Product Quality Monitoring of Shewhart Chart Based on Function Integration for Manufacturing Factory

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Abstract. This paper summarizes the mathematic principle of Shewhart chart, and gives a description of cutting and machining error for analysis of variety of manufacturing error. The approach of function integration of product quality monitoring using Shewhart chart is discussed in detail for manufacturing factory, which emphasizes the function integration with category tree. And the development of product quality monitoring software is investigated finally.

1. Introduction
Quality monitoring using Shewhart chart is a great achievement and development for quality testing and control in manufacturing factory, which can implement prior monitoring of product manufacturing process avoiding simple certification-test after finished machining, and improve the efficiency of quality control and working condition of quality operator and auditor. Quality monitoring with computer equipment / tools and technology has five gradual steps to execute in manufacturing factory: (a) preparing of quality monitoring, (b) acquisition of quality data with digital tester, (c) drawing of Shewhart chart using computer, (d) analysis of quality state and causing of unusual process, and (e) correcting and summarization. Manufactory factory may achieve distinguished or individual step with automatic measures or manual disposing according respective situation. Five steps of execution of quality monitoring in manufacturing factory are illustrated in figure 1. [1, 2]

Figure 1. Execution of quality monitoring with computer in manufacturing factory
Shewhart chart is the main and very important tool of monitoring process quality in manufacturing factory. The principle of Shewhart chart is probability theory. Generally, in sampling space $S$, for occurring probability of random event $A$, we have

$$\forall H_0, \exists \kappa, \text{ meet } W = \{ \kappa | r_{1/2} \} \text{ or } W = \{ \kappa | r_{1/2} \}$$  \hspace{1cm} (1)

Here, $H_0$ is the original hypothesis, and $\kappa$ is the statistic quantity, $\alpha$ is acceptance domain while $\omega$ is rejection region, and $r$ is one among $Z, \chi^2, F, \ldots$ that $\alpha$ is confidence factor.

Quality monitoring based on Shewhart chart is a key mean for quality management and control. In the mass and large batch production, main monitoring tools include XAve chart/ XAve-R chart, Median chart/ Median-R chart, and X chart / X-Rs chart for measuring values, and C chart, U chart, NP chart, P chart are usual monitoring tools for counting values. In the little batch production, CUSUM chart and EWMA chart are main tools for monitoring producing process. This paper proposes mathematic base of product quality monitoring, and introduces briefly types of Shewhart chart, and practical application of Shewhart chart for manufacturing factory is considered lately in detail. In the end, the computer implementation of Shewhart chart is mainly discussed based on factual application of manufacturing factory. [3, 4].

2. Mathematic Basis of Product Quality Monitoring

2.1. Change Property of Product Quality and Mathematical Summary

2.1.1. Changing is absolute and existed forever in manufacturing process. Because of the changing of cutting and machining condition, manufacturing process must become variety and machining error also waves in cutting and machining process. Especially, cutting heat and cutting force will greatly infect the variety of cutting and machining condition for NC machining, and it will be directly change the machining error of part.

Generally, for output of cutting and machining, e.g. error of dimension, it can be described as following:

$$y = y_0 + (a_1x_t + a_2x_t^2 + \cdots + a_nx_t^n) + \cdots +(a_1x_t + a_2x_t^2 + \cdots + a_nx_t^n) + \varepsilon$$  \hspace{1cm} (2)

where, $y$ is real output, $y_0$ is base that will not change, $x_t$ ( $i = 1, 2, 3, \ldots$ ) is inputting and disturbing in cutting and machining process with changing, $a_i$ is coefficient related to $x_t$, $\varepsilon$ is white noise that changes randomly. Therefore, changing of output is forever according to cutting and machining process.

2.1.2. This changing includes two kinds of type: fixed error and random error. Fixed error will change the characteristic of inspection result, and random error will not. Fixed error will directly infect correctness of inspection value, and random error will infect accuracy of inspection value at some measure.

Generally, if measuring value or counting value of research object is subjected to sampling space, the random error will be obeying to random distribution, i.e., appearance of random error will distribute randomly. Thereupon, appearance of random event is obligated to a big probability, and appearance of fixed error will be very tiny probably. In other words, if measuring value or counting value of research object appears this kind state of little probability, it implies that the process has produced fixed error. Thereof, if inspection result has occurred under random error, it is under control. Otherwise, the inspection value has changed by fixed factors, and it is out of control.

2.2. Monitoring Rules

In Shewhart chart, for measuring value, the sampling distribution of statistical value is normal distribution:

$$x \sim N(\mu, \sigma^2) = N(\mu, \sigma^2/n)$$  \hspace{1cm} (3)
We symbolize that UCL represents upper control limit of value, LCL represents lower control limit of value, and CL represents central line of value. According to equation (1), giving $\alpha=0.0027$ or $\alpha/2=0.00135$, we have

$$\begin{align*}
\text{UCL} &= \mu + 3\sigma, \\
\text{CL} &= \mu, \\
\text{LCL} &= \mu - 3\sigma.
\end{align*}$$

Therefore, Limits of Shewhart chart in equation (4) above can used to monitor the quality variety of manufacturing process with measuring value.

