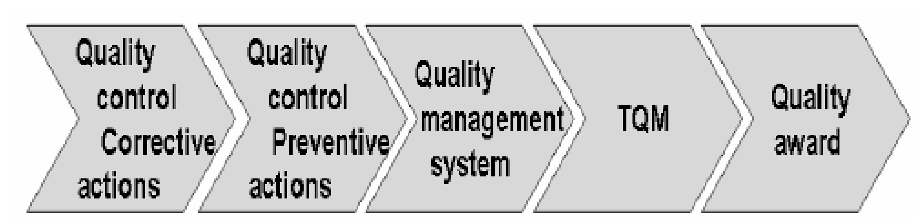

Fig. 1. Development of quality management concept

Having the quality management system in place is a prerequisite of its successful application on a day to day basis. Management has to show commitment to development and improvement of quality management system. When in function the quality management system provides useful information obtained through different process analyses and audits (Injac, 2002). Continuous improvement process is based on application of Deming's quality cycle or PDCA-cycle, shown on Fig. 2. The PDCA-cycle is an integral part of process management and is designed to be used as a dynamic model.

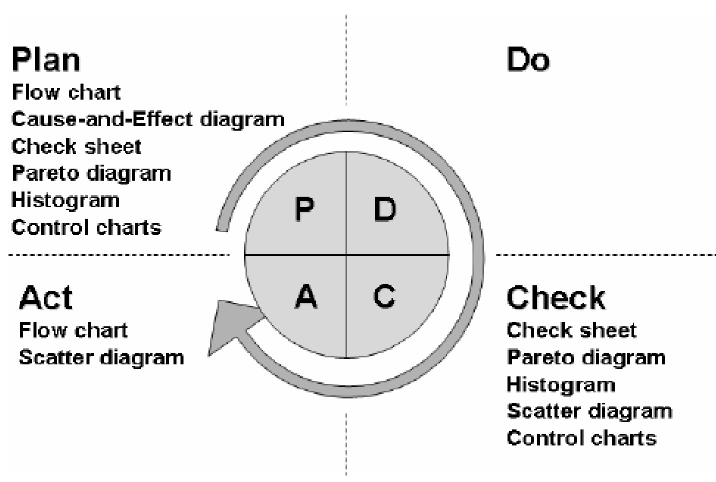

Fig. 2. PDCA-cycle

The completion of one turn of cycle flows into the beginning of the next. Main purpose of PDCA-cycle application is in process improvement. When the process improvement starts with careful planning it results in corrective and preventive actions, supported by appropriate quality assurance tools, which leads to true process improvement (Paliska, et al., 2007).

Seven Quality Control Tools

The 7 QC Tools are simple statistical tools used for problem solving. These tools were either developed in Japan or introduced to Japan by the Quality Gurus such as Deming and Juran. In terms of importance, these are the most useful. Kaoru Ishikawa has stated that these 7 tools can be used to solve 95 percent of all problems. The following are the 7 QC Tools:

1) Pareto Diagram
2) Cause & Effect Diagram
3) Histogram
4) Control Charts
5) Scatter Diagrams
6) Graphs
7) Check Sheets

The model for systematic usage of quality tools for process monitoring, data acquisition and quality improvement is shown on Fig. 3 (Keller, 2005).

