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Study on quality control tools and techniques adopted in automobile and aerospace sector

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ABSTRACT

Quality Engineering (QE) tools are the crucial tools or techniques which are the valuable cornerstones that guides in incessant improvements in any automobile or aeronautical company. Hence quality engineering guarantee that quality products are being manufactured at the nominal levels. Manufacturing and service forms utilize various statistical tools and methods for quality improvement and quantification of products. In this competitive market, companies identify and implement the best practices to constantly develop their processes. This paper discusses the tools and techniques of quality management approaches utilized by companies in Automobile and Aeronautical Industry in their complete manufacturing process to get along with the global standards. The major quality control techniques like APQP, PPAP, FMEA, SPC, MSA are described in this research work and how the six-sigma model effectively plays a crucial role in the industries.

Keywords— *Quality engineering, Statistical tools, Automobile and aerospace industry, Six-sigma model*

1. INTRODUCTION

Quality Management tools help employees identify the common problems which are occurring repeatedly and also their root causes. Quality Management tools play a crucial role in improving the quality of products and services. Quality control is used in all phases of the company but is awfully relevant for production and engineering in the development systems to guarantee services or products. Quality control is used to satisfy the customer's requirements and is crucial in the production part of companies. Quality Control (QC) is a systematic check of various factors that influence the quality of the product. It depends on materials, tools, machines, type of labor, working conditions, etc. In contrast to inspection, quality control activity emphasizes the future quality of production. Quality control is aimed at preventing defects at the source, based on the corrective action procedure and an effective feedback system. Quality control is categorized into three main associate-areas, those are Off-line quality control, Statistical process control, and Acceptance sampling plans.

Because of the negative consequences of poor quality, organizations try to prevent and correct such problems through different approaches to quality control. Some organizations use the term quality control to refer only to error detection, while quality assurance concerns both the prevention and the detection of quality problems. Organizations must have a department or employee dedicated to identifying defects and promoting high quality. Process control techniques should be very effective. Process control is an important part of the company's efforts to plan regarding quality and correct the causes of defects in the components it produces for commercial and heavy equipment automotive vehicles. Quality teams meet weekly to address and prevent problems. When a failure occurred in a product line, to correct the process certain procedures are being directed to the operators by directors to ensure the quality and productivity. To gain the customer trust quality products have to be delivered under standard procedures by manufacturing defect-free parts. The major core quality tools discussed in this research work include –PPAP, APQP, FMEA, SPC, and MSA. Sig-Sigma is an effective tool adopted by many automobile and aerospace companies to assure the quality of its products. Here in this research paper, a brief discussion is done on how this tool is being adopted in Toyota and Ford Motors.

Benefits of implementing quality control tools (Singh, Sidhu, & Singh Bains, 2016):

- Helpful in controlling reject rate/rework.
- Benefits of reducing production cost.
- Reduction in customer complaints.
- Improvement in process.
- Helpful to find the root cause of the problem.

2. REVIEW OF LITERATURE

(Prajapati, 2012) concluded that SPC techniques in aerospace and automobile industry offer customers a great range of sealing solutions.SPC analysis assists in enhancing the productivity of the complete manufacturing process by reducing the number of defective products, by saving re-work cost and the valuable time. For every product, the suggested preventions can reduce the loss of industry in term of time and money. Improvement in the rejection level of products in the industry is observed, shocker seals are the major concern as the rejection level of the product is more than 9.1%. Implementing according to the recommendations for these shocker seals, the capability of the process improved.

(Dalalah & Hani, 2016) highlights that measurement variability influences the performance of the process capability index and the product quality, by decreasing the monitoring competency of the statistical process control charts. The measurement system is not appropriately right; the apt value of the product is inaccurate. This is a drive to enhance the measurement system. In the measurement system, the right measurement results are produced under each use. This ideal measurement system for correct measurement is produced under each use. Ideal measurement system establishes the attributes of zero statistical error. These ideal measurements do not occur and reliance on the measurement system for the analysis and accomplish the variability in this measurement system to consider them under reasonable range. MSA is a crucial tool in ISO/TS 16949 quality management system. It utilizes the graphical methods and mathematical statistics to execute the variability of the measurement system. We identify the variations in computing field measurement. Under MSA, calibration and instrument correlation are evaluation methods for the measurement system and is used to calculate the consistency of measurement system and certify that process is constant

(Armin, 2010) in his paper "Six Sigma – Project management for zero defect quality in the automobile industry" identifies that Six-Sigma is complete solution introduced and is applied consistently if the organization directors and managers deliver complete commitment and company culture emboldens transparency in case of errors, rigorous control over projects and aspiring for quantitative results. Automobile manufacturers claim for zero defect quality from suppliers. Companies who indulge in developing a great level of Six Sigma expertise at earlier stage accomplish high-cost reductions and competitive advantages. This research work discusses six sigma specialists- Champions, Master Black Belts, Black Belts, Green Belts, and Yellow Belts, analyze the financial impact of six sigma.

