Statistical Process Control Automation in the Final Inspection Process: An Industrial Case Study

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Abstract - **This case study arises from the need to make more robust and effective quality assurance procedures of the products by automating the final inspection process. The case study explains how the automation of the inspection process was performed in a company from the automotive sector. Knowledge, involvement and commitment of operators and respective managers should not be neglected because their reaction against the change procedures influence the success of any automation performed. The successful introduction of automation contributed to a more efficient process and from the pilot station to the remaining stations problem solving and continuous improvement was evidenced.**

Keywords - **Automation, final inspection, quality assurance, statistical process control, variability.**

I. INTRODUCTION

The literature suggests that the statistical process control (SPC) is a powerful technique for monitoring, managing, analyzing and improving the process performance through the use of statistical methods [1]. SPC allows to evaluates the variability present in a given production process and triggers control/improvement actions. This leads to an increased knowledge about the process and enhances its subsequent performance.

There are several approaches that propose the implementation of SPC. Reference [2] argues that there are two approaches to implement SPC: the organizational approach, i.e. where are established responsibilities (team training responsible for the project) and discussed issues related to the management top; and the methodological approach, which relates to the processes themselves, i.e., acts more locally, involving all agents necessary for the proper result of the implementation of SPC, giving emphasis to the awareness of the whole organization to the purpose of implementation, importance, benefits and knowledge of the basics of SPC. The SPC implementation process must be followed and discussed through follow up's, thus balancing the performance of the ongoing implementation.

The methodological approach incorporates the following steps:

1. Knowledge of the processes and their critical quality characteristics;
2. Implementation of a pilot process and cost-benefit analysis;
3. Measurement system analysis;
4. Construction of control charts;
5. Evaluation of process capability;
6. Follow-up and consolidation.

However, this implementation process may not be successful. According to [3], a number of factors contribute to the failure of the SPC implementation in some organizations:

- Lack of involvement and top management commitment;
- Deficit of training and awareness in SPC;
- Failures in the interpretation of control charts and taking action;
- Poor knowledge of the critical features of the product;
- The SPC is just a requirement of customers.

With the development of information technologies and new software, with increasing capabilities and features, it is more convenient to use technology in sampling procedures (measurements) of a given characteristic in production processes and their storage in the database for subsequent statistical analysis [4]. The arguments presented can be the basis for a quality assurance system supported by a computer. Thus, it is necessary to find or to develop a computerized system for SPC that best suits the needs and characteristics of the organization (size, production quantities, number of processes, etc.).

A computerized SPC system [5] can serve as business development support tool, as it allows the visualization of the analysis performed and results in a simplified manner. This author points out several benefits to using a computerized SPC system:

- Ability to create control charts automatically, thus optimizing the view of the operator and their perception about the state of the process;
- The process state can be automatically indicated to the operator through notifications or alerts.

These types of automated systems (computer, data acquisition sensors, cables, software, etc.) can also reduce the incidence of human error by the above factors and improve the effectiveness and efficiency of the sampling process. However, at the of selection and acquisition

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phase of this type of systems, the factors underlying its implementation should be balanced, as this requires the use of various resources. For example, training the operators involved in the use of the computer system and changing practices and procedures. The costs of acquisition, training and maintenance of the system are also relevant in the selection phase.

There is lack of publications presenting case studies on how industries are implementing computerized SPC systems and there is lack of empirical evidence on their implementation obstacles and benefits. This paper describes a case study on a manufacturing company that supplies the automotive industry with segments to be incorporated in car engines. The company decided to automate an existing SPC activity in a final inspection process.

II. METHODOLOGY

The case study approach, applied in this work has been used by several authors [6], [7], when attempting to understand complex organizational problems. “It is the method of choice when the phenomenon under study is not readily distinguishable from its context” [8]. Furthermore, to fully understand how industries are implementing computerized SPC systems and to know their implementation’s obstacles and benefits, an in-depth knowledge of the organizations would be required.

The case study protocol will describe the automation implementation methodology of the final inspection station of the finished product “iron cast piston ring without cover”:

A. Context analysis;
B. Study and analysis of the acquired software;
C. Creation of a multidisciplinary team & planning;
D. Involvement of section responsible;
E. Hardware installation;
F. Designing software interface;
G. Software configuration in the monitoring station;
H. Creation of control plans;
I. Awareness and training of operators;
J. Consolidation and Monitoring.