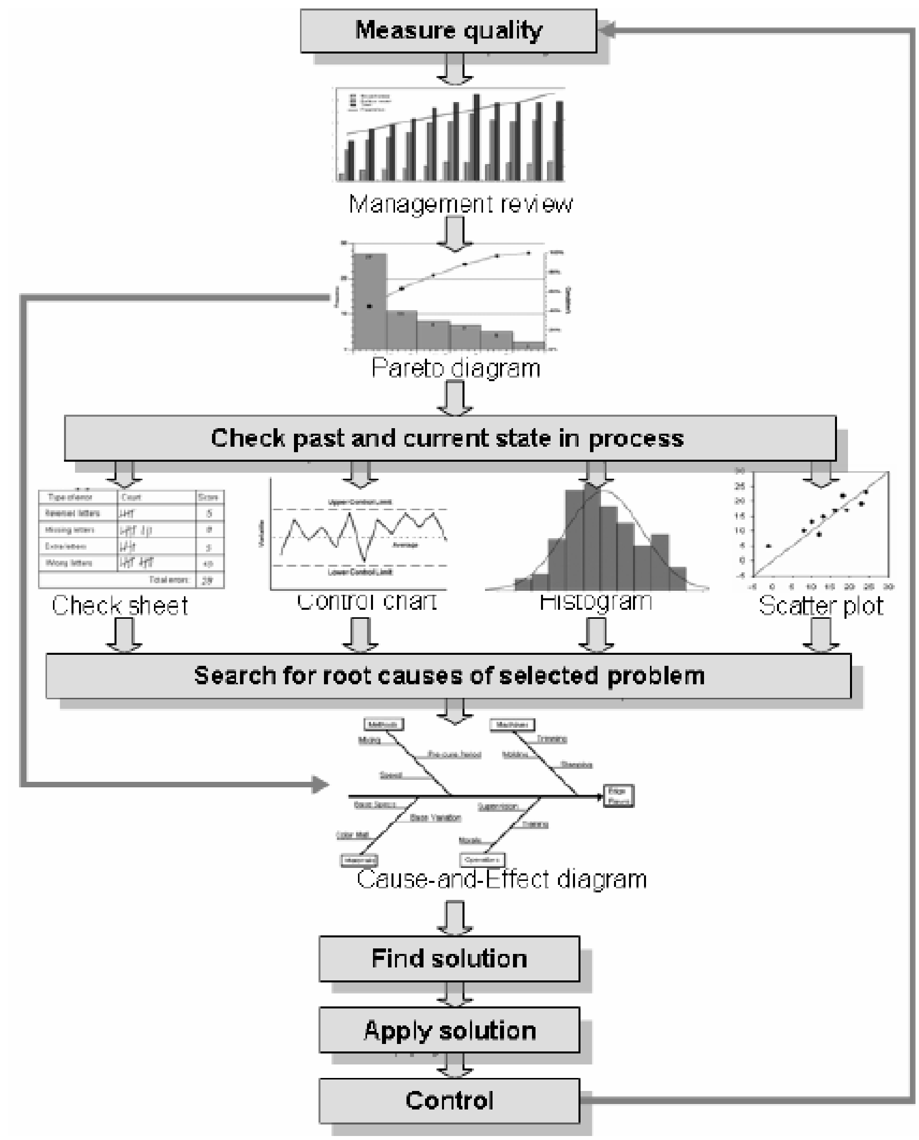

Fig. 3. Seven quality tools (7QC tools) for quality improvement

Six Sigma Methodology

Six-Sigma has the potential to change the quality program of an organization. When the selected quality program is Six-Sigma, the organizational goal is to reach a sigma level of 6, or the objective of 3.4 defects per million opportunities (Zare Mehrjerdi, 2011). Six-Sigma is a business strategy and a systematic methodology, use of which leads to breakthrough in profitability through quantum gains in service quality, product performance, productivity and customer satisfaction (Shahin, 2010). In the midst of 1980s, Motorola (Stamatis, 2004), under the leadership of Robert W. Galvin, was the initial developer of Six Sigma. Six-Sigma is a disciplined methodology that uses data and statistical analysis to measure and improve a company's operational performance. It focuses on identifying and eliminating "defects" in processes and has produced hundreds of millions of dollars in new profitability in a wide variety of industries. A large part of the success of Six Sigma lies in its ability to add a communication layer to industrial processes. Visual information systems populate the working environment with clear signals for parts delivery or tool changeover (Antony, 2004). Briefly, Six Sigma provides a suitable strategy with appropriate indicators toward continuous improvement. Six Sigma methodology and statistical methods ensure the throughout improvement in quality and reduction in rejects with the definition of targets and visions. Implementation of Six Sigma will be achieved through a series of successful projects. Project can have different sizes and durations. Depending on the scope of the project, they are categorized as: (El-Haik, 2005)

Six Sigma Strategies

DMAIC Process

Gross (2001) states that "what is needed in an effective Six Sigma implementation is a road map in order to provide a structured approach for implementing a Six Sigma program." The roadmap is a way to set up a plan so that decision makers can have expectations of the program's success. A typical Six Sigma road map is the DMAIC (Define, Measure, Analyze, Improve, and Control) methodology, which is followed by many in their quest for Six Sigma quality.

