Continuous Improvement Through Integration of Quality Tools

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Abstract

Continuous quality improvement is now the focus of research and application in quality engineering. To achieve continuous improvement, it's necessary to integrate quality tools and to plan, design and control the whole process of creating quality. Based on the extensive literature review and the philosophy of concurrent quality engineering, the paper analyzes the relationships among major quality tools such as QFD, FMEA, DOE and SPC and presents a basic model and structure for the integration of quality tools.

Key words: Concurrent quality engineering, Integration of quality tools, Continuous improvement

1. Introduction

To keep or gain competitiveness in the market place, manufacturing business companies are required to continuously improve quality and service, reduce cycle time and cost. Unfortunately, continuous quality improvement has not been successfully implemented in manufacturing industries, it remains a concept to be striven for. How to implement this simple concept and develop a practical roadmap for continuous improvement is difficult to solve. For a manufacturing business, quality begins with conceptual design and ends with the end use of the product. If we take a look at the creation of "quality", quality is comprised three parts: quality of design, quality of conformance (meaning how well a manufacturing process meets quality specification given by design), and quality of service. The product quality is determined by the former two parts. Traditionally product design, manufacturing and service departments are separated and "over the wall" was a common practice, and customers' needs and wants were not communicated within the company This resulted in long development time, poor quality, high cost, loss of business opportunities and finger-pointing between departments.

From 1980's, with the fierce global competition, many manufacturing companies realized the importance of achieving competitive advantages through improving quality. To achieve high quality, Motorola initiated Six-Sigma program which is now widely adopted by businesses all over the world. During the implementation of Six-sigma, many companies learned from their experience that Six-sigma is not just "manufactured", it is "designed into the product" since design determines the inherent quality. Some experts claimed that design contributes at least 80% of quality. If it is true, we can assume that at least 80% quality problems may be caused by poor design. That's why GE started DFSS(design for six-sigma) training for its engineers.

In the mean while, to improve quality during the process from design to manufacturing and service, many quality tools are being widely used, such as the magnificent seven tools, Quality Function Deployment (QFD), Failure Mode and Effects Analysis (FMEA), Statistical Process Control(SPC) and Design of Experiments (DOE) etc.

Today, there are many software packages of QFD, FMEA, and Statistical software that includes DOE/SPC. But all these software tools are standalone. In fact, all these tools are correlated and some of them should share common database. Since they don't share a common database, it is very difficult for the engineers to have a big picture of the product and its processes. And it is difficult to achieve continuous improvement.

From concurrent quality engineering point of view, product design and process design should be integrated to achieve design for manufacturing (DFM). If there exists a common plate form on which these software tools are built, It will be rather easy for a cross-functional design team to share data, reduce cycle time and improve quality.

This research will focus on the integration of quality tools from product design to process control to achieve continuous quality improvement from product design to manufacturing. The tools include Quality Function Deployment, Failure Mode and Effect Analysis, Design of Experiments, Statistical Process Control and Benchmarking etc.

The advantages of the integration include:

(1) Maintain the data integrity.
(2) Easy to implement continuous improvement
(3) Easy to implement cross-functional designing even though design engineers and manufacturing engineers are in different places.
(4) Process optimization can be achieved with different tools
(5) Easy to keep track of process changes
(6) Easy for process documentation
(7) Easy for training new engineers.

