Improving Defect Tire Curing Process With Six Sigma Method at Tire Manufacturing Industry

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Abstract

In the tire manufacturing process, the tire company's amount of defect tends to increase above the target maximum. To improve the quality of tire manufacture, and analysis to decrease the number of defects is conducted using the six sigma concept. Over the last two decades, there has been a growing awareness of the need to improve quality. This paper aims to implement the DMAIC cycle as an element of continuous improvement in tire companies. In order that achieves it, the analysis with the application of DMAIC is done. The propositions of improvements, which can be implemented in the organization to increase the effectiveness of the production process, are also presented. The actions implemented contributed to a significant reduction in the defective tire, which was approximately 67 pcs per month. The study thus culminated in a decrease of 0,08% on the indicator of defects by the production system

Keywords: DMAIC, Quality, Improvement, Six Sigma.

1. Introduction

In the competitive context of the automotive industry, organizations commit to deliver products or services close to perfection, promoting the philosophy of zero defects and first-time-right production (A. Pugna, et.al, 2016). Over the last years, the Six Sigma program has become increasingly popular and widespread in many organisations across the world and in several types of industries (V. Arumugam, et.al, 2016). This methodology was generally adopted at the end of the 80s at the Motorola company, which used the term Six Sigma to describe the approach used to measure defects and improvements in quality (V. Arumugam, et.al, 2016; Y. Eslami, et.al, 2014). However, there were also companies such as AlliedSignal, 3M, and G.E., pioneers in the use of the Six Sigma program, which reported savings of millions of dollars from the 90s onwards as a result of this implementation (D.S.L. Marzagão and M.M. Carvalho, 2016). Initially, the Six Sigma methodology only targeted production processes; nevertheless, other types of sectors such as marketing, purchasing, warehousing, and customer support centers, between other services and functions, also currently have this methodology implemented with the aim of continuously improving their processes and ensuring customer satisfaction (J. Antony, et.al, 2012). This methodology is widely acknowledged as an application of tools and statistical or non-statistical techniques to maximize the returns on investment made by organizations (J. Antony, et.al, 2005). This is achieved through the optimization and control of the organization's processes, aiding management in the maximum enhancement of the value produced by using as few resources as possible (A.K. Singh, and D. Khanduja, 2014; T. Pyzdek, 2003). The improvement cycle - Define, Measure, Analyse, Improve, and Control (DMAIC) - constitutes one of the keys to the success of the Six Sigma program (J. Antony and R. Banuelas, 2002). Through this approach, the improvement obtained in products and processes converges, in the sense that they become more efficient and effective (T. Pyzdek, 2003).

The present study was developed in an industrial tire manufacturing company located in Karawang, Indonesia. The study's main objective was to improve the tire curing process, which is responsible for the production of green cure tire to become tire. One of the production system's performance indicators (KPI) is designated as a work-off generation (non-conforming product), which was found to be above the required target. This constituted the main reason for this study, which focus was to enable its reduction. The structure of this article is divided into five sections: the first one presents the introduction; section 2 consists of a review concerning the approaches to continuous improvement in Six Sigma processes; section 3 deals with the methodology used in the development of this study; section 4 describes the work developed at the Continental Mabor company through the implementation of the DMAIC cycle and, finally, section 5 presents the final conclusions.

2. Literature Review

Over the last years, companies have been confronted with big competition in global economics. Many of the companies which used the Six Sigma approach have achieved success in their activities (M. Ertürk, et.al, 2016). Six Sigma application an innovative approach to the continuous improvement of processes and is a methodology of Total Quality Management (T.N. Desai, and R.L. Shrivastava, 2008). The Six Sigma concept was introduced in the 80s by Motorola and application an essential feature of its own quality improvement program (H. Wang, 2008). The term Six Sigma refers to a statistical performance target of operating with only 3,4 defects for every million opportunities (P.S. Pande, et.al, 2000). As a result of the investment of 170 million dollars in Six Sigma training provided to its workers, Motorola reported savings of 2,2 billion dollars in expenses relating to poor quality (J. Antony, 2006). This management strategy has gained popularity since it was adopted and explored by various organizations worldwide; General Electric (G.E.), Boeing, Kodak, and Sony, among others, reporting great improvements in performance and savings of millions of dollars (A. Ansari, et.al, 2011).