Defining

The define stage of the Six Sigma methodology is the beginning of the spectrum for a Six Sigma project. This steps purpose is to identify potential projects, to select and define a project and to set up the project team. Gryna (2001) specified five general steps of the define stage. These are summarized as:

1. Identifying Potential Projects
2. Evaluating Projects
3. Selecting Project
4. Preparing Problem and Mission Statement for Project
5. Selecting and Launching Project Team

Measuring

The measure phase of the Six Sigma methodology identifies key product parameters and process characteristics and measures current process capability. This phase also concentrates on key customers and their critical needs (De Feo et al., 2002). The steps in this stage as outlined by Gryna (2001) include:

1. Measuring the baseline performance and verifying the project need
2. In the Process
3. Planning for Data Collection
4. Validating the Measurement System
5. Measuring the Process Capability

Analyzing

The analyze phase of the Six Sigma paradigm essentially analyzes past and current performance data to identify the causes of variation and process performance. The steps of this include:

1. Collecting and analyzing data
2. Developing and testing theories on sources of variation and cause-effect relationships.

Improving

The improve phase of Six Sigma essentially designs a remedy, proves its effectiveness and prepares an implementation plan. In this stage, the team must be ready to veer back and forth between far-out ideas along with the details of executing a plan (Pande et al., 2002). The steps include:

1. Evaluating alternative remedies
2. Designing formal experiments to optimize process performance (if necessary)
3. Designing a remedy
4. Proving effectiveness of the remedy
5. Dealing with resistance to change

Controlling

The control phase, which is the last phase of the Six Sigma methodology, is where the designing and implementation of certain activities to hold the gains of improvement occur. Statistical Process Control (SPC) is something that can be used in this phase. The steps include (Wortman, et al., 2001):

1. Designing controls and documenting the improved process

2. Validating the measurement system

3. Determining the final process capability

4. Implementing and monitor process controls

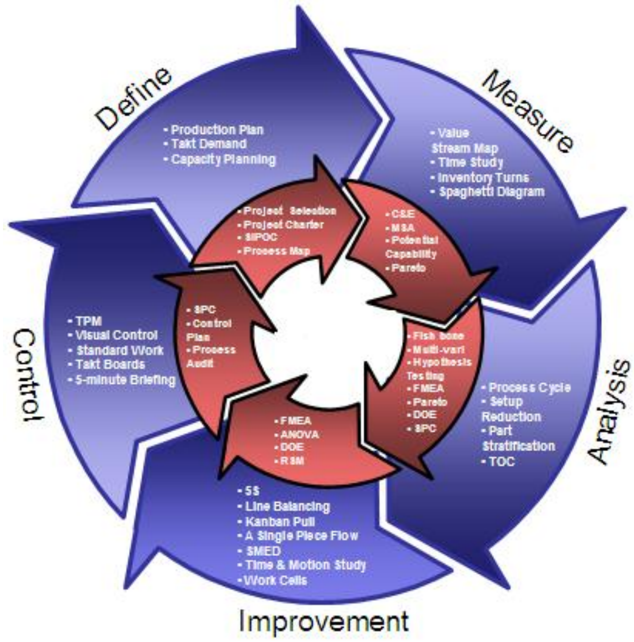

Fig. 4. DMAIC Cycle

Sepahan Oil Company

Sepahan Oil Company trades in petroleum and petrochemical products in the world. Today, this company operates in most of the world's counties and is best known by our familiar brand names like Exxon, Esso, and Mobil. Sepahan Oil Company makes products that drive modern transportation, power cities, lubricate industry and provide petrochemical building blocks that are vital to thousands of consumers. Ever since its establishment and with regard to the type of design and anticipated capacity, Sepahan Oil Company was considered the major supplier of motor oil in the country. Sepahan Oil Company is capable of securing over 30% of approximately 600 million liters of engine oil used domestically. "Alvand" and "Arzhan" engine oils allocated the highest share of the market to themselves for years, and at present, special trade names of Sepahan Oil Company such as "Speedy" and "Jey" rank first among domestic and foreign suppliers.