For counting value, the sampling distribution of statistical value is Binomial distribution and Poisson distribution:

(a) Binomial distribution – NP chart and P chart

$$x \sim B(n, p)$$

Equally, according to equation (1), giving $\alpha=0.0027$ or $\alpha/2=0.00135$, we have

$$\begin{align*}
\text{UCL} &= \bar{X} + 3\sqrt{\frac{\bar{X} (1-\bar{X})}{n}}, \\
\text{CL} &= \bar{X}, \\
\text{LCL} &= \bar{X} - 3\sqrt{\frac{\bar{X} (1-\bar{X})}{n}}.
\end{align*}$$

(b) Poisson distribution – C chart and U chart

$$x \sim X(\lambda)$$

Similarly, according to equation (1), giving $\alpha=0.0027$ or $\alpha/2=0.00135$, we have

$$\begin{align*}
\text{UCL} &= \bar{C} + 3\sqrt{\bar{C}}, \\
\text{CL} &= \bar{C}, \\
\text{LCL} &= \bar{C} - 3\sqrt{\bar{C}}.
\end{align*}$$

Consequently, Limits of Shewhart chart in equation (6) and (8) above can used to monitor the quality variety of producing process with counting value.
Shewhart chart has applied in manufacturing factory for long time and got great achievement. Many alternative methods have been adopted to apply continuously Shewhart chart in medium and little batch production, through enlarging the sampling batch of quality item of manufacturing part is a good way. On the other hand, Shewhart chart can monitor large quantity production object in medium and little batch production, for example the process of drilling hole of length-plus lift bar [5].

2.3. Types of Shewhart Chart for Product Quality Monitoring [3-6]
For Shewhart chart for product quality monitoring, there are two modes of large volume production and medium and little batch production. At the same time, there are two kinds of types of measuring value chart and counting value chart for large volume production. Then, CUSUM control chart and EWMW control chart as two main kinds of control chart for medium and little batch production, they are alternative types of Shewhart chart which principle is similar. The detail types of Shewhart chart in product quality monitoring are shown in figure 2.

3. Development of Product Quality Monitoring Software [3-6]
The unified modelling language and tools are adapted to develop this engineering. And Visual c++ is used to programming of product quality monitoring software.

![Figure 3 Application of Shewhart chart based on function integration](image)

3.1. Features of Quality Data in Manufacturing Factory and Application of Shewhart Chart [1-4]
The application of Shewhart chart should be taken in practice for distinguished work shop, and the procedure of quality monitoring application of Shewhart chart based on function integration for manufacturing factory is shown in figure 3. At cutting and machining shop, large volume production of standard part should use $\bar{x} - R$ chart and $\text{Median}$ chart, and casting shop, lacquering shop, and forging shop should mainly apply control chart of number or percent defectives and number or percent faults, including $NP$ chart, $P$ chart, $C$ chart, and $U$ chart. For example, drilling diameter of length-plus lift bar is used $\text{Median}$ chart to monitor, and inside diameter of axial bear is applied $\bar{x} - R$ chart to monitor. On the other hand, casting faults can be monitored adopting C chart, and lacquering quality can be monitored using U chart, and contour and face of ring can be monitored applying NP chart or P chart.
3.2. Function Integration Based on Shewhart Chart [3-6]
Function integration in product quality monitoring software means that all drawing tasks of Shewhart chart are integrated upon category tree on the left part of UI, and through the right key of mouse user can start any type one of Shewhart chart, including XAve-R control chart, Median control chart, X control chart, NP control chart, P control chart, C control chart, U control chart, etc. Figure 4 has illustrated how function integration use popup menu to integrate all starting of Shewhart chart based on divisions of general manufacturing factory in product quality monitoring software.

3.3. Function Program Flow [5, 6]
Visual C++ is used to design this product quality monitoring software. The program flow diagram of inspection data gathering and drawing Shewhart chart is shown in figure 5.

3.4. Computer Implementation Based on Function Integration
Product quality monitoring software takes the category of quality monitoring as the sketch, while function integration of control chart is executive body. The category of quality monitoring is built based on general architecture of manufacturing factory, and function integration of control chart has
considered Shewhart chart as the criterion. Computer implementation of product quality monitoring software, in which casting quality monitoring of bow is illustrated with C chart, is shown in figure 6.

![Computer implementation of product quality monitoring software](image)

**Figure 6.** Computer implementation of product quality monitoring software

4. Conclusion
Summary of the mathematic principle in this paper can be reference to all kinds of Shewhart chart, and description of cutting and machining error can applied in analysis of variety of manufacturing error. As an advanced and meaningful technology, product quality monitoring software can implement prior monitoring of product manufacturing process avoiding simple certification-test after finished machining, and improve the efficiency of quality control and working condition of quality operator and auditor. Product quality monitoring using Shewhart chart based on function integration with visual C++ improve the software usability and it is fitted to apply in quality monitoring for manufacturing factory in actuality.

5. References
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