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STUDY ON THE DEFECTS AND TO IMPROVE THE PROCESS CAPABILITY OF TREAD RUBBER USING DMAIC METHODOLOGY

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Abstract - *The customer satisfaction is one of the keys that lead to the success of every business organization. It is the extent of the products that meets the customer demands. This differentiates the organization from the competitors in the market and gives the competitive advantage. This paper aims to evaluate processes in a tread rubber manufacturing company and to find out the process capability using DMAIC (Define, Measure, Analyze, Improve and Control) methodology. This paper also investigates about various kinds of defects in the tread rubber manufacturing. The DMAIC methodology improves the process and enhances the quality of the product. The problems in tread rubber manufacturing are variation in the tread rubber dimension and some defects which appear in the extrusion process. Using this DMAIC methodology the process capability can be improved and other defects can be rectified by various modifications.*

***Key Words*: Six Sigma, DMAIC, Defect Analysis, Process Capability, Tread rubber manufacturing.**

1. INTRODUCTION

Today the technology is evolving day by day. Many products are invented and evolved by using these technologies in order to fulfil the need of the people. The needs of the customers are always changed over the time. An organization will only succeed by satisfying the need of the customer. In the current pandemic scenario, every business is build over the trust and relationship between the customer and manufacturer. The evolution of the tyres makes the life of the man easy and faster. The increase in the number of vehicles increases the demand of the tyres rapidly. The quality, performance and durability of the tyres are very important in the satisfaction of the customers. The quality tyres must conform to its specifications and free from any kind of defects. There are many methodologies and tools used by the companies for the continuous improvement. Among them, DMAIC methodology is a well known improvement cycle used by the companies. The DMAIC methodology is an improvement cycle which can be used in every process. It is the acronym for Define, Measure, Analyze, Improve and Control.

1.1 Tread rubber

The tread rubber compound is the intermediate form of the actual tyre. It is the portion that provides the adequate grip and friction on the road. As it has more contact on the roads, there is a high chance for wear and tear. So the quality of the tread is very significant in determining the performance of each tyre. The tread rubber is manufactured by a series of processes such as mixing, calendaring, extrusion etc. The raw materials used for the tread rubber are natural rubber, synthetic rubber, carbon, chemicals etc. The raw materials are mixed in an inter mixer and then it undergo a series of calendaring. Finally it is extruded through a particular die.

1.2 DMAIC methodology

DMAIC is an important quality management tool that can be used as a method of quality improvement among many others. DMAIC is an abbreviation for Define-Measure-Analyze-Improve-Control. This method is based on the Deming cycle of process improvement. It is the process of improving many different areas of the enterprise. The DMAIC cycle is made up of five interconnected stages [3].

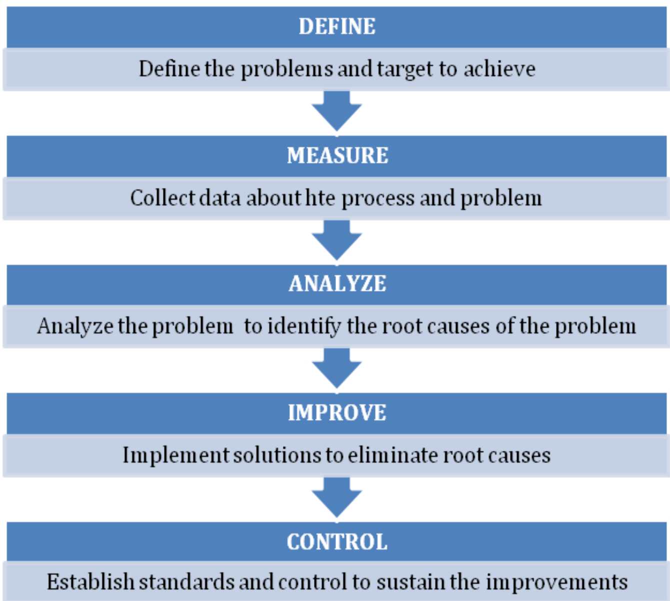

Fig -1: DMAIC methodology

1.2 Scope of the project

The improvement in every aspects of the production process increases the quality of products and thereby value of the company. The DMAIC methodology helps to understand the problems related to the process, its constraints etc. It will solve every issue regarding the process, wastage, and quality inorder to make the process more efficient and reliable. This methodology has a systematic way to rectify any kind of problems. There are many tools that are used under DMAIC for improving the process. In this project DMAIC methodology will improve the current process by rectifying each defect.