III. CASE STUDY

A. *Context analysis*

The main reasons that led to the automation of product quality assurance operations were:

- To have a database that brings together all the measurements taken during the production process;
- To improve procedures for data traceability;
- To make data more reliable;
- To improve the efficiency of existing SPC;
- The difficulty in making various types of statistical studies.

In the automation process of a production operation, it is crucial to understand the procedures involved. The following information was necessary to develop a "new control plan":

- Product characteristics (classification given to the feature in question, type of control, size of the sample checked, type of inspection, etc.);
- Information needed to make the traceability of collected data;
- Treatment given to critical characteristics of product quality - this organization's practice is to evidence capacity of the supplied lots. SPC is performed in productive operations by manual filling control charts. It was performed a final inspection operation, calculated C_{pk} index to critical quality characteristics (sample of 50 parts), and then the information was registered in an excel worksheet, a procedure time consuming and unreliable.

The implementation of such software should contribute to improve the communication between various hierarchical levels of a particular industrial organization, from the operator (through its role in integrating the values of the measurements collected during the production process), through engineering (doing data analysis, triggering improvements in production processes) and finishing in the top management (by increasing the knowledge of production processes, there is a better boost for new projects and investments).

B. *Study and analysis of the acquired software*

The acquired software was the *Q-DAS*®. Through its analysis it was found that this allowed the acquisition of data automatically (*procella* module) and the *qs-STAT* module was efficient to record and analyze data.

C. *Creation of a multidisciplinary team & planning*

The creation of a multidisciplinary team, which brings together expertise in various areas of knowledge, allows to define responsibilities, setting deadlines, defining a plan to follow. The team responsible for the project shall periodically establish meetings of follow up, to analyse the state of project compared to the established objectives and the overcome difficulties encountered along the automation of the operation.

D. *Involvement of section’s responsible*

In any process of implementing a new application or working procedure, it is essential to involve the leaders of the section concerned, to get their input and facilitate the tasks to perform in the workplace or section, as well as the involvement of operators. In the implementation there were meetings with the supervisor and the head of quality section, and held a workshop with the following agenda:

- Brief presentation of the software and its modules;
- Approach of the reasons that led to the automation of the process;

- Presentation of the implementation schedule and the respective action plan;
- Talk about the change procedures;
- Survey of training needs and planning needs;
- Decision of where to install computer equipment.

E. *Hardware installation*

The IT department was asked by the project leader to proceed to the installation of necessary hardware and software (*procella* and *qs-STAT* modules).

F. *Designing software interface*

The basis of automatic acquisition of measured values to avoid manual registration lies in creating an interface between the measuring equipment and the software (Fig 1). To do this, a multiplexer (equipment consists of several modules, as many as the number of measuring equipment at the workplace) is required. Each measurement equipment has been associated with a communication channel.

The responsibility for carrying out the cataloging of existing measuring equipment at the station, to purchasing connecting cables and equipment needed for data entry (pedals and depicted buttons) and managing the creation of interfaces in the post in question was assigned to the company's metrology laboratory. Data entry equipment and *procella*, allows the operator, while carrying out measurements, to see the values in real time.

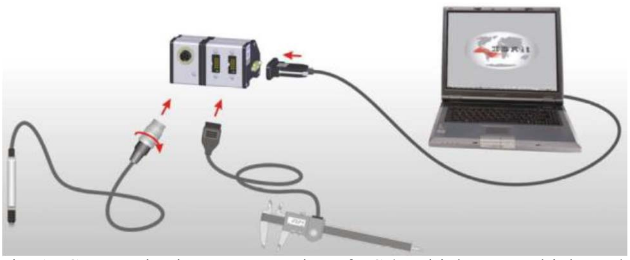

Fig. 1. Communication representation of PC / multiplexer; Multiplexer / Inspection, Measuring and Test Equipment (IMTE)

G. *Software configuration in the monitoring station*

Q-DAS is a software module with standard settings. To be used it has to be adjusted and adapted to the needs and requirements of each organization. It was necessary to improve the data acquisition mask, to facilitate the data-recording task to operators. The procedure adopted in the monitoring operation had the following steps:

1) *User creation for applications*: The users were created for the pilot monitoring station, aiming to be able to open two applications (*procella* and *qs-STAT*) simultaneously. Each user has permissions to input values, do data queries and visualize and print reports.

