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CONTRIBUTIONS RELATED TO THE DEVELOPMENT AND IMPLEMENTATION OF ADVANCED SYSTEMS FOR STATISTICAL PROCESS CONTROL

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Abstract: *This paper presents the existing approaches and systems for performing statistical process control and following the analysis of the classic method, opportunities for improvement are identified. The second part of the paper presents the personal contributions on the development and implementation of an advanced system for statistical process control, which are based on innovative approaches for data acquisition, real-time processing using control charts. The advanced systems presented in this paper are the future for statistical process control, allowing the usage of novel improvement processes in a collaborative environment.*
Key words: *advanced systems, collaboration, data acquisition, software, statistical process control.*

1. INTRODUCTION

In the current context of the competitive market, in which all companies wish to identify any aspect that will bring them an advantage over the competitors, several areas of interest arise. One is the product design area, where companies try to find the most attractive design for their product in order to sell the product, as easily as possible. With these new designs or designs which have the scope of impressing, new challenges arise in the manufacturing area. As futuristic designs usually incorporate new materials and never before seen product features or functions. One good example is the mobile phone industry, where the products are continuously evolving and generating new challenges during the manufacturing and assembly of the products. Thus, a second area where companies look for the advantage over the competition is the manufacturing of the product. During the manufacturing process the raw materials are continuously transformed into semi-finished goods, components, sub-assemblies and at the end into the final product. In this journey the raw materials are processed via manufacturing processes which are composed of various components. Taking in consideration all the inputs for a manufacturing process, it is inevitable to have variation of each individual input of the manufacturing process.

To have an advantage over the competition when building complex products, some companies use specific tools to manage the manufacturing processes. These tools are oriented in the direction of supporting the management of the process inputs and to certify that the outputs are according to the requirements, throughout the product life cycle. The tool which has been identified and has been successfully used in various industries is Statistical Process Control. This statistical tool has the advantages of being a data driven tool, which allows the analysis and prevention of unwanted sources of variation. Companies which are using Statistical Process Control as a tool embedded in their manufacturing process control, have witnessed improvements in their respective manufacturing processes, which in term has allowed them to be more consistent when building the products. This consistency in the manufacturing processes is reflected on the

quality of the product and is term in the satisfaction of the customer. Companies using Statistical Process Control within their processes have risen to become the best in their industries, profiting from the advantages of this tool. Companies which are choosing not to use Statistical Process Control, are in general the companies which are challenged by the lack of competent resources needed to implement and oversee this process. Within this paper a new approach Statistical Process Control is presented with the scope of reducing the resources needed to manage such a complex tool. The advanced systems for statistical process control allow the continuous monitoring of the manufacturing processes and facilitate the continuous improvement of the manufacturing processes and of the product.

2. STATISTICAL PROCESS CONTROL

2.1 Applicability of statistical process control

Statistical Process Control is and has been used in almost all industries, starting with the defence and aerospace industry, continuing with the automotive industry where it has seen its peak usage. Also, other industries such as pharmaceutical, electronic and energy are using Statistical Process Control as a mean of controlling the manufacturing processes. One fairly new industry where Statistical Process Control has seen its revival is the Aerospace industry, where with the release of new Statistical Control requirements with the AS 9100 suite of standards. The main standard for the aerospace industry for statistical process control being the AS 9103 standard, named "Variation Management of Key Characteristics". Another aerospace standard which strongly recommends the usage of Statistical Process Control is the Advanced Product Quality Planning (APQP) standard AS 9145 which is named "Requirements for Advanced Product Quality Planning and Production Part Approval Process" [1]. All of the above plus some contractual requirements from the main aerospace producers Airbus and Boeing make the usage of Statistical Process Control within the aerospace industry as mandatory. This creates new challenges for the companies engaged in this industry, which is well known for high number of requirements coming from contract, industry, product or even process. Implementing and using Statistical Process Control for an aerospace company poses a lot of challenges which are directed in the following areas:

- Finding competent personnel to oversee the Statistical Process Control tool within the organization.
- Ensuring that enough competent personnel is available to cope with the amount of data which needs to be analysed.
- Procurement of the necessary consumables for the activity.

