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Application of DMAIC method in an industrial case study

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ABSTRACT

Purpose. In the present work DMAIC methodology is implemented in a Portuguese enterprise. The main goal is to reduce the percentage of non-conformities in an injection molded part for the automotive industry, through the elimination of defects that appear after painting.

Design/methodology/approach. The DMAIC method was adopted to find an optimal set of factors that reduce the existing non-conformities. Along the five DMAIC phases, different quality tools were implemented to identify the root causes of the problem and to develop an action plan to reduce defects and minimize the process variability.

Findings. In the application of this method, teamwork and brainstorming were essential for satisfactory results in a short period of time. A key finding is that the analysis of the possible causes that gave rise to the problem must be carried out separately, in order to easily identify the changes that created a significant improvement in the process.

Research limitations/implications. The project is not fully completed since some of the improvement actions are being implemented.

Originality/value. This paper describes a practical application of DMAIC methodology that contributed to reduce part defects and improve the production process of a Portuguese company.

Keywords: DMAIC, quality improvement, non-conforming.

Paper type: Case study

INTRODUCTION

The automotive industry is part of a very demanding market, where the search for innovative products and technologies is constant. There is a great competition in this market, creating an increased concern within companies to implement methods that improve processes, eliminate faults, defects and errors, reduce cycle times and costs of operations. Implementing DMAIC methodology leads to increased customer satisfaction as well as the profitability of the company by improving the quality of products and processes (Cavanagh *et al.*, 2005).

The opportunity to develop the present work came from the challenge to implement DMAIC methodology at Fehst Componentes, Lda, Portugal. This methodology was selected with the aim of increasing the value of the organization through scientific methods, in order to reduce the percentage of non-conforming parts and minimize the process variability. This company is a supplier for the automotive industry, specialized in plastic interior decorative components.

To achieve the intended objective, it was necessary to define the problem, collect historical data, analyze the actual process, implement statistical methods and quality tools, create an action plan, and lastly, develop a strategy to maintain good quality.

The paper is organized around four main sections: an introduction; a brief overview of DMAIC methodology; a case study with discussion of its results and its practical implications; and finally, the conclusions.

DMAIC

For the development of a business through continuous improvement of the processes, products and services, the Six Sigma is strategically applied as a systematic and organized method to achieve quality (Allen, 2006; Mast and Lokkerbol, 2012; Costa *et al.*, 2019). Six Sigma combines statistical and scientific methods to measure and improve the operational performance of an organization by drastic reductions in customer-defined defect rates, adding value to the product and process (Allen, 2006; Costa *et al.*, 2019). Within Six Sigma framework DMAIC appears as a method to find and reduce the variations and to eliminate defects (Patel, 2016). The DMAIC is the most popular approach to support the Six Sigma strategy, in improving products and processes already existent in the organization (Mehrjerdi, 2011; Costa *et al.*, 2019). In order to solve a problem identified by the organization, the DMAIC methodology uses a set of tools and techniques in a logical fashion to arrive at sustainable solutions that will minimize or eliminate the problem, placing the organization in a competitive position (Shankar, 2009). The DMAIC methodology consists of the Define, Measure,

Analyze, Improve, and Control phases and each phase covers a set of chronologically interlinked rational and statistical tools (Shankar, 2009; Hutwelker, 2019). The following stages should be considered during the implementation of DMAIC: Define (D), which the main purpose is to identify the problem that needs a solution, to define initial goals and targets (Patel and Shah, 2015; Smętkowska and Mrugalska, 2018), and to create the team responsible for the implementation of the DMAIC method (Zasadzien, 2017; Hutwelker, 2019). Measure (M) where the goal is to gather information about the current performance of the process (Antony, 2006; Mehrjerdi, 2011), namely the strengths and weaknesses, to determine the gaps for improvement (Antony, 2006). During Analyze (A) phase, different tools and methods are used to find the root causes of the problem (Smętkowska and Mrugalska, 2018; Hutwelker, 2019) and to determine the key process variables linked to defects that are affecting the output of the process. (Antony, 2006; Patel and Shah, 2015). In the Improve (I) phase an action plan is created to fix the problems identified and to prevent them from recurring (Antony, 2006; Mehrjerdi, 2011; Smętkowska and Mrugalska, 2018). Control (C) is the last phase of the DMAIC methodology, the results of changes implemented at the improve stage are evaluated and monitored (Mehrjerdi, 2011; Smętkowska and Mrugalska, 2018).