Research sample and sample size

In the canning hall production, a full array of production and filling lines has been installed which consist of 210-liter, 20-liter, 4-liter and 1-liter barrels. The 4-liter canning and filling production line, which encompasses most of the wastes is investigated as illustrated in Table 1. The statistics included in the Table are extracted from the company's records, databases and documents.

Table1. Percentage of waste in canning and filling processes of Sepahan Oil Co.

Wastage / Line production	Canning (Percentage)	Filling (Percentage)	Total (Percentage)
4 Lit	6%	1%	7%

Definition of the goal

As it is addressed in Table 2, with regard to the production plan and the existing constraints in this project, 0.3% is specified as the project target by the Six Sigma improvement team for canning scrap rate and 0.05% is specified for the wasted oil.

Table 2. Six Sigma project charter at Sepahan Oil Company

4-liter	Actual	target	Improvement
Canning	6 %	0.3 %	0.95 %
Filing	1 %	0.05 %	0.95 %

Discussion and Analysis

Identifying CTQs

After determination of the six major failure modes for concentration that contribute in the highest degree to the wastage in the whole process are cutting, welding, bottom seaming, movement prior to filling, and filling and top seaming. For each of these points it was necessary to identify the Critical to Quality (CTQ) factors.

Table 3. The identified CTQs at the 4-liter line in Welding section

No.	Section	CTQ	Operational definitional of CTQ
1	Welding section	Unadjusted feeder	The number of scrap cans
		Worn out parts during production	The number of scrap cans
		Inappropriate thickness and bare electrode hardness	The number of scrap cans
		Unadjusted device crown	The number of scrap cans

A schematic diagram of the operation is given in Figure 5.