In the context of organizations' business dealings, Six Sigma is a strategy that is used both to improve profitability as well as ensure efficiency in all operations, with the purpose of meeting customers' demands and expectations (Y.H. Kwak, and F. T. Anbari, 2006). It consists of a strict, focused, and extremely efficient application of practices and quality concepts and tends towards an approach of error-free performance in organizations (T. Pyzdek, 2003). Unlike other movements aimed at improving quality, which primarily focuses on the product or service provided to the final customer, Six Sigma methodology places emphasis on the quality of the organization's global system (K.Y.B. El-Haik, and K. Yang, 2003). Some of the benefits ensuing from the implementation of this system include cost reduction, improved productivity, growth in market share, customer loyalty, reduction in cycle times and defects, amongst others (P.S. Pande, et.al, 2000). The strategy of this approach, as a problem-solving or process improvement methodology, resorts to a series of well-defined steps, which constitute the DMAIC cycle and are one of the keys to success in the implementation of the Six Sigma program (J. Antony, 2002).

The operation of this cycle is similar to other problem-solving procedures used in production systems, such as Deming's Plan-Do-Check-Act cycle and Juran and Gryna's Seven-Step procedure (J. De Mast, and J. Lokkerbol, 2012). This cycle consists of five stages, beginning with the definition of the problem and of all aspects which are relevant to the project (Define). During the second stage, one carries out a measurement of the problem, namely, all defects which result in its occurrence (Measure) (R.D. Snee, 2004). The next stage consists of analyzing the collected data, with the purpose of determining the problem's root causes (Analyze) (H. De Koning, and J. De Mast, 2006). The objective of the process improvement stage is to eliminate the previously identified causes (Improve). In the last stage, one must control and monitor the process to ensure that the problem does not remain (Control) (H. Erbiyik, and M. Saru, 2015). The success in the implementation of the Six Sigma methodology, through the DMAIC approach, is not restricted to the automotive industry (J. Antony, et.al, 2012; P. Kaushik, and S. Kumar, 2017). Its use can be extended to many other sectors, such as the field of Healthcare (J. Van Den Heuvel, et.al, 2005; N.E. Eldridge, et.al), the PCB (Printed Circuit Board) industry (J.P.C. Tong, 2005), as well as others related to energy (P. Kaushik, and D. Khanduja, 2008) and food (H.C. Hung, 2011).

3. Methodology

In order to carry out this study, the methodology used began with a review of the literature. This was undertaken by means of published books and scientific articles dealing with the Six Sigma methodology, with the purpose of giving a basis for the study of the production system presented. The study was initiated through the application of the DMAIC cycle of Six Sigma methodology. In the first stage (the define phase), one established a problem definition by creating a Project Charter, which consisted of the high-level project planning using a milestones chart and plotting the process by means of a SIPOC diagram (Supplier, Inputs, Process, Outputs, Customer). The second stage (measure) was carried out by measuring process performance through a data collection plan. In the third stage (analysis), one used tools (Pareto, Ishikawa diagram) to determine the root causes of the problem. The fourth stage consisted of the implementation of improvement actions aimed at eliminating the causes which had been identified previously. Lastly, during the control phase, the process was monitored, and one proceeded with the quantification of the impact ensuing from the implemented actions.

4. Result and Discussion

The production system consists of six sections; however, the curing sections are the most relevant in this work (see Fig. 1). The curing process is cooking raw tires into ripe tires by providing grooves of tire and tire hardening processes. The curing section receives the green tire from the building section. The non-conforming green tire during this process is called a defect tire. The generation of defective tires is one of the indicators used by the factory to analyze the performance of the system and its evolution over time. This quantitative indicator measures the percentage ratio between the amount of defective tire and the amount of tire produced in the curing section.