2) *Establishment of information catalogs*: To facilitate data input and traceability for each new final inspection lot, information catalogs (operators ID, measurement equipment codes; product's families, etc.) were created.

3) *Creation of masks "part" and "characteristic"*: The design form tool available in *procella* and *qs-STAT* modules enables the creation of masks for entering information that characterizes a given piece. Fields were created for this purpose: part number (AN); description; family, type of inspection (operation), code and customer design modification number, customer information, type of control (variable or attributive), unit of measurement, characteristic classification according to the internal standard (QG-089); input type (manual or automatic), design specification limits, sample size; Inspection, Measuring and Test Equipment (IMTE) used and their respective codification; IMTE resolution, etc.).

4) *Database organization*: The database was organized so that the information it contains is easily accessible to all users. Data were arranged by type of inspection (operation) and product family.

5) *Creation of data acquisition mask*: The data acquisition mask was set using the new form design tool. This mask should function as "virtual" control plan, allowing the operator to view the characteristics to inspect, its specifications and their state.

6) *Creating a button bar with features*: Sometimes it becomes necessary to create a button bar with configurable functions that are relevant to the operation under study. For the case study sidebar buttons were created (shortcuts to relevant functions).

7) *Configuration of the summary monitoring report*: It was created a report prototype with a summary of monitoring information so that the operator can approve or disapprove the part and hence the batch. This report has the following information: descriptive information of the operator and the part and batch analysis; a summary table for the controlled variables (indicating the minimum and maximum recorded), capacity index (C_{pk}) and a flag (green or red) corresponding to the compliance or non compliance of technical requirements.

H. *Creation of control plans*

The creation of process control plans is important, because any error in these plans may compromise the monitoring operation. To create control plans the study and analysis of customer specifications was carried out in the following steps:

1) *Creation of control plans for each part produced*: Plans have been created for all parts produced.

2) *Creation of characteristics in control plans*: For each control plan customer designs are analyzed and defined and coded the quality characteristics, according to the standard (*QG-089*). After identifying all necessary characteristics and specifications a template was designed to input data.

3) *Definition of communication channels*: Consists in the identification of characteristics for which it is allowed the interface between software and IMTE.

4) *Definition of mandatory / optional characteristics*: In the control plan, the characteristics that are of mandatory inspection are signaled.

I. Awareness and training of operators

The training and awareness of operators involved in the monitoring section consisted of two parts: a theoretical part of presentation and introduction to the software; and a practical part of monitoring and consolidation of the monitoring operation.

The theoretical approach of consisted of a presentation to monitoring operators followed by a discussion of the following topics:

- The software *Q-DAS*® and its modules;
- Main reasons (key benefits) for automating the final inspection operation;
- Interface between software and IMTE;
- Implementation schedule;
- Description of the main tasks undertaken in the automation of post;

After the theoretical training given to monitoring operators on the basics of operation of *procella* and *qs-STAT* applications, it was practiced to carry out final inspection operations following a new procedure for the inspection operation. This new procedure involves:

1. Perform a filter by part number (AN72516.00) to open the part control plan;
2. Enter additional information identifying the final inspection performed to the batch;
3. Select optional characteristics to be inspected;
4. Perform the necessary measurements and records of all the characteristics selected for inspection;
5. Consult the capability indexes (C_{pk} values) of the critical characteristics;
6. Print the summary report of the monitoring operation.

This procedure was detailed and documented in a user manual.

J. Consolidation and Monitoring

The automation of the monitoring station was considered completed after a monitoring period of the operators involved in the operation. It was held a meeting with members of the team responsible for the automation and the head of the quality section, to draw conclusions from the project (including a reflection on the feedback obtained by operators). This reflection came out with some guidelines to take into consideration for the improvement of this process, of which the following stand out:

- Design and implement a way to decrease the frequency of mistakes in data entry of the inspected lot, and in particular identification code;
- Design and implement a way to decrease the frequency of mistakes in choosing the control plan;
- Simplify the completion of the process of the initial data required;
- Simplify access to features required for the monitoring operation.