CASE STUDY

The case study was born at Fehst Componentes, Lda. with the challenge to reduce the percentage of non-conforming parts in injection moulded components that are painted. The company used the DMAIC method on the most critical product, defined as High Gloss Blend. The steps to manufacture this product are described in Figure 1.

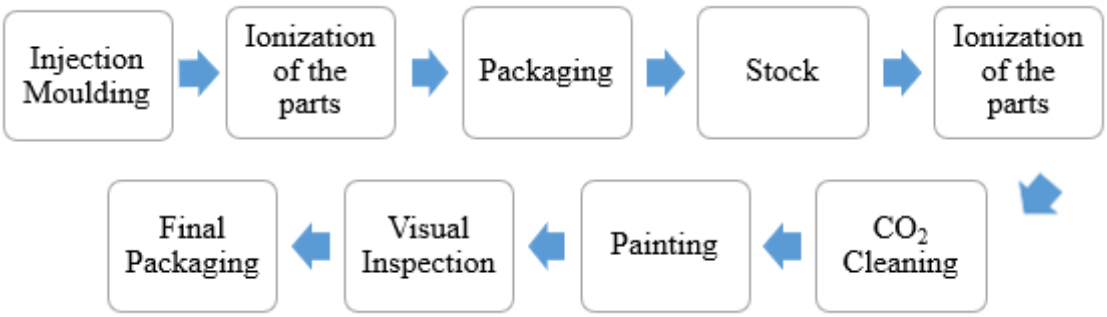

Figure 1 – Manufacture steps of the High Gloss Blend parts.

Define

The first stage started by defining the problem and by identifying the objectives to be achieved. An in-deep analysis was performed from April to September 2019 to find the component that presented

the highest percentage of non-conforming parts. Therefore, the problem is the high level of non-conforming parts on the High Gloss Blend after paining.

Due to the fact that High Gloss Blend parts have a high gloss finish, a complex geometry and a high-quality requirement from the customer, the company considers a percentage of up to 22% of non-conforming parts acceptable. However, as observed in Figure 2, in the last semester the percentage of non-conforming parts reached values higher than the objective defined by the company. The most critical result occurred in September, reaching a value of 47.6% of non-conforming parts.

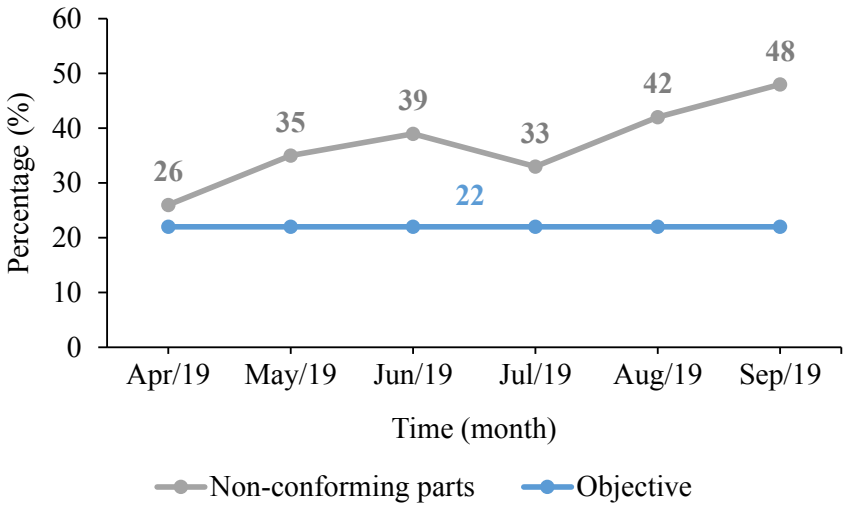

Figure 2 – Percentage of non-conforming parts between April and September 2019, in the High Gloss Blend component. Source: Internal data of Fehst Componentes, Lda, 2019.

Measure

To know the main defects and its quantity a visual inspection is made through a system with sensors, where all non-conforming parts are counted. However, the company's system only distinguishes two types of defects, inclusions and pits, that are depicted in Figure 3. Other types of defects are counted by the sensor like "others". A Pareto chart was used to analyse the results (Figure 4). It is observed that the defect that requires priority in resolution are the inclusions.