2. Literature Review

The concept of continuous quality improvement is not new. Deming(1994) presented his continuous improvement philosophy based on PDSA(or PDCA) cycle. Juran(1988) advocates a ten-step quality planning process in an input-output format which aims at continuous improvement. And his approach is very similar to the Japanese quality function deployment approach (Kolarik, 1995). Both PDSA and Juran's ten-step quality planning are general concepts without explanation of how quality tools support or incorporate in the concepts. T. N. Goh (2000) presents a "seven S" approach highlighting a strategy for the effective deployment of statistical engineering. He also points out that "it is important to recognize that these tools are most effective when applied in an integrated fashion." But he does not provide a roadmap for the integration of quality tools. Taguchi (1986) divide quality improvement activities into off-line quality planning and on-line quality control. The activities of off-line quality planning include system design, parameter design and tolerance design. System design is a high level design based on specific engineering technology. Parameter design is to optimize the product/process parameters using design of experiments(esp. Taguchi's orthogonal arrays). In other words, parameter design is to select the best product or process parameters to achieve the best output in terms of quality. Tolerance design is to achieve the robustness of quality characteristics based on parameter design and find out the tolerance settings for each parameter. In fact, the key factors identified through off-line quality planning can also be used for determining what to control and how to control in on-line monitoring and control. Kailash C Kapur(1993) gives a structure of quality engineering based on Taguchi's philosophy . Susan M. Sauchez etc(1993) presents that QFD and DOE are useful for off-line product design. Based on Clausing's Four-phase Model (Cohen, 1995) of QFD, the deployment process from voice of the customer(VOC) to voice of the engineering(VOE, including product/process planning and control) is a continuous flow in which FMEA, DOE, SPC and other quality tools can play important roles.

In his FMEA book, D.H. Stamatis (1995) presents a roadmap of product engineering and FMEA which illustrate the joint use of QFD, FMEA, DOE and SPC(see Fig. 1). He Zhen (2000) presents a general continuous quality improvement model and gives a flow chart for manufacturing process continuous improvement based on the integration of DOE and SPC.

From quality engineering point of view, to continuously improve product/process quality. It is necessary to integrate all the quality tools as well as quality data and reduce quality bottlenecks systematically.

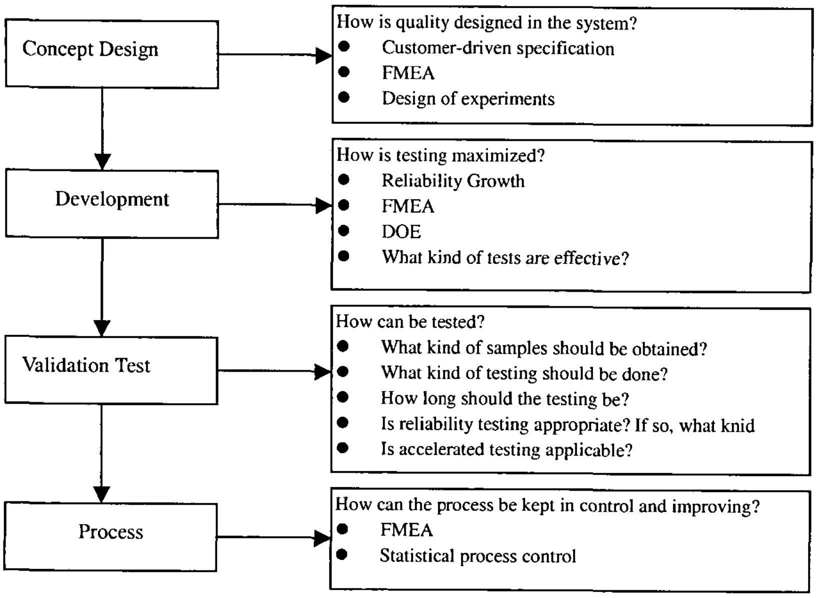

Fig. 1 The roadmap of product engineering and FMEA

3. Integration of Quality Tools

3.1 Analysis of the Relationship between Quality Tools

As mentioned above, different quality tools are used in different stages of creating quality. To achieve integration of quality tools, it's necessary to analyze their relationships.

(1) QFD and FMEA

QFD is a tool that translates the customers' requirements, part characteristics, manufacturing operations and product requirements. FMEA is to find out the potential failure modes within a system, a product or a manufacturing/ service process. QFD and FMEA have a lot in common in terms of continuous improvement. QFD must be performed before a system FMEA. With QFD results, it's very helpful for the cross-functional design team to identify the followings during FMEA.

- What are the key customer requirements.
- How the reliability and safety of a product relate to its engineering characteristics.
- How the severity of a failure mode relates to customer's requirements.
- Create a systematic picture for system FMEA.
- Reduce subjective bias toward the evaluation of Severity(S), Occurrence(O) and Detection(D).