All the above are necessary when implementing classical Statistical Process Control which involves a lot of human involvement and resources.

2.2 Disadvantages of classical statistical process control

Statistical Process Control as it has been developed over time and with the tools available at the time, has become a tedious activity in its classical format. Classical Statistical Process Control is defined as the activity of performing statistical control with either pen and paper or in a non-automated way. This classical method unfortunately in some cases outweighs the benefits of Statistical Process Control making it unusable for some companies.

Some of the disadvantages of classical statistical process control are:

- Manual data collection.
- Manual chart plotting.
- Extended time for identification of out-of-control events.
- Analysis is performed periodically, not continuously.
- Lack of a link between corrective actions and out-of-control events.
- Inability to browse historical data or analysis.
- Blocking of highly skilled human resources for repetitive tasks.

To mitigate the above disadvantages of the classical Statistical Process Control the need has arisen for more advanced systems for statistical process control. Such advanced systems allow the company using it, to allocate resources better and still profit from the benefits of Statistical Process Control.

3. ADVANCED SYSTEMS FOR STATISTICAL PROCESS CONTROL

3.1 Development of advanced systems for statistical process control

As mentioned above the necessity of advanced systems for statistical process control started due to the high number of resources needed to perform Statistical Process Control in the classical format. The development of advanced systems for statistical process control has been aided by the current development on the fields of automation, IT, and software.

Manufacturing processes are developing more and more into highly automated systems which are developed as such to reduce the human resources needed to perform the processes and at the same time to reduce the inherit variation caused by a manual process. Automation relies on an ecosystem of sensors and controllers which linked together with the scope of performing a specific activity. In general, the activities where automation has been implemented, are in the range of simple and repetitive activities.

Fig. 1. Example of Programmable Logic Controller from EATON [2]

Nonetheless by linking a series of simple and repetitive activities into a more complex process, it is possible to fully automate a manufacturing process. These ecosystems to function are dependent on the data flowing within the components and in general, towards control units which include the programming needed to perform the respective process. The existence of the flow of data and of the centralized collection of the data within the control units or programmable logic controllers or PLC (Figure 1) becomes one of the foundation stones for the development of advanced systems for statistical process control, by facilitating the data collection.

The recent developments in IT and software have also facilitated the development of advanced systems for statistical process control. In the last decade it has been possible to develop such advanced systems and operate them with the necessary computational speed. Early advanced systems for statistical process control were developed and used in a local network, with access to the system being possible only from within the local network. Although not optimal by today's standards these early advanced systems for statistical process control have been able to show massive benefits within the organizations where it was used. The local software developed has allowed the processing of the process data into graphical formats such as control charts. These control charts from the software allowed one major new improvement in the field of Statistical Process Control, which is having real time control charts. This type of chart in combination with the software programming allows the continuous and real time update of the charts without any human intervention, besides from the data collection. A second major improvement supported in new advanced systems for statistical process control is the ability to program specific rules by which the software can identify any out-of-control events within the control chart. This improvement removes the need of human analysis of control charts used for Statistical Process Control. A secondary improvement which can be developed in advanced systems and based on the continuous automatic trend analysis is the triggering of automatic notification for the process owner or responsible. Notifications can be generated any time the out-of-control rules are broken, and human intervention is needed to bring the manufacturing process back in to control.