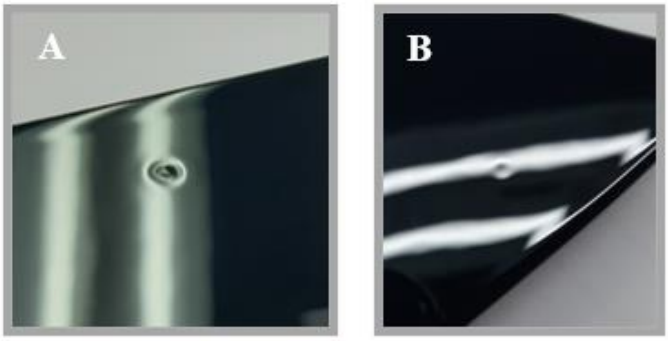

Figure 3 – Main part defects detected by the sensor: (A) Inclusion (B) Pit.

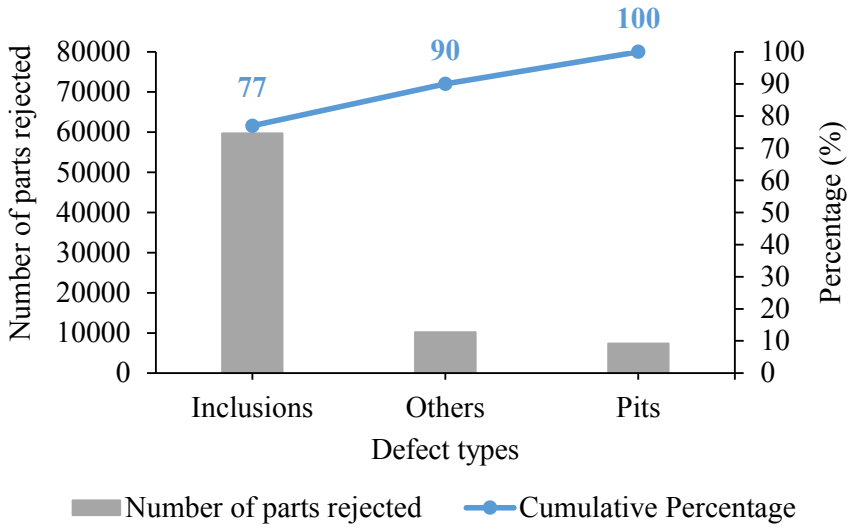

Figure 4 – Pareto chart for the number of parts rejected during the month of April through September 2019. Source: Internal data of Fehst Componentes, Lda, 2019.

Analyse

The inclusion defect is characterized by the appearance of a protrusion on the surface of the part after painting, as seen in Figure 3. The cause for it may be the static electricity of plastic parts that is prone to accumulate impurities during the operations between the injection phase and the painting phase, leading to the inclusion defect (Crawford, 1998).

To discover the possible causes of this defect, brainstorming sessions were made, which brought together process engineers and quality engineers. Ishikawa diagram was built and 5 Whys method was applied. They are presented in Figure 5 and Table 1, respectively. In view of all the information collected, the main causes that require a thorough analysis were selected, namely: handling of parts after injection production; packaging; and cleaning of parts with carbon dioxide (CO_2).

Improve

To eliminate the root cause of the problem it is important to analyse them and to implement solutions. Regarding "Handling of parts after injection production" it is important to refer that when parts are painted, more care should be taken. Fingerprints or other types of contaminations influence greatly the adhesion of the paint. For this reason, it is convenient to use gloves. However, the material which the gloves are made, the recurrence of changing gloves or even the choice of light or dark gloves can influence the possible contamination of the surface of the parts.