2. RESEARCH METHODOLOGY

2.1 Define

This initial stage of the DMAIC methodology is critical to the project's success, and a thorough characterization of its components is required. To that purpose, a project plan was created, which defined the challenge and the goals to be achieved, as well as the scope and teams participating.

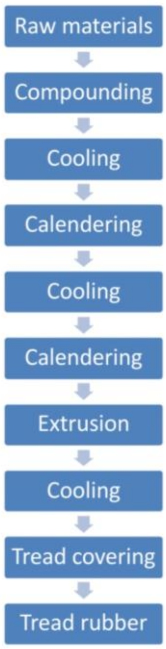

Fig-2: Tread rubber manufacturing processes

In the first phase, the processes of tread rubber manufacturing are evaluated and studied. The tread rubber is manufactured by a series of processes such as mixing, calendaring, extrusion etc. The raw materials used for the tread rubber are natural rubber, synthetic rubber, carbon, chemicals etc. The problems are identified and the project goals and objectives are defined to improve the current process. The problems identified in the tread rubber manufacturing are fluctuation in the extrudate geometry, defects such as bubbles, cracks, soft region in the centre of the extrudate and sharp edges on the tread rubber.

2.2 Measure

In this phase, information gathered in order to assess process capabilities. Analyzing the process on the extrusion lines was part of a data collection inorder to identify the defects. The dimensions of 30 samples of T-DURA tread rubber were measured and process capability index and process capability ratio are determined in order to check whether the process is capable or not. For width, process capability index (Cpk) is 0.64 and process capability ratio (Cp) is 0.65. For thickness, Cpk and Cp are 0.59 and 0.62 respectively. From this phase, it is clear that process is not capable.

2.3 Analyze

The goal of this phase was to identify the fundamental causes of defects and reasons of variation in the process. During the analyze phase, the process was studied to identify potential approaches to bridge the gaps between the current quality performance of the process and the target established. The x-bar and R-chart are quality control charts that are used to evaluate the mean and variation of a process based on samples collected over a specific time period. In both charts, control limits are used to track the mean and variation of the process as it progresses. From the control chart of width and thickness, the deviation from target value are identified. For example, analysis of thickness is shown below.