(Ahmed & Hassan, 2003) analyzed that effective quality management could not be made effective without utilizing the tools and techniques The choice of any method or tool is not automatic and is situation specific. Tools resolve the existing problems as it identifies the problems in particular tools which are applied. Some factors which specify a group of companies are not successful in smearing the quality tools effectively.

(Noviyarsi & Yusof, 2005) most automobile suppliers in Malaysia applied all seven basic tools for everyday functions. The new seven tools are not effectively applied as often as seven basic tools. Other than the seven basic tools –brainstorming, sampling, mapping, rating, and ranking are other tools with great application in the case of Malaysian automotive suppliers. The five best-applied techniques are Process Capability Analysis, Failure Mode and Effect Analysis (FMEA), Statistical Process Control (SPC), cost of quality and benchmarking. The results depict that companies have a clear understanding of all the seven basic tools.

3. THE CORE QUALITY TECHNIQUES ADOPTED BY VARIOUS INDUSTRIES

3.1 APQP (Advance Product Quality Planning)

When new products are introduced in the market there are many opportunities for complex products and supply chain to become a failure one. Advanced product quality planning (APQP) is a structured process intended to guarantee customer satisfaction with new process and products. APQP existed in many methods and forms since last few decades. Originally referred to as Advanced Quality Planning (AQP), APQP is adopted by many automobile companies to ensure quality and performance. In the early 1980s; Ford Motor Company published the first Advanced Quality Planning handbook for the vendors. APQP assisted Ford vendors to develop suitable prevention and detection controls for new products that support the excellent quality of the business. With experience and lessons learned from Ford AQP, North American vehicle OEMs mutually created the APQP process in 1994 and then updated in 2008. APQP is proposed to combine the joint planning activities that all OEMs require for the automotive industry into one single process. Suppliers use APQP to bring new products and processes to successful validation and to steer continuous improvement. The various phases involved in APQP are described in **Table 1** in brief.

Table 1: Phases in APQP

Phase 0- Prepare for customer	Phase 1- Plan and define program	Phase 2- Product design and development
• Competitive market research • Process and product bench marking • Complete risk analysis and reliability study • Customer input based on CSR. • Establish KPI's	• Define quality and project goals. • Initial Bill of Material (BOM) • Preliminary process flow • Critical SC, CC, HIC characteristics • Project team selection and kick off plan • APQP documents	• Design Failure Mode and Effective Analysis (DFMEA) • Design for manufacturing and assembly • Prototype control plan Engineering and Material Specifications • Team Feasibility commitment

Phase 3- Designing and developing the process for product manufacture	Phase 4- validating the process and the product	Phase 5- Launch, Assessments and continual improvement
• Review the quality system • Process FMEA • Process flow chart • Pre-launch control plan • Measurement system analysis • Preliminary process capability plan • Packaging standards and specifications	• Results of MSA • Production Validation Testing • Production control plan • Quality planning Sign-off	• Improved customer satisfaction • Reduced Variation • Improved delivery performance • Internal and external timing • Gateway Approval

3.2 PPAP (Production Part Approval Process)

In aerospace and automobile industries, The Production Part Approval Process (PPAP) is a customary process in both aerospace and automotive industries that assists both the suppliers and manufacturers communicate and support the production designs and processes. To gain a better understanding of the necessities of suppliers and manufacturers, PPAP guarantee that the processes for manufacturing parts are consistent at required production rates in the automotive industry, entire PPAP process is followed by PPAP manual which is published by Automotive Industry Action Group (AIAG). The manual consists of PPAP checklist which includes all the requirements for an absolute PPAP package. The checklists are categorized in different PPAP levels. Here 18 possible elements must be checked off. The aerospace industry also has a similar set of elements which has to be completed throughout the design, planning, and development of the entire production process. Each PPAP level identifies the explicit requirements for each element and recognizes which elements have to be given to the customer. The supplier should complete every applicable element whatever be the PPAP level. A PPAP is required anytime a new part of the change to an existing part or process is being planned. Customer may demand a PPAP during the life of a product. For suppliers should maintain all the quality system and documents. PPAP includes the set of instruction on the approval process of any products. Other than PPAP submission, Partial Submission Order (PSW) should also be submitted by supplier along with 18 elements in process requirements. In case if the report on PPAP is not approved until all the conditions are met the entire processes have to be repeated. The eighteen elements in the PPAP process is mentioned in Table 2.