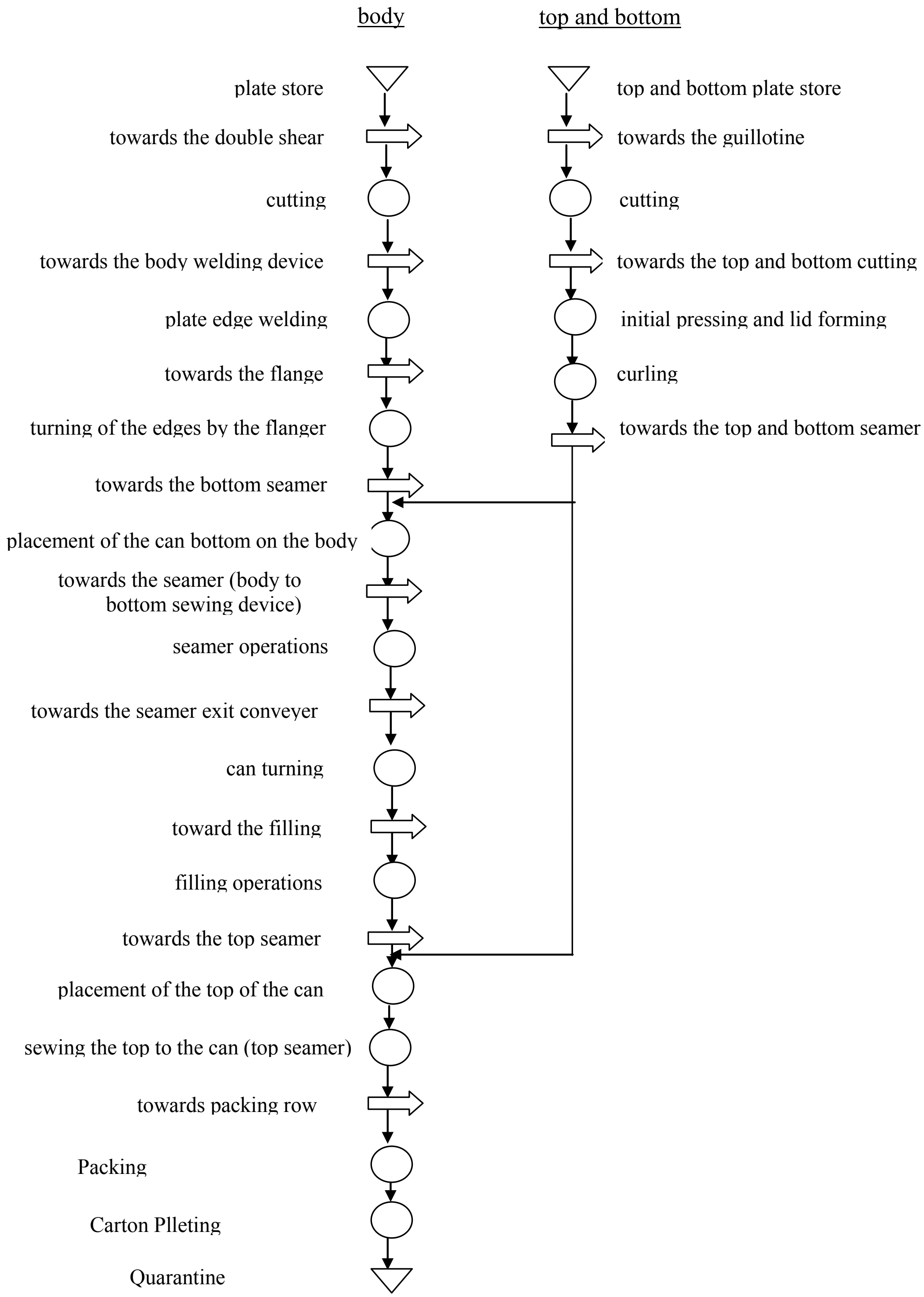

Fig 5. Process of the Production Line and 4-litre filling operation before improvement

Measure phase

In order to effectively execute the measure phase, first a compiled plan for data collection is designed for the collection of the required data and the design of the required forms. Those responsible for data collection are trained for sampling and filling out the forms. The data of the related forms are recorded in a table. In order to approve of the measuring system and the validity of the data, the MSA technique and Gage R&R methods are employed.

Table 4. The measurement of the identified CTQs at the 4-liter line in Welding section

No.	Section	CTQ	Scrap percentage	
			For filling	For canning
1	Welding section	Unadjusted feeder	-	0.60
		Worn out parts during production	-	0.50
		Inappropriate thickness and bare electrode hardness	-	0.40
		Unadjusted device crown	-	0.10

The capability of process and the present Sigma level

After measuring the CTQ values of the addressed six failure modes, the capability of process and the present Sigma level of the process before improvement are calculated (Table 5). It is important to note that the standard deviation for σ is considered to be 1.5.

Table 5. Process capability and production line of 4-liter Sigma level before the implementation of the Six Sigma technique

	Capability of process	Sigma level
Canning section	0.55	3.14
Filling section	0.77	3.80

Analyze Phase

Based on the data obtained during the measure stage, the following steps are taken:

1. The study and analysis of the process with the purpose of problem identification

2. Presenting the views suggested by the problem-solving team with regard to the causes of the problem
3. Conducting tests by means of statistical tools in order to substantiate the basic causes for the problem

In order to implement the above-mentioned steps, the FMEA technique, the cause and effect diagram and the Pareto analysis for identifying the root causes of the problem are adopted for welding section modes which are explained.

Welding section

The factors which produce the most scraps at the welding section are unadjusted feeder, worn-out parts during production, inappropriate thickness and hardness of the bare electrode, and unadjusted device crown which comprise 0.6, 0.5, 0.4, and 0.1 percent of the scrap, respectively. Table 6 displays the FMEA of the Welding Section.

Table 6. FMEA of Welding Section

Potential failure mode	Potential failure effects	severity	Potential causes of failure	Occurrence	Current process control	Detection rate	RPN
Unadjusted feeder	Number of scrap bodies	8	Operator of precision tools	6	Daily, weekly, and monthly control	5	240
Part wear and tear during production	Number of scrap bodies	5	Operator of precision tools	5	Weekly control	5	125
Unfit hardness and thickness of the bare electrode	Number of scrap bodies	4	Operator of precision tools	5	Daily control	3	60
Unadjusted device crown	Number of scrap bodies	3	Operator of precision tools	3	Daily control	3	27

The problems of this section result in scraps in can bodies. It can be seen that the highest RPN is due to feeder non-alignment, mainly due to the lack of operator skills and of precision tools. Daily, weekly and monthly controls on the feeder are not fully effective. The second highest RPN is due to the erosion of system segments during manufacture. Next are RPNs of 60 and 27, due to, unsuitable diameters and thicknesses of the bare electrodes and unfit system crowns respectively.