Also the results of FMEA can be very

useful for re-evaluating the House of Quality(HOQ) and target setting of quality planning in QFD.

(2) QFD and DOE/SPC

One of the key things for building HOQ in QFD is to clearly identify the relationship between different product quality characteristics, product quality characteristics and process quality characteristics, part quality characteristics and process parameters. In building the correlation matrix, the correlation is determined by subjective experience of the cross-functional team. If the judgement of the team has some bias, the result of QFD is questionable. Philips J. Ross (1988) points out that DOE can be used to identify the relationship between "what" and "how" in HOQ. It's not possible to identify each cell of the matrix through DOE. The correlation is determined by engineering knowledge and/or experience. But if there are many interactions between factors, DOE is quite effective.

QFD provides guidance for selecting output responses in DOE during product/process quality optimization. Since QFD closely relates VOC and VOE, QFD also provides how to operationally define a process before implementing process control using SPC.

(3) DOE/SPC and FMEA

DOE/SPC includes many statistical tools for identifying the significant factors that bring about failures in FMEA analysis, especially when many factors and their interactions may influence the occurrence or severity of a certain failure. For the purpose of screening, fractional factorial DOE, Taguchi Methods or Plackett-Burman design are appropriate tools. The results of DOE can also be helpful for improving FMEA as well as improving product/process design. Also the result of FMEA is very helpful for selecting which process and what quality characteristics should be controlled.

(4) DOE and SPC

DOE is used to identify the significant factors that influence product or process quality characteristics and determine how these factors contribute the output responses of a product or process. Through DOE a product or a process can be optimized. It's obvious that DOE is an active tool for problem solving and continuous improvement. The purpose of SPC is to keep the process statistically in control. From statistical point of view, DOE is to reduce variation and SPC is to control the variation so that the process won't be deteriorate. SPC can tell us which process is a bottleneck and DOE can help us to eliminate it. Also the key quality characteristics and significant factors identified by DOE is helpful for SPC to choose what to control.

3.2 Structure for the Integration of Quality Tools.

Based on the above analysis, we presents the integration structure of quality tools as shown in Fig. 2.

(1) The activities of continuous improvement are divided into design and manufacturing and they are highly integrated through quality tools.