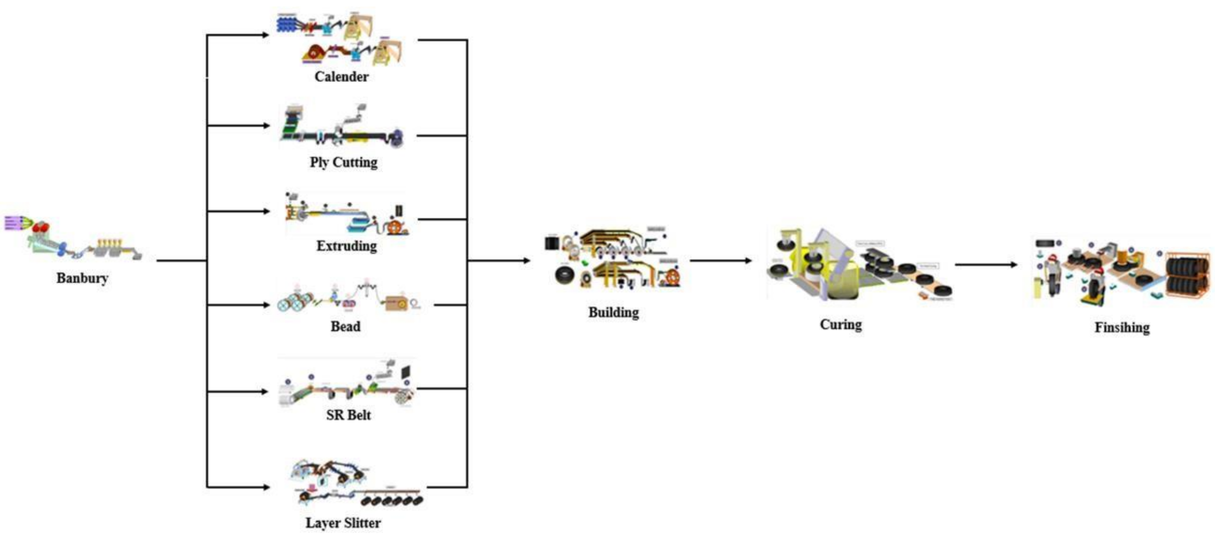

Fig. 1. Diagram of the production system (from the Mixing to Finishing)

4.1 The Define phase

This first stage of the DMAIC cycle is an important thing to the project's success, and a complete definition of its elements must therefore be undertaken. To this end, a Project Charter was drawn up, which identified the problem and established the objectives to be reached, as well as the scope and teams involved. In order to assist planning, one set up a Gantt graph (see Fig. 2), which established the deadlines for the conclusion of the various project phases. The project began in January 2019 and extended over a time period of 12 months.

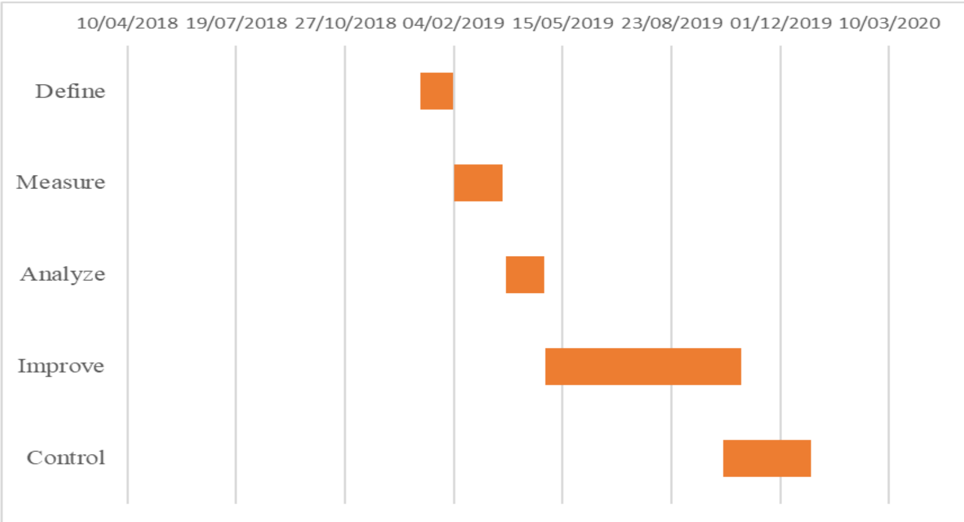

Fig. 2. Gantt chart for project planning

A SIPOC diagram was drawn up with the purpose of plotting the extrusion process and delineating its context. On this diagram, one defined the suppliers and relevant entries for the process, as well as the sequence of activities, ensuring outputs, and the customer's satisfaction. In this particular case, both the suppliers and customers were internal, as they constitute a part of the same production system. This tool allowed one to highlight information that was relevant to the project, thus focusing on critical activities in the process. The five main stages which occur during the curing process are described in Table 1.