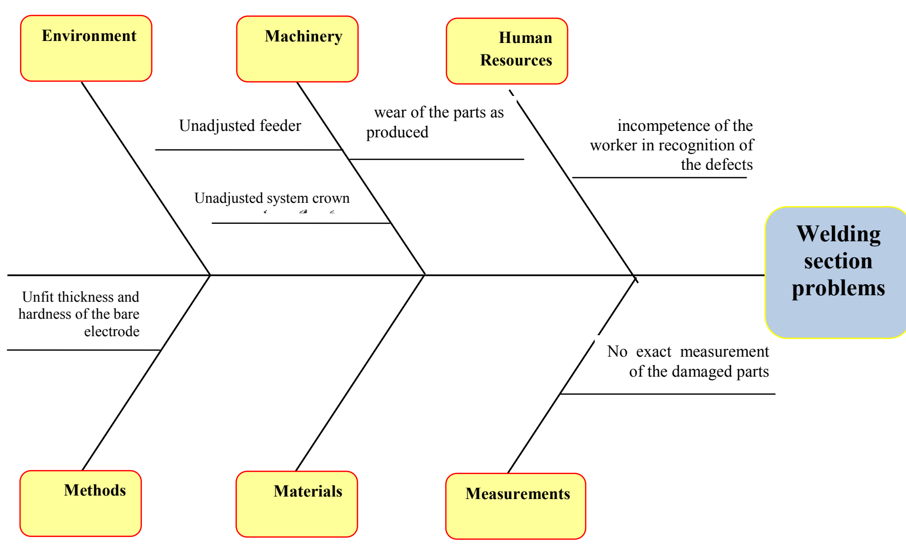

Fig 6. Cause and Effect Diagram for Plate Welding section

Figure 6 shows the cause and effect diagram and this, as well as the Pareto diagram point to the unadjusted feeder and the scrap parts during manufacture as the main causes of the problems in the Welding section. In addition, the improvement team identified the inaccurate diameters and thicknesses of the bare electrodes, the defective crown system and the inability of the worker to recognize damaged sections as the second set of critical problems.

Pareto diagram

The causes leading to the production of scrap were first analyzed and the results were as follows: **Scrap Cause**	**Percent age**
a) Inability of worker to recognize defective parts	9
b) Wear and tear of parts during production	28
c) Unadjusted feeder	38
d) Unadjusted system crown	10
e) Unfit thickness and hardness of bare electrode	15

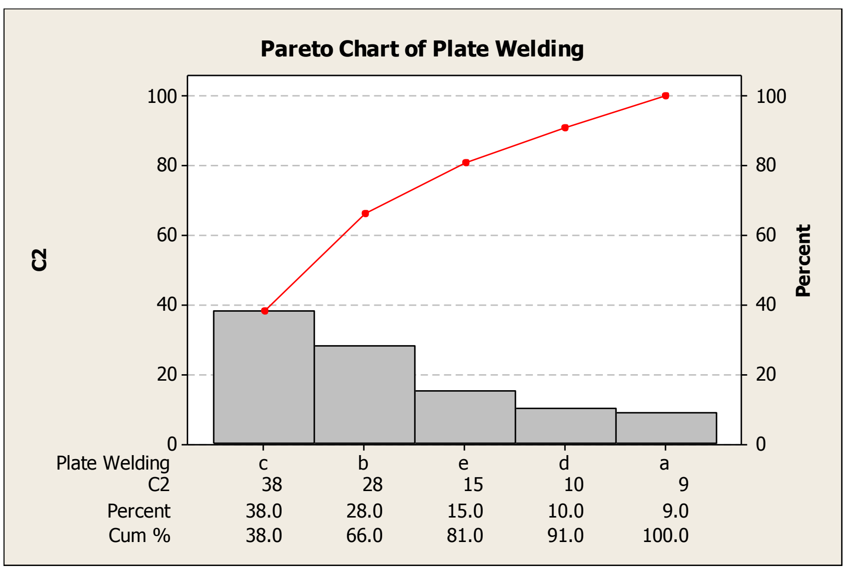

Fig 7. Pareto Diagram for Plate Welding section

Gemba Field Analysis

The Gemba field analysis (Table 7) also confirmed the causes identified by the improvement team for the resulting scraps. As can be seen, each of the causes identified during the brainstorming sessions, is denoted by (-), which means that the rate of scraps also increased on the corresponding date.