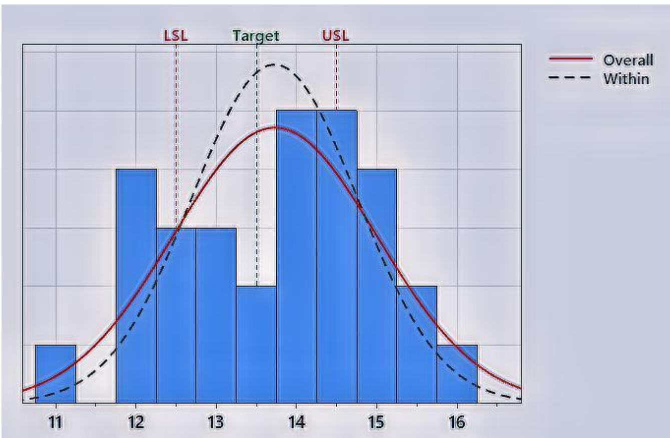

Chart 1: Deviation of thickness

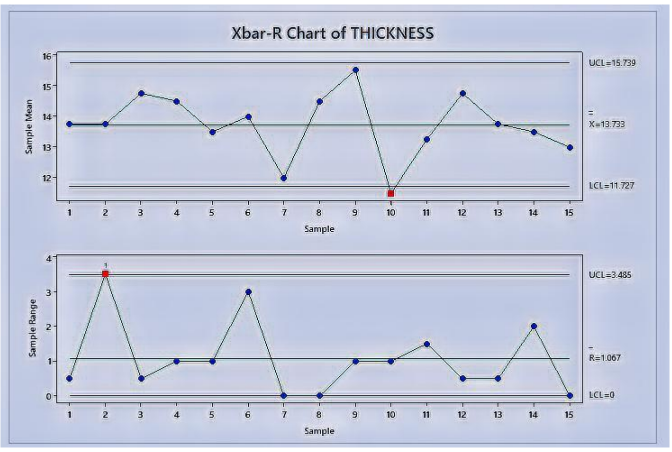

Chart 2: x-bar and R-chart of thickness

From the x-bar and R-chart, it is clear that the variations of thickness are under control. But the process is not capable to conform the product to the required specification limit. A process is considered to be competent if almost 100 percent of its output meets the standards. Here process is in command while still failing to meet specification requirements. This result is same as for width.

Following data analysis, an Ishikawa diagram was created to establish cause-and-effect relationships.

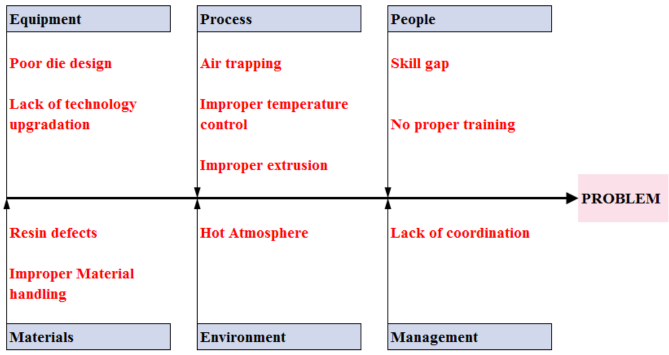

Fig-3: Ishikawa diagram

The defects seen in the tread rubber manufacturing are shown below

Table-1: Defects in tread rubber

S.No	Defect	Cause
1	Bubbles	Moisture content
2	Trapped air	Improper extrusion
3	Fish eyes	Resin defect and improper mixing
4	Fracture	Improper extrusion
5	Rough surface	Over heating
6	Sharp edges on extrudate	Poor die design
7	Fluctuation in extrudate geometry	Improper extrusion

The common failure or flaws in the rubber is same as of every extrusion process. The three main causes are mould design, material selection, and processing. Failures occur during processing in many circumstances, and these failures produce defects in extruded components such as rough surface, extruder surging, thickness variation, uneven wall thickness, diameter variation, and centering difficulty. Processing flaws in extrusion goods include a lack of understanding of the processing procedure, the use of insufficient or obsolete machines, a lack of skilled personnel, machine breakdown, and inappropriate working surroundings.

2.4 Improve

During the improvement phase, various approaches to accomplish things better and faster at a lower cost were examined. The remedies for the defects are identified. The percentage of loss would be reduced if the above solutions were used.

Table-2: Remedies for the defects

S.No	Defect	Remedies
1	Bubbles	The material must be pre-dry Vent must be used in the extruder
2	Trapped air	Avoid the over-speed of extrusion
3	Fracture	Maintain the speed of extruder.
4	Rough surface	Cool the barrel of extruder
5	Sharp edges on extrudate	Check for uniformity in die heating
6	Fluctuation in extrudate geometry	Use Digital Pressure gauge Use Digital temperature sensor for uniformity

The implementation is not so easy. Personnel are resistant to change. They are content with the way things are. It requires more support from the management. The implementation may require capital investment. The measurement process is repeated after implementation. The new process capability index and process capability ratio are determined. For width, process capability index (Cpk) is 0.69 and process capability ratio (Cp) is 0.7. For thickness, Cpk and Cp are 0.75 and 0.65 respectively. Analysis after implementation is shown below.