Table 1. The five main stages which occur during the curing process

Stage	Operation	Description
1	Green tire preparation	The green tire produced in the building section is transported to a zone near the curing machine line and stored in the tire cart.
2	Booking green tire	At this stage, the green tire is booked at the green tire table and is transported through the operator. In the green tire table, the green tire is booked for taken by VCL (vertical chuck loader) into the curing machine. One of green tire table is consist of three green tires.
3	Green tire take out	The green tire is entered into the curing machine (molding)
4	Curing	In the curing process, the green tire is cooked in a machine with
5	Cooling	After the green tire become a tire, the tire must be cooled with naturally cooling

4.2 Measure phase

During this phase of the DMAIC cycle, one collected data with the purpose of measuring process performance. A data collection plan was drawn up, which included monitoring the process on all of the curing section. This data collection process included a record of the rejected green tire during the occurrence of setups or disturbances in the curing process. During this measurement process, which took approximately 52 weeks, seven trials were carried out every week, each consisting of a three-hour time period. After measurements were undertaken, one established the state of defects tire. The current values are presented in Table 2.

Table 2. Percentage of defect tire during the production

Production	Tires
Defect - Setups	5%
Defect - Disturbances	4%
Defect - Samples	1%
Defect - Returns	3%
Acceptable pieces	87%
Total	100%

4.3 Analysis phase

The objective of this phase was to determine the defect's root causes, as well as the sources of variation in the process. After analyzing the data collected, an Ishikawa diagram was drawn up to establish cause-effect relations (see Fig. 3). This describes the possible root causes of the defective tire. During the measurement phase, one proceeded with data collection to enable setting up a Pareto chart to prioritize the analysis of disturbances (see Fig. 4).