Table 7. Gemba Field Analysis of Plate Welding before improvement

Worker skill	Worn out parts	Feeder adjustment	Crown adjustment	thickness and hardness of the bare electrode	Scrap percentage
+	+	-	+	+	1.40
+	+	+	+	+	5.00
+	+	+	+	+	0.04
+	+	-	+	+	1.80
+	+	+	-	+	1.50
-	+	+	+	+	0.50
+	+	-	+	+	1.80
+	+	+	+	+	0.03
+	+	-	+	+	1.60
+	+	+	+	-	1.60
-	+	+	+	+	0.60
+	+	-	-	+	3.30
+	+	+	+	+	0.06
+	+	-	+	+	1.70
+	+	+	+	+	0.14
+	-	-	+	+	3.70
+	-	+	+	+	3.30
-	-	+	+	-	4.10
+	-	-	+	+	3.80
+	-	-	-	+	4.20

Statistical Tests

Table 8 is the statistical analysis of the welding section. The analysis proves the significance of all the identified causes of the existing problems, although the correlation coefficients are not high.

Table 8. Correlation Analysis of he Causes of Welding Problems

Causes	Correlation coefficient	p-value of the correlation test
Incompetence of worker in recognizing defects	0.025	0.00
Wear and tear of part during production	0.018	0.00
Unadjusted feeder	0.013	0.00
Unadjusted system crown	0.016	0.00
Unsuitable thickness and hardness of bare electrode	0.022	0.00

Table 9. The coefficient between waste and variables of welding section

Criterion variable	waste		
Significant level	Square of correlation coefficient	Correlation coefficient	Statistical indicators / Predictor variable
0.011	0.314	*0.566	1
0.001	0.455	**0.675	2
0.027	0.245	* 0.495	3
0.007	0.342	**0.585	4
0.032	0.231	*0.481	5

The table shows that the correlation coefficients (based on r2) between wastage and variables 1 through 5 are significant.

Improvements implemented

On the basis of the above 4-point analysis of the problems in this section, the following improvements were implemented:

1) A preventive maintenance schedule was established.
2) A system to identify defective parts was set up.
3) A 2-hourly system to check hardness and surface alloy for electrical conductivity during production was put in place, since the two ends of the wire are different.
4) A system was set up to re-check hardness and thickness of plate before it entered the feeder.

Conclusion

In order to survive in a competitive market, improving quality and productivity of product or process is a must for any company. Some simple techniques like the “seven basic quality control (QC) tools” provide a very valuable and cost effective way to meet these objectives (Rohani and Teng, 2001). In this study, the importance of the improvement team was emphasized. It is important to note that many enterprises limit the productivity enhancement of employees to the acquisition of skills. However, about 86% of productivity problems reside in the work environment of organizations. The work environment has effect on the performance of employees (Taiwo, 2010). One of the main aims of this paper was to enhance quality in the oil industry through the Six Sigma methodology with the SPC tools. There is a lack of systematic approach in ascertaining critical factors to quality as well as the use of Six Sigma and its toolbox in special applications including the oil industry. According to DMAIC cycle and implementation FMEA and cause and effect diagram, the phases were implemented in order of define, measure, analysis, improve, and control. Each phase comprised different tools and various techniques which were used as required. Table 8 shows the data comprised of the criteria before and after the implementation FMEA and the cause and effect diagram. Figure 8 shows the critical points for attention superimposed in red on the process diagram.