IV. IMPROVEMENTS IMPLEMENTED AFTER THE AUTOMATION OF THE MONITORING STATION

From the reflection carried out at the end of the automation project and the guidelines proposed to improve this process, the following measures have been proposed and implemented:

1) *Introduction of a barcode reader in operation:* The production order that accompanies a lot throughout the production process contains codes identifying the batch and the pieces that make up the plot. To decrease the frequency of mistakes occurring in choosing the correct control plan and the introduction of additional data, it was purchased a barcode reader for the monitoring operation. This tool also helped to streamline / automate the process of filling the initial data required and the selection of the correct control plan.

2) *Introduction of an identification card operator*: Given the efforts to automate all of the information required at the beginning of each final inspection, it was also automated the insertion of the identification of the operator responsible for that operation, by creating cards with identifying bar code to each operator .

3) *Reconfiguration of the initial filter*: The introduction of the barcode reader and the operator identification card has created the need to change the initial filter configuration. Changes have been made to the control plan selections, amongst others.

4) *Optimization of the data acquisition mask*: The data acquisition mask has been modified to make the process of data insertion easier and more intuitive and thereby also contribute to the reduction of mistakes in the insertion of the inspected batch code. They also changed some colors to facilitate visual management features inspected / to inspect.

5) *Rewriting the sidebar functions in procella*: New buttons were designed on the sidebar of *procella* application with functions to perform the monitoring operation.

6) *Introduction of side bar functions in qs-STAT*: It was recognized the need to add, in *qs-STAT* module, buttons similar to the ones created in the *procella* module with the basic functions to be performed in the application for the final inspection operation.

V. RESULTS ANALYSIS

A. Time savings

Tables I and II present the time duration of the registration operation of the values of the critical quality characteristics and times for the achievement of statistical studies before and after the automation process of the final inspection station for a given production lot.

TABLE I
DURATION OF MEASUREMENT PROCESS BEFORE AUTOMATION

Quality characteristic / *statistical analysis*	**Time spent (sample of 50 items)**
closed gap	00:06:40
radial thickness	00:04:32
parallel height	00:06:24
tangential force	00:06:42
statistical analysis	00:09:07
Total time (h:min:s)	**00:33:25**

TABLE II
DURATION OF MEASUREMENT PROCESS AFTER AUTOMATION

Quality characteristic / *statistical analysis*	**Time spent (sample of 50 items)**
closed gap	00:03:57
radial thickness	00:02:44
parallel height	00:04:10
tangential force	00:04:52
statistical analysis	00:00:00
Total time (h:min:s)	00:15:43

Data suggest a reduction of about 43% in the total duration of the inspection process of the critical quality characteristics in the inspection station with the proposed automatic data system. For the same lot, a reduction of about 64% at the time of the final inspection operation was obtained with this system, considering the reduction in the time spent in doing the statistical analysis.

Given that on average are performed in this station 5 final inspections per day, about 1125 annual inspections, representing the automation of this final inspection savings of about 338 hours of actual production per year.

B. Feedback given by the organization due to the automation of final inspection stations

After the automation of all final inspection stations in various sections of the company, the team responsible for the project evaluated the results achieved and considered them as very positive. One aspect to be highlighted was the perception of learning occurred as the automation process progressed. The experience gained in this process allowed reducing the time spent and improvement of practices to be used, spreading so the concept of continuous improvement.

Overall, there is a perception that there are reductions in the mistakes occurred in this process, however there is not yet a significant period of time to allow for a quantitative analysis.

VI. CONCLUSION

During the automation of the operation under study, it was necessary to create a team devoted to design and setting the implementation strategy to be carried out. One of the determining factors for the success of this project was the effective involvement and awareness of the department's leaders, and the operators responsible for the final inspection operation. Thus, it overcame some initial resistance and resulted in the acceptance of the new procedures.

It can be concluded that automation of the final inspection operation performed on the final product allowed making the quality assurance process more efficient. The reduction of time reduced from 33 minutes to less than 15 per station. Additionally, the equipment for data acquisition with revised procedures made the process, according to the perceptions of the involved more reliable. Thus, the advantages of automating the final inspection process were verified in this case study, according to initial expectations.

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