Continuous Improvement Using Statistical Process Control in the Mexican Automotive Motor Remanufacturing Industry: a case study

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Abstract. Although there have been many breakthroughs in the quality management field, Statistical Process Control (SPC) is still a widely used tool among manufacturing companies worldwide, following the same principles dictated by Shewhart in 1924. This research encompasses the successful case of the capability enhancement of a critical machining operation in an automotive plant located in Mexico dedicated to the remanufacturing of truck engines, resulting from examining the $\overline{x}$ and R control charts and directed by the Plan-Do-Check-Act cycle (PDCA). The results obtained derived from a comparative analysis of data of two different time periods in the process of machining bushing diameters, where a process capacity increase of 13.08-5 in the Process Capability Index (Cpk) and of 17.2% in the Process Performance Index (Ppk) were obtained. The decrease in expected out of specification parts improved by 72.7%. Process variability also was improved given the 8.33% reduction in the mean range. The research contribution is the empirical identification of gaps and opportunities in the areas of quality assurance and quality control using qualitative and quantitative methodologies.

Keywords: Statistical Control Process, PDCA Cycle, Mexican Automotive Industry.

1 Automotive Plant Caste Study

The automotive industry is the 3rd most important industry in Mexico, and the 5th worldwide in terms of volume and number of transactions, with an important positive impact to the employment rates in Mexico [1]. It generates 3.7% of the Mexican Gross Domestic Product (GDP) and creates around 800,000 direct jobs annually [2]. The role of the automotive industry in the economic structure and its impact on investment flows have been assessed by Manuel Garcia-Remigio et al. [3]. Among the strengths of the auto-parts mexican industry in manufacturing and workshop are the outstanding performance in technological transference, its qualified labour [4]-[5], and its flexibility [6]. Mexican automotive industry has shown to be resilient facing the crisis caused by

Covid 19 [7]. Nevertheless, maintaining a consistent and certifiable quality system has been a challenge.

The following case study refers to an automotive plant located in the State of Mexico near Mexico City, which will be named "APMex" for trade secret reasons. APMEx belongs to the manufacturing sites network of a large automotive corporation with headquarters in Germany and it is the sole manufacturer of their specific products for North America. APMEx is divided into two business units from which the one referring to this case study is the remanufacturing unit; it is ISO 9001 certified and its quality control management function is based on PDCA. In this facility, SPC is based on metrology and it is established by the Process Performance Index (Ppk) with a sample of 25 measurements of every remanufactured part monitored by monthly $\bar{x}$ and R control charts. The whole system is defined by the technical compliance management system. 100% inspection is done for the machining processes. Metrology is one of the key aspects of the facility, therefore training is conducted not only during induction but also every six months.

APMex had previously shown interest in a University-Industry collaboration with Universidad Iberomericana Mexico City in the area of quality control. The Chemical, Industrial and Food Engineering Department responded with an academic group formed by faculty members and students (undergraduate and graduate). During 2019 and 2020, the academic group conducted an analysis of $\bar{x}$ and R control charts for the machining of the engine block's bushing diameter. This analysis is described in the Methodology section.

1.1 Methodology

In the automotive industry, SPC is an extensively used methodology for continuous improvement of the manufacturing processes to upgrade the companies competitivity [8] as well as it those in a wide variety of industries [9]-[10]; as it helps to visualize the production process behavior and capability, as well as identify the problems and areas of opportunity within the production process [11]. The methodology used in this study included four stages: The first stage was the comprehensive evaluation of the machining process of core-remanufacturing in APMex, the most relevant process was selected using ten $\bar{x}$ and R control charts of critical quality variables that included different remanufacturing parameters of the crankshaft, the crankpin and the engine block. The second stage was the evaluation of the process control charts ($\bar{x}$ and R) following the principles of the SPC methodology. The third stage was the selection of the proposal for improvement and its implementation. In this case, the use of a gage was selected as the best course of action. The gage was intended to be used at the beginning of the process in order to guarantee the quality of the product. After this implementation, the new control charts $\bar{x}$ and R were compared with those obtained in the first stage in order to determine the percentage of improvement after the proposal was implemented in the process. The fourth stage was the analysis of the decision-making process to improve the process quality control. For this stage, semi-structured interviews of the operative management team were conducted based on the PDCA Deming Cycle aiming to explore particular issues concerning the quality management function and decision-making process. The interviews were carried out in 45-60-minute sessions with APMex General, Division and Quality Managers. After the interviews, an analysis of the managerial decisions taken was made aiming to identify opportunities for improvement.

2 Results

The following figure shows the $\overline{x}$ and R control charts show historical data (before the proposal implementation – see Fig. 1).

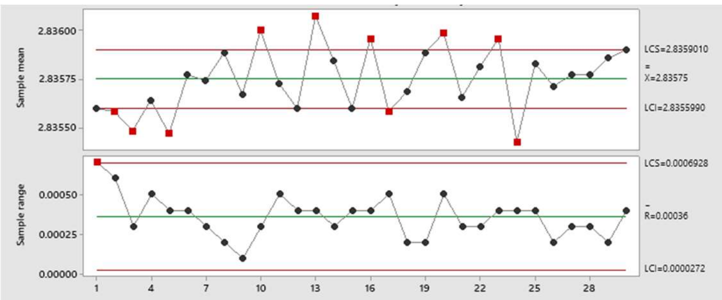

Fig. 1. $\overline{x}$ and R control chart for bushing process (before proposal implementation).

After the proposal implementation, the results from a comparative analysis of data of the two different time periods in the process of machining bushing diameters show a process capacity increase of 13.08-5 in the Process Capability Index (Cpk) of 17.2% in the Process Performance Index (Ppk) (see Fig. 2). The decrease in expected out of specification parts improved by 72.7 Process variability also was improved given the 8.33% reduction in the mean range. From the information gathered through the interviews and their analysis, it was found that the SPC system used by the company was useful for the data gathering stage and the identification of the possible causes of failures, on the other hand, when production problems are detected, the decision making seems to be bureaucratic and actions aren't taken timely. Additionally, it is noticeable that a simple solution as the one presented in the proposal (the use of a gage) had not been considered before by the company to improve their production quality. This could be associated to "workshop blindness", narrowing the vision of production operators and managers compared to the fresh vision of students.

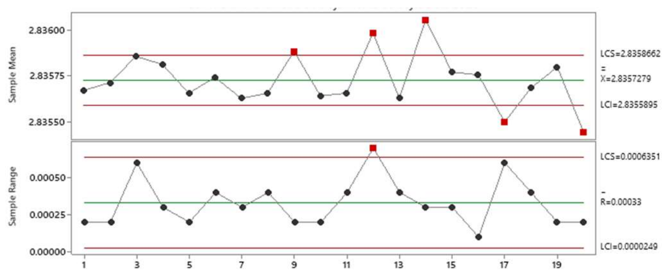

Fig. 2. $\overline{\text{x}}$ and R control chart for bushing process (after the proposal implementation).

3 Conclusions

As it has been stated, there is an opportunity to improve the decision-making process in APMex. Even though the company is well organized, with specific areas and a clear distinction of functions, there are unresolved issues due to the established information flow from CEP, affecting the expected product quality. In this case, communication among operators and the managers is diverted from the objective of immediate identification of effective corrective and preventive actions. Possible solutions are improving data management, training, and information transfer to provide prompt responses and not overlook the quality control objectives of the processes. On the other hand, the importance of entailment between industry and specialized academia is confirmed as a productive relationship to detect and solve operative quality problems.

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