Table 2: PPAP Process Elements

S. no	Elements of PAAP Process
1.	Design documentation
2.	Engineering change documentation
3.	Customer engineering approval
4.	Design failure mode and effect analysis
5.	Process flow diagram
6.	Process failure mode and effect analysis
7.	Control Plan
8.	Measurement system analysis study
9.	Dimensional Results
10.	Record of Material/Performance Tests
11.	Initial process studies
12.	Qualified laboratory documentation
13.	Appearance approval report
14.	Sample Production parts
15.	Master sample
16.	Checking aids used for production
17.	Customer specific requirements
18.	Part submission warrant

3.3 FMEA (Failures Modes And Effects Analysis)

Failure Mode and Effects Analysis (FMEA) is used as a development tool for the development of products, process, and services. In developing the FMEA, the operational team detects the fault modes and take necessary actions to decrease the potential failure(Rana, Zhang, & Akher, 2018). Input is collected from experts in the field of quality, design, product line, production, and marketing to ascertain that possible error modes are recognized. The FMEA is utilized during the accomplishment of the product for troubleshooting. The standard FMEA process evaluates error modes for detection, severity, and occurrence. The multiplication of these values contributes to the risk priority number (RPN). FMEA is a reliability tool that identifies failure modes of a particular product or system, frequency and possible causes (Arinez, Biller, Meerkov, & Zhang, 2010). The life cycle of a product is calculated by the functional work team. Ford, General Motors and Daimler Chrysler, have together developed an international standard referred to as SAE J1739-2006 documentation for FMEA. This document generates the general guidelines for the function of different types of FMEA. Initially, the probable failure modes and the possible causes, along with their effects, are recognized and later current controls are identified (Judi, Jenal, & Genasan, 2011). The FMEA method calculates the RPN for each error mode and then suggested recommended actions to reduce the RPN. The basic steps are identifying the underlying

causes and possible problems that may occur, and then deriving RPN that can direct improvement efforts to the areas of greatest concern. Process Failure Mode and Impact Analysis (PFMEA) is a systematized group of activities designed to recognize and evaluate the possible failure of a product/process and the effective recognition action that could eliminate or reduce the occurrence or improve the defect power, document the process and to follow. to avoid the possible cause of the failure. FMEA is performed by a multi-functional team of experts from different departments (Arabian-Hoseynabadi, Oraee, & Tavner, 2010). The risk of each malfunction is prioritized based on the risk priority number (RPN). A company must use FMEA to the full to improve the reliability of products and processes to achieve its complete benefits. The main goal of a company to develop the FMEA report is to meet customer demand. The FMEA is a formalized but subjective analysis for the systematic identification of possible root causes and failure modes and the estimation of their relative risk. The main goal is to identify risks in a design and then to limit or avoid them. FMEA strives for higher reliability, higher quality, and more safety. FMEA concentrates on identifying the severity and criticality of errors. FMEA is a completely bottom-up approach. The process of FMEA is depicted in figure 1.

RPN ensures to concentrate on the most critical failure modes, and classify the remedial actions in two categories:
(1) Preventive actions to prevent the failure situation; and
(2) Corrective actions to minimize the effects caused by a failure.