With the above-mentioned benefits, the early or local advanced systems for statistical process control have opened the horizon towards further development of the advanced systems. One recent new opportunity has arisen with development of cloud computing and cloud data storage (Figure 2) which allow the advanced

systems for statistical process control to be used from anywhere on the planet. This has opened the door for implementation of more complex advanced systems which take in account the need of more interaction within the advanced system. The introduction of complex process flows within the software has allowed a major step in the collaboration field. For example, customers can access the suppliers advanced systems for statistical process control and visit relevant analysis and results. Taking in consideration that all the system is data driven, the customer can see the actual results of the supplier for their respective products and with the help of the complex collaborative process flows they can interact. Collaboration within the advanced system for statistical process control allows the definition and follow-up of corrective actions. Effectiveness of the implemented corrective actions can be checked directly and remotely later. Such advanced systems can reduce the need of onsite supplier audits or visits, thus reducing costs and resources.

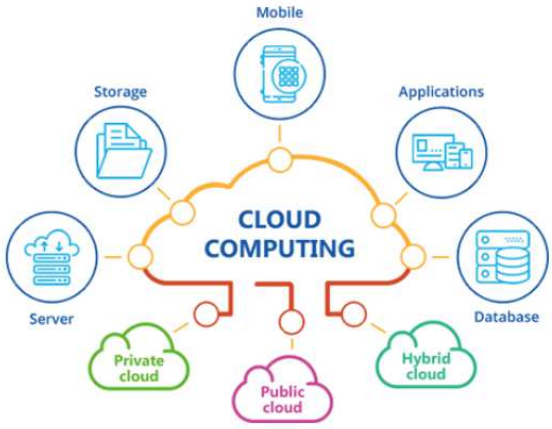

Fig. 2. Typical layout of cloud computing [3]

Cloud based advanced systems for statistical process control are powerful tools for any organization which has the goal of continually improving its manufacturing processes and at the same time creating a collaborative relationship with its customers and by ensuring open access to relevant data and allowing a "one stop" view of its current state by means of Statistical Process Control.

3.2 Inputs and data sources

As it is already known for any specialist working with manufacturing processes, all processes are unique and are based on variables such as:

- Company,
- Location,
- Layout,
- Technology,
- Equipment,
- Materials,
- Level of automation,
- Human resources skills.

All the above create a mix, which when developing and implementing advanced systems for statistical process control require a preliminary mapping or analysis of the manufacturing process. This analysis has the target of identifying the necessary inputs required by advanced systems for statistical process control. This is a mandatory step, as without it the following inputs would be missing:

- Product special characteristics, which are to be defined on the advanced system and observed by the customer.
- Process special characteristics, which are to be defined for continually improving the manufacturing process.
- Measurement systems and types used for data collection.
- Measurement system accuracy or repeatability & reproducibility (Figure 3).

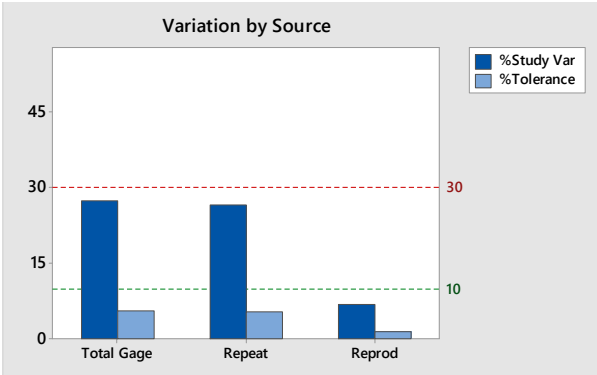

Fig. 3. Typical Gage R&R study result

The most important input for advanced systems is the type data source. Based on the research presented in this paper three types of data sources have been identified:

- Manual data collection, which is mainly used for manufacturing processes centred around

human work. In this category fall manufacturing processes such as manual assembly, manual drilling, etc. To perform Statistical Process Control with advanced systems, it is necessary to add an additional step for the operator, where he would report the results in an electronic format or directly in the advanced system software.