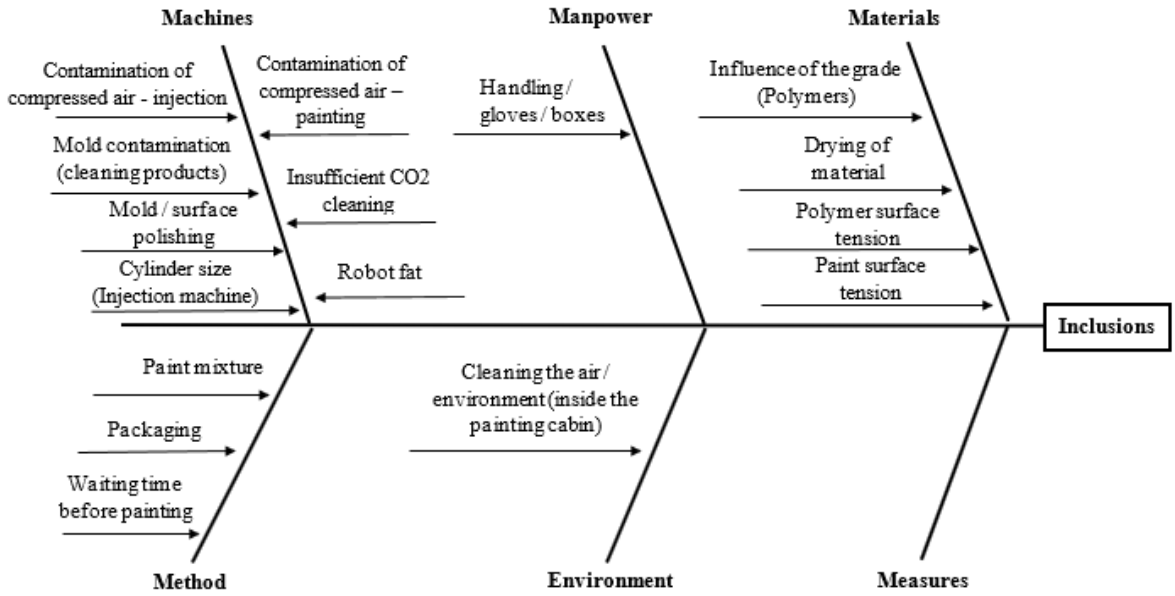

Figure 5 – Ishikawa diagram for the inclusion defect (Elaborated by the authors).

Table 1 – 5 Why´s for the inclusion efect (Elaborated by the authors).

Problem definition	Why?	Why?	Why?	Why?	Why?
Appearance of the inclusion defects	Contamination on the surface of the parts	Polymers has hight static electricity	Ionization system is not enough	The pieces gain static electricity again	Handling and packaging

In order to verify the possible influence of the hand's transpiration in the accumulation of fat in the parts, a test was made to 640 parts manipulated only with nitrile gloves. All the steps were completed just like normal production. Table 2 shows the number and type of defects after painting the parts.

Table 2 – Influence of the gloves used in handling the parts.

	Number of parts with inclusions	**Number of parts with pits**	**Number of parts with "others"**	**% non-conforming parts**
Use of nitrile gloves	72	21	364	71.4%

The percentage of non-compliant parts was 71.4%, well above the maximum percentage for this component. The main defect was defined by the sensor as "others". A close look at these parts identified that the defect appeared on the surface that the employee contacted when collecting the parts from the carpet in the injection moulding stage to proceed to the packaging.

Since the lot painted just before had a percentage of non-conforming parts below 25%, and did not contain any parts with this defect, it was concluded that the nitrile gloves mark the parts and hinder the adhesion of the paint to the surface of the parts. As a process improvement, gloves were changed, opting for white cloth gloves. Due to the colour of the gloves, the dirt is more visible, which makes changing gloves more frequently.

After the injection process, the parts go through an ionization system that aims to remove static electricity from the parts and reduce impurities, reducing the possibility of creating the inclusion defect. Subsequently, the parts are packed and remain in stock until they are painted.

In order to verify the influence of ionized air and packaging on the percentage of non-conforming parts, 3 tests were carried out. In the first test, 640 parts that did not pass through the ionized air system were packed in plastic bags. In the second test, other 640 parts that passed through the ionized air system were packed in plastic bags. In the last test, 640 parts that passed through the ionized air system were packed with anti-static plastic bags. Table 3 shows the results obtained in each test.

Table 3 – Influence of the ionization system and packaging on parts.

	Number of parts with inclusions	**Number of parts with pits**	**Number of parts with "others"**	**% non-conforming parts**
Parts without ionized air and anti-static bag	129	25	21	27.34%
Parts with ionized air and without anti-static bag	86	30	25	22.03%
Parts with ionized air and anti-static bag	74	2	7	12.97%

Over the course of the tests, the percentage of non-compliant parts decreased. The parts that passed through the ionized air system and packed with anti-static bags presented 12.97% of non-conforming parts, which is much less than the maximum percentage defined by the company.

Given these results, it was decided to realize a broader study, including the results obtained in December 2019. Therefore, throughout this month the packing of the parts between the injection and painting phase used only anti-static bags.