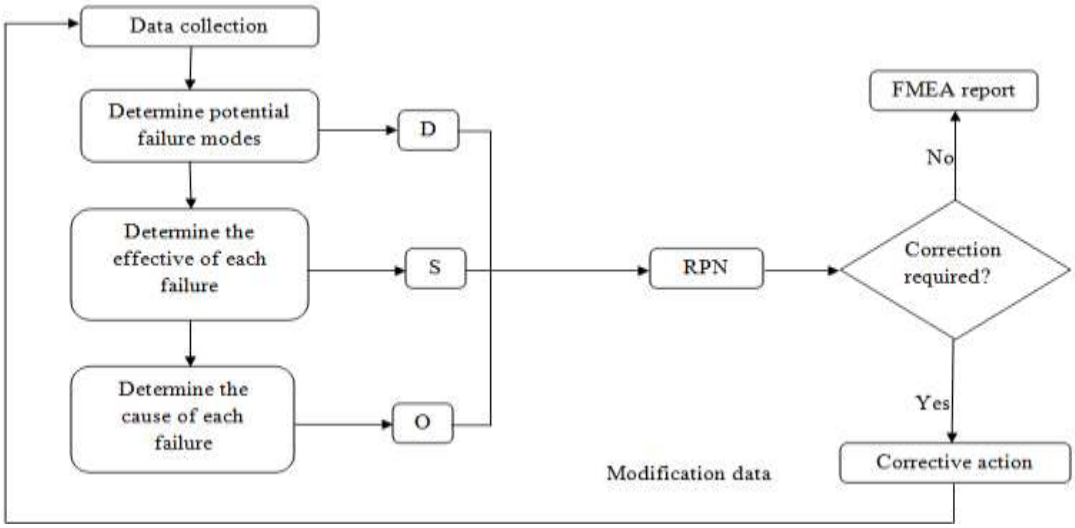

Fig. 1: Process of FMEA

3.4 SPC (STATISTICAL PROCESS CONTROLS)

Quality is considered as an important quality for both the survival and competition in the business world. Hence many organizations utilize SP to accomplish good product quality. SPC is one essential element in TQM which is still considered important. SPC utilizes statistically based methods for monitoring and evaluating to maintain control status(Duffuaa & Ben-Daya, 1995). There are many articles which address the implication of SPC in various industries. These articles discuss the application of SPC in the organization process but its main focus is on the production side.SPC improves the quality of the mountainous work in industries. This statistical process includes techniques from random sampling to sophisticated methods. There are seven different tools used here(Chaudhry & Higbie, 1989)

- Data gathering.
- Histogram.
- Cause and effect (fishbone) diagram.
- Pareto analysis (diagram).
- Control charts.
- Scatter diagram.
- Checklist

4. INTEGRATION OF QUALITY TOOLS IN MAINTENANCE: AN EXAMPLE

Consider a plant which has two machines (A&B). Over the last few months, the downtime of machines A has increased. Maintenance department tried to figure out the reason behind this and control the existing problem. Initially, data from both machines are collected. The duration and no. of downtime is being recorded. The histogram is constructed for both machines and then compared. On analyzing the histogram of machine A, a considerably slant on the right side of the histogram is noted. The team tried to identify the causes behind this. The team identified the possible reasons for the excessive downtime: frequency of preventive maintenance such as lubrication, quality of spare parts; process-related to excessive vibration and practices of the new operator. Pareto diagram identified the root causes of downtime. The root causes were the frequency of lubrication and vibration levels. A scattergram examined the correlation between downtime, vibration, the frequency of lubrication. A strong correlation was identified between downtime and vibration. It highlights that the new operator did not maintain the right setting of the machine which results in high vibration level in machines. The checklist was utilized for the operation and maintenance of the equipment. A control card for regulating the downtime for both machines was constructed and implemented. The above example demonstrates that quality tools must be integrated to accomplish SPC's objectives in the technology regarding maintenance. In the above-depicted example, the tools are being utilized in the following order: data collection, checklist, histogram, cause and effect diagram, checklist, data set, Pareto chart, scatter plot, checklist, and finally control charts.

4.1 MSA (MEASUREMENT SYSTEM ANALYSIS)

Measurement System Analysis (MSA) is a basic research which quantifies the sources of disparity that persuade the measurement system. MSA is defined as an investigational and numerical method to identify the variation in the measurement process which exemplifies to overall process variability. There are 2 main types of measurement system analysis that depends on the type of data collected utilizing the measurement system. Measurement system analysis methods are used to analyze measurement systems for continuous and attribute data. It is crucial to point out the elements of the measuring system which influence the variation in the results and adds to the capacity of the measuring system. The possibilities of the measurement system are characterized by quantifying their precision. The accuracy is defined as a degree of correspondence between measured magnitude value and true magnitude value. The accuracy of the measuring system comprises three mechanisms: bias, linearity, and stability(Runje, Horvatić Novak, & Razumić, 2017). The precision of this measuring system comprises two components: reproducibility and repeatability. Gage R & R study (GR & R) is an explicit type of measurement system analysis that determines the precision of the measurement system.