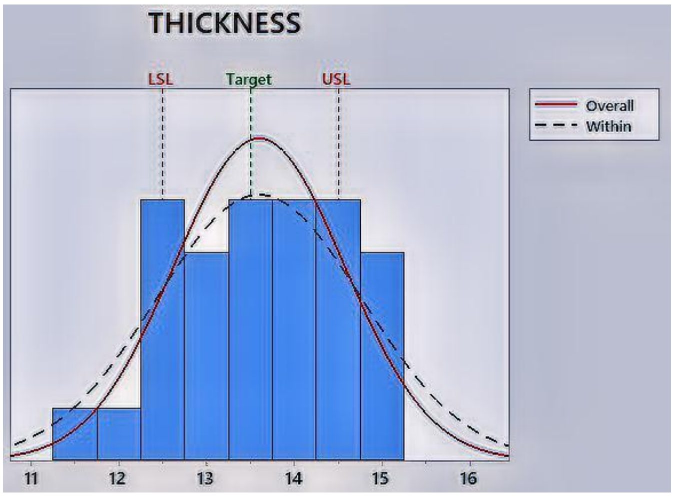

Chart 3: Deviation of thickness

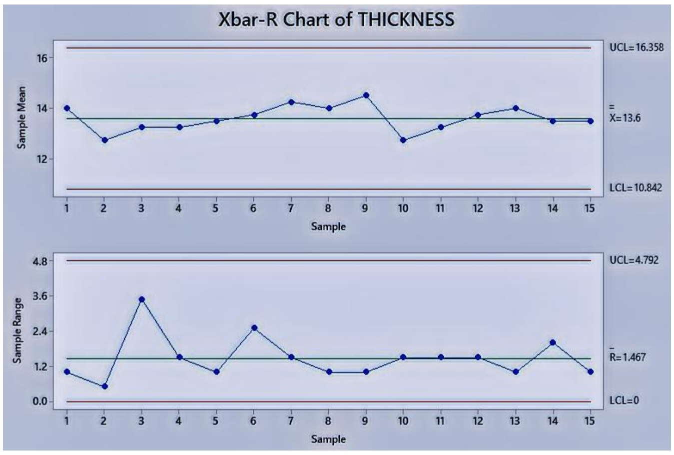

Chart 4: x-bar and R-chart of thickness

From the control chart of thickness, we can see the deviations from target value are reduced. Here the dimensions are more conform to the target value. The process capability is increased. This result is same as for width.

2.5 Control

The control stage verifies the quality of the modified process to determine whether the changes introduced during the enhance stage are sufficient and ongoing. It also manages the process's future state in order to limit departure from the objectives and assure that the correction is made before it has a negative impact on the process's outcome. The progress made in previous steps must be maintained for a long time in order for the organization to continue to succeed. We use the control phase to keep these process improvements going.

3. RESULT

After the implementation we can see the Process capability index Cpk and Process capability ratio Cp are increased. The variations of both width and thickness are under control. The process is much capable to conform the product to the required specification limit. The process is considered to be competent if almost 100 percent of its output meets the standards. Here process is not 100 percent perfect but it meets specification requirements precisely.

Table-3: Before implementation

PROCESS CAPABILITY INDICES	BEFORE	AFTER
Process capability index Cpk	0.64	0.69
Process capability ratio Cp	0.65	0.7

Table-4: After implementation

PROCESS CAPABILITY INDICES	BEFORE	AFTER
Process capability index Cpk	0.64	0.69
Process capability ratio Cp	0.65	0.7

4. CONCLUSION

In the first phase, problem is identified and the project goals and objectives are defined to improve the current process. In the second phase, process capability index and process capability ratio are determined in order to check whether the process is capable or not. From the findings it is clear that the process needs improvement. In the third phase the remedies for the defects identified. Some modifications are done and new process capability is determined in the fourth phase. Actually technology up gradation is required. In the fifth phase control is to be achieved for continuous improvement.

4.1 Suggestions

1. Modernization

The technology up gradation is needed. An extruder having automatic temperature and pressure control is required.

2. Proper training

Proper training is needed in each operations for the employers is necessary

3. Predictive maintenance

The maintenance is to be done in a planned manner.

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