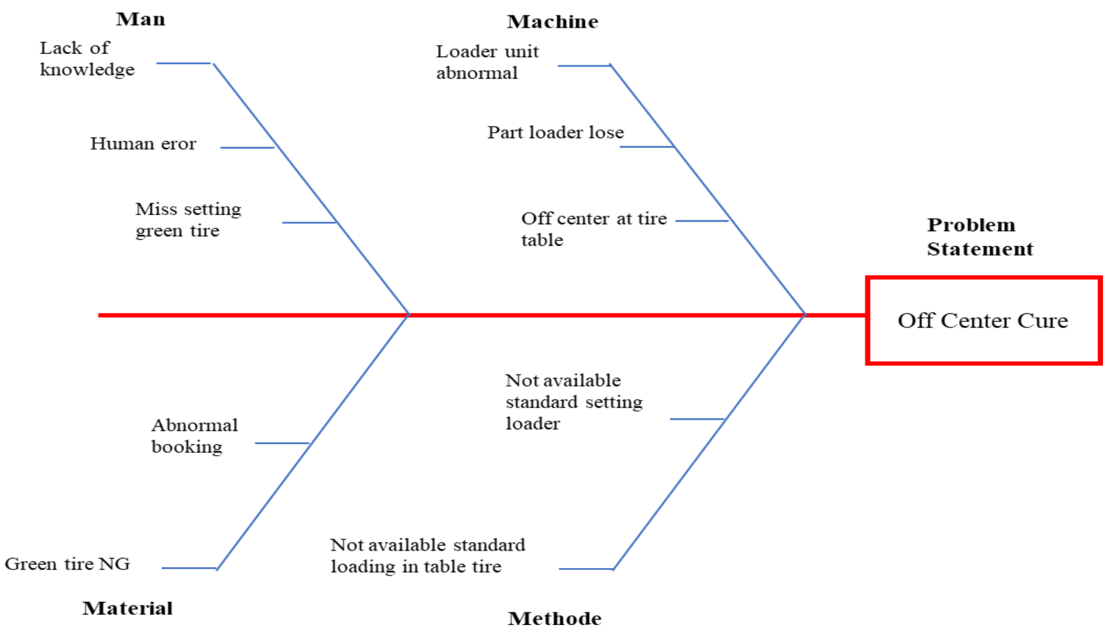

Fig.3. Ishikawa diagram

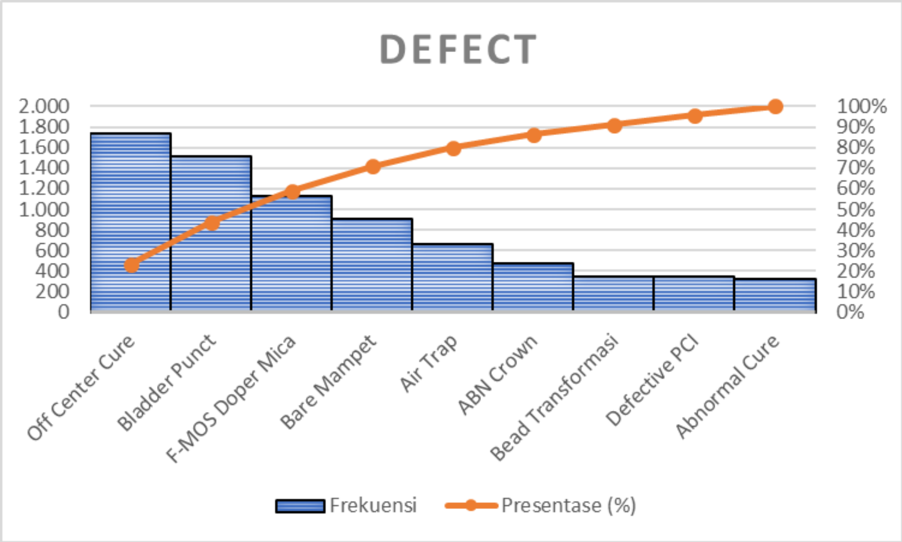

Fig.4. Pareto's charts for defects in the curing process

From the obtained data, one decided to focus on the major five defects (disturbances) in the curing process (see Table 3).

Table 3. Main disturbances and percentage of total defects in the curing process

Defects	Cumulative total defects
Off-center cure	23%
Bladder punch	21%
F-MOS doper mica	15%
Bare stuck	12%
Air trap	9%

4.4 Improve phase

In this phase, one identified and selected the improvement measures to be carried out (see Table 4). It concerned the occurrence of disturbances, and as was demonstrated in Table 3, one acted upon the main problem in the curing machine, which was established as being a failure in the curing machine.

Table 4. Improvement actions.

Machine	Event	Cause	Improvement actions
Curing Machine	Disturbances	Loader unit off-center	Tighten the bolt
	Disturbances	Top low ring abnormal	Setting as process
	Sets up	Green tire off-center at tire cart	Make a standard for setting green tire

4.5 Control phase

After the interventions were undertaken, one drew up a control plan to monitor the process and carried out new measurements in order to validate the impact of the improvements implemented. Once concluded, and considering that 22000 pcs are produced daily in the curing section was ascertained that the objective of decreasing the defects tire produced has been achieved, with a reduction of 0.08%. This was the outcome of all interventions undertaken and represented a decrease of 67 pcs per month (see Table 5). After repayment installments of equipment and labor costs had been calculated, the annual financial impact of these actions was translated into savings of about 522.000.000 million per annual for the company.

Table 5. Savings related to implemented improvements.

	Defect reduction (%)	Defect reduction (pcs/month)	Financial savings (Rupiah/year)
Curing machine	0,08	67	522.000.000.000
∑	0,08	67	522.000.000.000

5. Conclusion

The development of this study aimed to improve the curing process to reduce defects in tires. This objective was reached through the use of Six Sigma methodology, as well as its associated tools, which allowed for the identification and efficient intervention in problems such as a failure of the curing process. The actions implemented contributed to a significant reduction in the defective tire, which was approximately 67 pcs per month. The study thus culminated in a decrease of 0,08% on the indicator of defects by the production system. Some of the direct consequences of this reduction in costs associated with poor quality are translated into greater efficiency of resources, as well as an increase in productivity and the elimination of rework. In this sense, the use of Six Sigma methodology played a decisive role in the achievement of the proposed goal, ensuring that there was a systematic and disciplined approach to the issues at hand through the DMAIC cycle. This provided the necessary support to the organization so that it was able to produce more quickly, more economically, and with greater quality.

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