- Semi-automatic data collection can occur in processes where special measurement systems are used which have a proprietary software that do not allow the connectivity of the device to the IT network. Such measurement systems in general allow the export of various templates from which it is possible to retrieve the data and upload into the advanced system for statistical process control.
- Automatic data collection is the preferred way of uploading data into advanced systems and is generally observed in highly automated manufacturing processes where product and process data is being generated with help of specialized sensors (Figure 4).

Fig. 4. Highly automated extrusion process [4]

In general, the amount of data being generated by automated manufacturing processes surpasses the actual need for Statistical Process Control. It is usual to have data being generated for each second when running the manufacturing process and this can create some challenges for the advanced system definition. Smart ways must be defined to collect the relevant data into the advanced system without creating floods of data, that can slow down the overall system or create unnecessary internet bandwidth usage and increase of cloud costs.

3.3 Implementation for advanced systems for statistical process control

When implementing advanced systems for statistical process control the following considerations must be taken in consideration:

- Develop and establish management support by creating a business case for implementing the system. This can be easily achieved especially in industries or sectors where the use of statistical process control is mandated by contracts and industry standards. Nonetheless the business case must include the major milestones and resources needed to implement a fully functioning advanced system for statistical process control.
- Nominate a project leader who has the necessary competences in all the areas necessary to implement the advanced system. Main areas are:
  - Statistical Process Control,
  - Manufacturing Processes,
  - Maintenance or automation,
  - Data acquisition, IT and software.
- Define project specific multifunctional team which covers the necessary competences as listed before. Multifunctional team must undergo a training module on statistical process control, in order to understand the necessity and benefits of such advanced systems.
- Develop and establish a project timeline that incorporates all the processes where the advanced system for statistical process control must be implemented. Including detailed planning of each individual task that needs to be performed by the multifunctional team in order to implement the advanced system.
- Define project key performance indicators for the project scope. Using key performance indicators will allow a one page view on the progress of the project. This is especially important as any drift from project timeline will be visible and mitigation actions can be defined to bring the project back on time.
- Definition of a pilot manufacturing process, in order to run the project activities and to be

able to identify any hidden activities which have not been foreseen in the initial planning. Pilot implementation is especially valuable as is allows all multifunctional team members to get in sync with all the activities and iron out unplanned discrepancies.

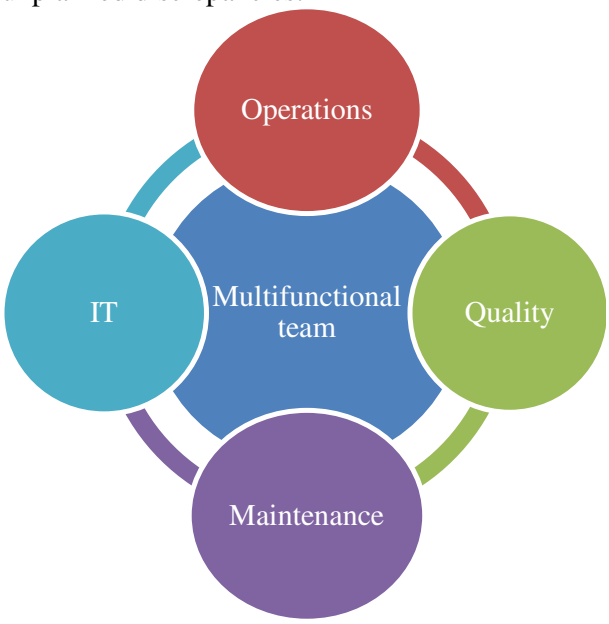

Fig. 5. Multifunctional team composition

- Extended implementation, which relies on the methodical implementation of the activities included in the detailed planning. Special attention has to be paid on the key performance indicator, by means of periodical reviews with the multifunctional team (Figure 5) and also from time to time with the organizations management team.
- Check the quality of the work being performed. Project team leader and the multifunctional must check if all the activities are closed to the desired level of quality. Some of the important items are:
- Correct definition of product and process special characteristics.
- Definition of optimal control charts for each individual characteristic [5].
- Accurate data collection.
- Optimal data flow for each individual characteristic.
- Correct definition of reactions plans.
- Establish with the customer the relevant list of product special characteristics to be shared.
- Ensuring that the necessary resources are available to maintain the advanced system for statistical process control beyond the closure of the implementation project [6].
- Establish the handover protocol to the relevant functions after implementation project closure. This must ensure the smooth use of the advanced system for statistical process control.