The last point to analyse and improve is related to the cleaning of parts with CO_2. Before painting the parts, it is necessary to ensure that the surface does not have any impurity created during its production. In the paint cabin, the parts are cleaned with CO_2 which leads to the contraction of the fat and dust and its further elimination. The CO_2 used in the painting phase is supplied through bottles with a capacity of 6 working hours. However, a variation on the number of defective parts during the use of the bottle was identified, therefore it is an important topic to be analysed.

A study was carried out in which the percentage of non-conforming parts was counted in a sample of 400 parts before changing the CO_2 bottle and 400 parts after changing the bottle. The study was realized on a day when the percentage of non-compliant parts did not exceed 22% and the only defects that appeared in the parts were pits, inclusions and lack of paint. Table 4 shows the results obtained in the study.

Table 4 – Impact of changing the CO_2 bottle on parts.

	Number of parts with inclusions	**Number of parts with pits**	**Number of parts with "others"**	**% non-conforming parts**
Before changing the CO_2 bottle	59	18	11	22%
After changing the CO_2 bottle	48	7	10	16.25%

After changing the CO_2 bottle the percentage of non-compliant parts was 16.25%. With this study it is concluded that the efficiency of the bottle is not constant throughout its use, specially at its end when low CO_2 level in the bottle is attained.

In order to solve this problem, the solution was to instal a cryogenic tank with high storage capacity, and above all, a constant gas flow during the entire use time. This way, it would not be necessary to change the CO_2 bottle daily and the parts could be cleaned throughout the entire production.

Control

In the previous phase, some causes for the appearance of inclusions in the parts were defined and solutions were found. However, to implement changes such as the construction of a CO_2 reservoir, becomes impossible in a short period of time. Therefore, only some improvements such as changing the gloves used in handling the parts and changing the packaging type to carry the parts could be adopted.

The evolution of non-conforming parts along 2019 is depicted in Figure 6. At the start of the project in September and thought most of the year, the percentage of non-conforming parts was very high. Upon identification of the cause, solutions were tested. By October upon implementing the changes in the procedures of handling and treating the sample before painting a significant reduction in the percentage of non-compliant parts was observed. In December, it was possible to reach the maximum percentage of non-conforming parts acceptable by the company for this component.

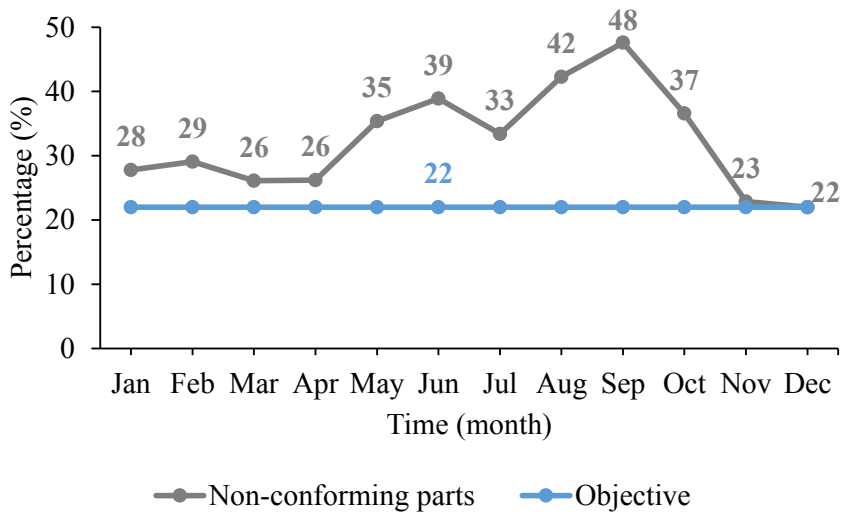

Figure 6 – Percentage of non-conforming parts in the High Gloss Blend component in 2019.
Source: Internal data of Fehst Componentes, Lda, 2019.

CONCLUSIONS

The application of DMAIC methodology, teamwork and brainstorming were essential for achieving satisfactory results in a short period of time. The separate analysis of the possible causes that gave rise to the problem was carried to easily identify the changes needed. Through this methodology, it was possible to significantly reduce the percentage of non-conforming parts in the component under study. Although the implementation of the methodology was focused on the defect that occurred most frequently in the production process of the High Gloss Blend component, all the improvements

implemented also reduced the appearance of other defects. The present case study proved that through the application of quality tools it was possible to significantly improve the company's production process.

In the future, it is suggested to implement the Six Sigma methodology in the company, in order to eliminate unproductive stage, develop and use the technology to drive improvements, both in new and existing projects.

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