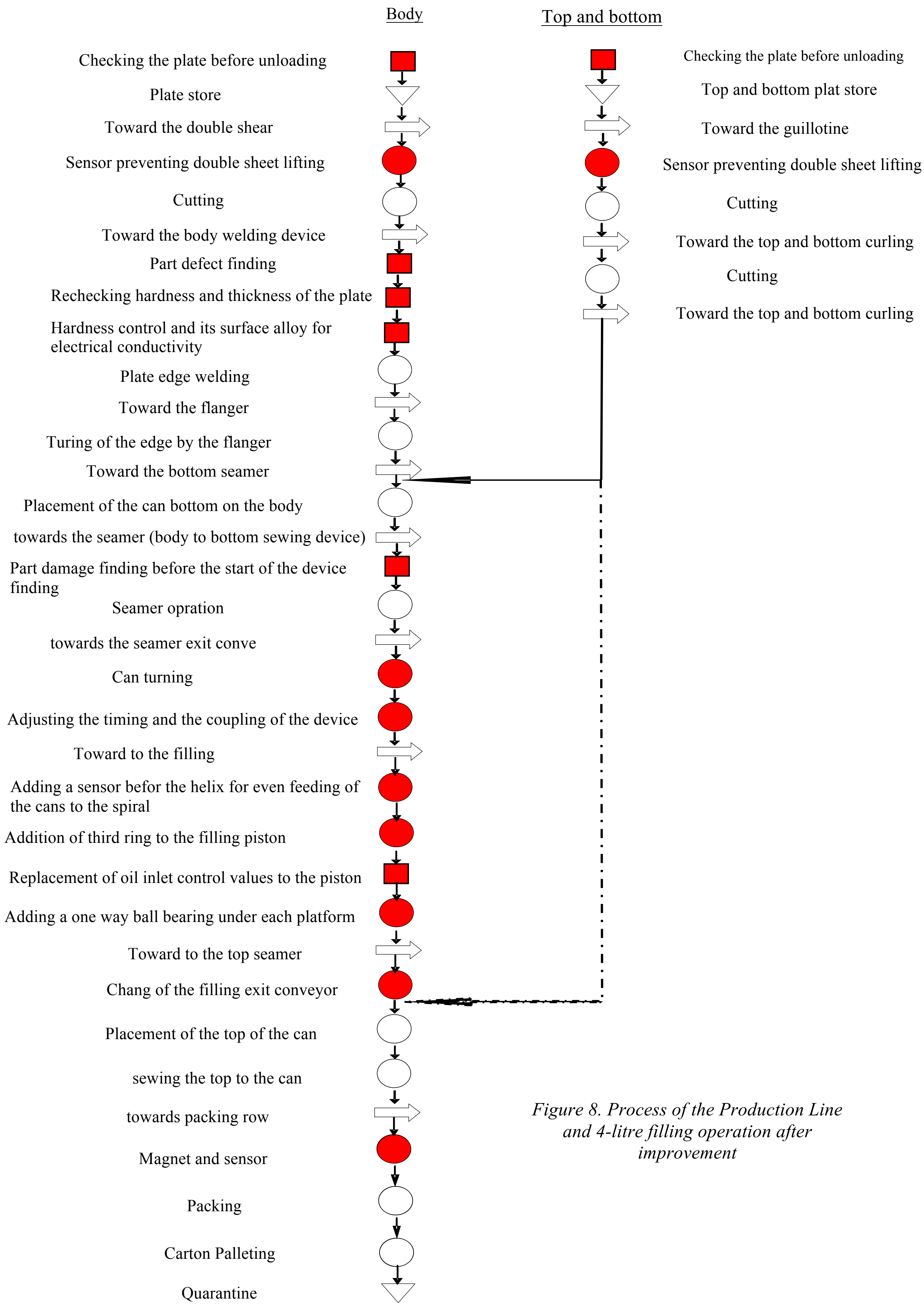

Figure 8. Process of the Production Line and 4-litre filling operation after improvement

Table 8. Comparison of the criteria before and after the implementation Six Sigma and SPC

Criteria	**Before**	**After**
Scrap can percentage	50000ppm	5000ppm
Percentage of the oil wasted	1%	0.05%
Sigma level at canning section	3.05	4.08
Sigma level at filling section	3.80	4.70
Process capability in canning (considering 1.5σ shift from the process mean)	0.6	0.9
Process capability in filling (considering 1.5σ shift from the process mean)	0.81	1.155

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