4. USING ADVANCED SYSTEMS FOR STATISTICAL PROCESS CONTROL

Compared to the classical way of using statistical process control, the advanced systems allow an easier usage of the method, by embedding most of the manual activities within the actual software. After ensuring that the advanced system is completely implemented, by following the milestones defined in the previous chapter, the organization must assign the responsibilities to maintain and use the advanced system for statistical process control. Thus, a group must be allocated for the maintenance and surveillance of the advanced system to ensure that the theoretical statistical process control methodology is adhered to.

Fig. 6. Out-of-control event identified by the advanced system for statistical process control

The local groups who are using on a day-to-day basis the advanced system must ensure that all relevant product and process special characteristics are defined in the system and that the data collection is maintained and is relevant for each characteristic. Of course, with the increased benefits that the advanced system for statistical process control brings, the process owners, following the definition, must only react to out-of-control events (Figure 6). These events occur when the advanced system identifies a trend in the control chart which breaks one of the rules applied within the advanced system. The system will automatically send out a notification

to all relevant personnel. The process owners must investigate the reasons for the out-of-control event and take the necessary actions to bring back the process under control (Figure 7).

Fig. 7. Example of reaction plan notification by the advanced system for statistical process control

Taking in consideration that the advanced systems for statistical process control are continuously monitoring the data, which is feed into the system, notifications are almost instantaneous. This real time analysis reduces drastically the time until the out-of-control events is detected and facilitates the speedy stabilization of the special characteristic and of the manufacturing process. After identification of the root cause for each out-of-control events, advanced systems require for the user to input the reason into the software. This functionality allows later to use this data and create lists of historical events and create relevant statistics and charts that allow the continuous improvement of the manufacturing process.

With the extended functionality of the advanced systems for statistical process control, the customer can oversee the process described above and conclude if the supplier is responsive to the out-of-control events. With collaboration possible in advanced systems the customer can define actions for the supplier in case it is not responding fast enough to the notifications.

5. CONCLUSIONS

With today's advancements in the field of technology, starting with the ever-increasing automation of the manufacturing processing, moving further to the high-speed internet and the developments around software. It is inevitable that classical and established methods such as statistical process control are included in this new wave of Industry 4.0 and IoT. This can be achieved only by embracing the development and implementation of advanced systems for statistical process control, which can become an advantage for any company who chooses such an advanced system. This paper includes all the necessary major steps for the development and implementation of advanced systems for statistical process control. As presented these advanced systems provide a lot of benefits to the organization using it. This ranges from requirements for better automation, more streamlined data acquisition, manufacturing processes stability monitoring, documented reaction plans, innovative collaboration improvement flows that can include the customer.

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CONTRIBUȚII LEGATE DE DEZVOLTAREA ȘI IMPLEMENTAREA SISTEMELOR AVANSATE PENTRU CONTROLUL STATISTIC AL PROCESELOR

Rezumat: Această lucrare prezintă abordările și sistemele existente pentru efectuarea controlului statistic al proceselor și în urma analizei metodei clasice sunt identificate oportunități de îmbunătățire. A doua parte a lucrării prezintă contribuțiile personale la dezvoltarea și implementarea unui sistem avansat de control statistic al proceselor, care se bazează pe abordări inovatoare de achiziție a datelor, procesare în timp real cu ajutorul diagramelor de control. Sistemele avansate prezentate în această lucrare reprezintă viitorul pentru controlul statistic al proceselor, permițând utilizarea unor procese noi de îmbunătățire într-un mediu colaborativ.

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