- GR&R analysis - crossed -two approaches: one is ANOVA and the other is a method of mean averages and ranges.
- GR&R analysis - nested -evaluation is done using the ANOVA method.

4.2 SIX-SIGMA

Six sigma aids to handle competition, which increased significantly in today's business world. To overcome the competition, better quality products have to be delivered to the customers at competitive rates. Six-sigma always maintains its dominant position when compared to other existing quality techniques as it's feasible and can be changed according to business needs. The importance of six-sigma increased rapidly and its application in business is overwhelming. Some major tools of Six-sigma which is being adopted in many industries are compiled together in Table 3 (Daru)

Table 3: Tools of Six-sigma

5 Whys	Process mapping
5S	Project charter
Affinity diagram/KJ Analysis	Pugh matrix
Analysis of Variance (ANOVA)	QFD/House of quality
Analytic Hierarchy Process (AHP)	RACI Diagram
Brainstorming	Regression
Calculators	Risk Management
Capability indices/Process capability	SIPOC/COPIS
Cause and effect	Sampling/Data
Control charts	Simulations
Design of Experiments (DOE)	Software
FMEA	Statistical Analysis
Graphical Analysis chart	Surveys
Hypothesis Testing	Templates
Kanban	Value streaming mapping
Kano Analysis	Variations
Measurement system Analysis (MSA)/Gage R&R	Normality
Poka Yoke	Pareto

5. TOYOTA

In the manufacturing sector, Toyota is one of the largest companies. The manufacturing department and production system of Toyota utilizes an integrated technical system. The competence of Toyota is the integration of logistic manufacturers and its interaction with the customers and suppliers. Currently, the world is changing and has become highly competitive and hence Toyota stands outstanding in terms of Quality. For attaining constant improvement in quality, it is essential that the whole organization is committed particularly in top management (Miller & Morris, 2008).

Currently, Toyota production system applies different concepts and quality initiatives like JIT, lean manufacturing, jidoka etc. Recently the standard of quality changed and all the concepts have to be improvised. Quality initiatives are momentous. For Toyota as it enhances the capability of Toyota Production System and manufacturing facilities. The capabilities of a highly competent process to generate output within the specified requirement refer to 'six-sigma'. Under six-sigma quality, the defect level is less than 3.4 Defect Per Million Opportunities (DPMO). Sigma refers to the numerical term that checks how far a process is being deviated from the level of perfection. Six-sigma technology focuses on the systematic process to nullify all the defects (Antony, Jiju Antony, Kumar, & Rae Cho, 2007). It utilizes statistical methods to direct the efficiency of the process. The main motive behind the implementation of six-sigma in the company is to determine the no. of defects in the process so that they can methodically figure and eliminate all errors. Here the main objective to adopt six-sigma is to decrease the cycle-time and reduce the defects.

Implementing and adopting six-sigma among global manufactures and supply operations in any organization is not a simple task. Broadly there are two ways to implement six-sigma in an organization. First is that a separate organization provide the service of six-sigma to the business model. Here the six-sigma model runs through the independent organization and helps to analyze the impact of the changes made in the organization. Second is by appointing a leader, Here the leader should be highly proficient in all the technical aspects of six-sigma and statistics. A higher degree of six-sigma expertise in a project is handled by black-belt (six-sigma methods and tools), if the project is more complex, it is led by Greenbelt.

6. FORD

Ford's successful implementation of six-sigma eliminates around $2.19 billion waste over last few decades. This issue of waste was resolved by implementing Lea Six-sigma techniques, to clear all the problems regarding waste. The company's methodology on eliminating waste since last decade and quality improvement identified a great impact on the operations of the company. The company's six-sigma model helped them to save a billion bucks globally. Six-Sigma saved Ford from many issues like insufficient productivity, the deprived source of resources, environment unfriendliness and low client satisfaction (Nair, 2018).

7. CONCLUSION

There are various approaches to enhance the productivity and quality and of any manufacturing company. In this paper, an effective research is done on the quality control tool and techniques adopted by both automobile and aerospace industries. With these tools, organization productivity and quality testing are proclaimed successful over the last few decades. The quest for better quality and productivity is never ending process as the market has become highly competitive and the need for customer satisfaction is important to gain a better market share. Six-sigma is a prominent tool utilized by many industries and its application in a business environment is booming up with no bounds. Many companies have implemented it effectively in order to reduce the defects in the goods manufactures and to eliminate waste and to completely enhance their business growth.

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