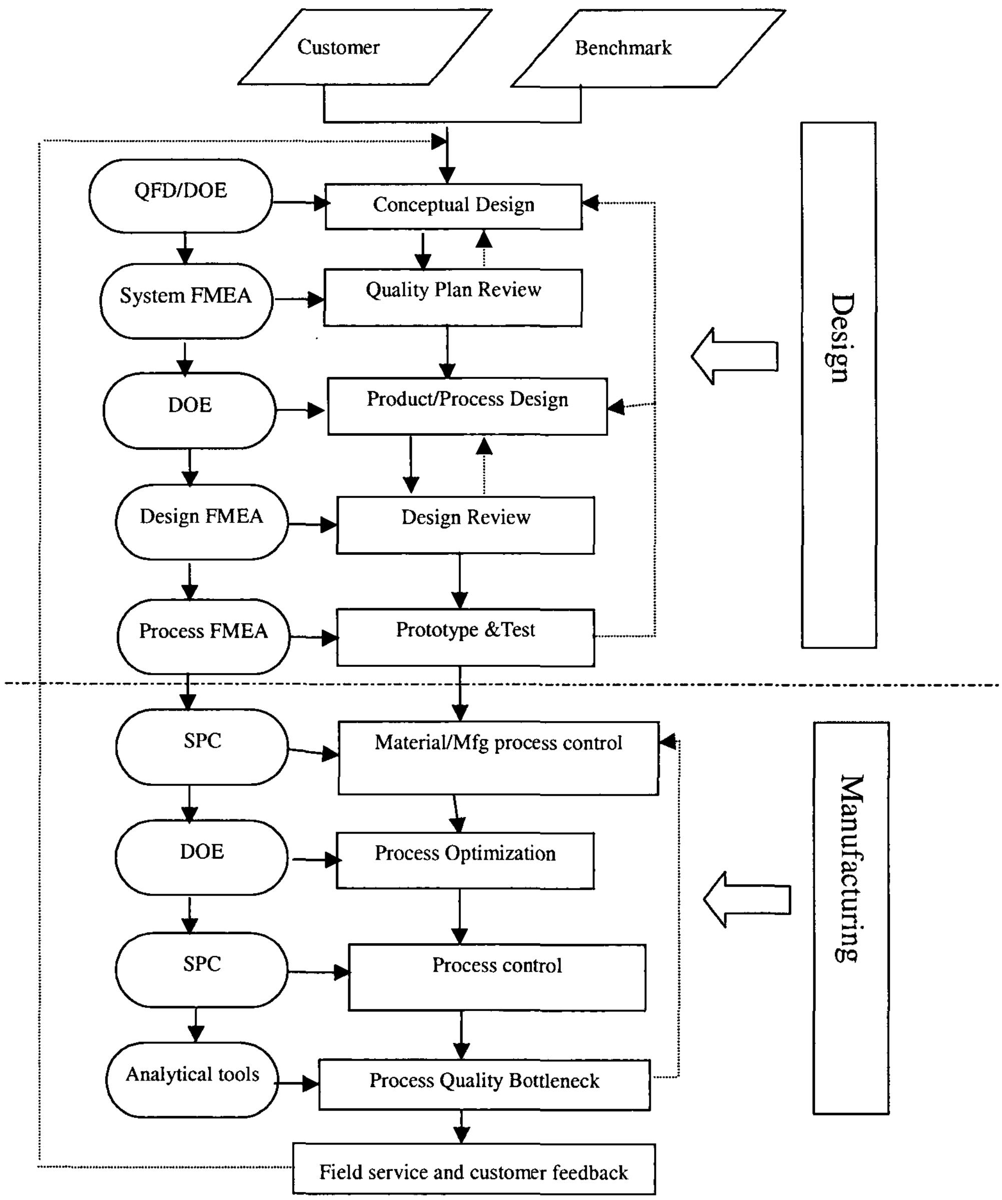

Fig. 2 Structure for quality integration

(2) At the preliminary design stage, there are two major sources of input: VOC and benchmarking information. Based on the engineering knowledge, the key quality characteristics of the product can be identified in QFD and DOE can be used to study the relationship among these quality characteristics.
(3) For the conceptual design, to guarantee its feasibility, reliability and safety, system FMEA can be used during quality plan review. This is key to find out the potential failures of the conceptual design.
(4) During integrated product/process design (IPD), one of the key issues is to design and optimize product/process parameters and their tolerances using DOE. At this stage, CAD/CAM and CAPP are useful for technical support.
(5) A formal design review is conducted using FMEA after completion of IPD.
(6) Before manufacturing, a process FMEA is essential to find out the potential failure in manufacturing process. Process FMEA is also important for determining control point of the process.
(7) During manufacturing process, DOE and SPC can be jointly used to continuously reduce process variation and improve performance.
(8) Field service and customer feedback data can be used for finding out bottlenecks in terms of continuously improvement.

3.3 Database Design for Quality Tools Integration

To implement quality tools integration, it is necessary to design shared databases for different quality tools. Based on the structure of quality integration, we have designed databases for quality tools integration. The databases include customer requirements and competitors benchmarking database, product quality characteristics database, part quality characteristics data, process quality characteristics database, process control database and other corresponding correlation databases. Many template files are also designed so that the results of DOE, SPC based on statistical software can be shared, such as process capability template, measurement system capability template, OCAP(out of control plan) template, DOE template. The correlation and linking of the databases and templates are also designed.

4. Conclusions

In this research we address the necessity, feasibility and advantages for quality tools integration to achieve CQI. And present a structure for the integration of quality tools. To construct a plate form for quality tools integration is a very complex job. Detailed system design is needed for software development.

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