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Research on product quality control of multi varieties and small batch based on Bayesian theory

Zhangyulei[1]MaoJian[1]
[1](*School of mechanical engineering, Shanghai University of Engineering Science, Shanghai)*

ABSTRACT: -This paper mainly studies the application of statistical process control in multi-variety and small-batch production environment. The paper puts forward the method of quality control based on Bayesian theory. First, Bayesian theory is used to estimate the parameters of the production process. Then Bayesian model is used to control the production of many varieties and small batches based on Bayesian parameter estimation. A Bayesian control model identification method is proposed. Finally, an example is given to verify the feasibility of the method. The results show that this method can be a quality control method for many kinds of small batch products.

Keywords:- multi-variety, small batch; Bayesian theory; quality control

I. INTRODUCTION

Dr. Juran, a renowned expert in quality management, presented at the annual meeting of the American Society for quality management ,Twentieth Century will be in the "productive century" in the annals of history, and the future of twenty-first Century will be the "quality of the century". With the continuous development of social economy and productivity, the international market competition is becoming increasingly fierce, the quality of industrial products has become one of the decisive factors of economic and technological. With the continuous development of global economic integration, the competition of enterprises is becoming more and more fierce. It is very difficult to win the competition in the international market if the product quality is not up to the "world class quality" level [1].

Since 1980s, with the development of economy, the diversification of product is variety, personalized customer demand, the manufacturing enterprises want to win customers, we must adjust their mode of production, the previous single variety and large batch production mode into many varieties, the flow line of small batch production, only in this the mode of production, the company can have a space for one person in the fierce competition [2].

In the fierce market competition, enterprises should be more successful in order to meet the requirements of customer diversity .With the increasing demand of multi variety and small batch products, the market order becomes the main production mode. With the transformation of manufacturing enterprises, the traditional production model has not been able to enable enterprises to have a place to live in, only the mode of production to multi varieties and small batch mode, enterprises will have a place to live in [3] .Zheng Weiwei, et al based on the analysis of the characteristics of multi variety and small batch products and the advantages of intelligent methods, proposed the integrated control model of product variety and small batch production process [4].Yu Zhonghua, et al discussed the method of quality control and put forward the corresponding block diagram based on the characteristics of multi variety and small batch processing. At the same time, the quality control system based on multi variety and small batch was proposed [5] . Liu Chunlei studied process quality integrated system of multi variety and small batch, respectively, from product quality to the product quality in the process of prevention and control, the quality control and prevention of quality defect and negative trends, summarize the quality problems of heavy equipment manufacturing enterprise part family history in the process of analysis and solution [6]. North China Electric Power University Du Yawei et al based on quality control technology are discussed in detail in the group technology and process, proposes the application process of encoding process family classification technology, application of statistical methods for data transformation, the histogram and control chart and process capability index to monitor the production process.A quality management system for multi variety and small batch was developed[7].Ceng Ruicui,from Nanjing University of Aeronautics & Astronautics, studied the method for determining the production process capability of complex products with many varieties and small batches, a method for judging the production process capability of complex product was put forward based on the maximum entropy model [8]. Li Benbo of Chongqing University studied the quality

control tide system of many varieties and small batches, and established a quality retrieval and matching information database based on similar cases. The research on the establishment of quality diagnosis database was establish[9]. In the study of multi variety and small batch production, the research of the Southeast University is to use cluster analysis method to classify the quality characteristics data, so as to establish the quality control chart [10]. The United States, such as Shang Chen proposed the concept of the quality framework, through the Internet to achieve the sharing of quality data and quality diagnosis decision making real-time [11]. Vosniakos George et al. used computer to store and add quality characteristic number. And so on, the discrete quality control management system is established[12] . Lee C.Chang et al. Study on the design and implementation of quality control system in integrated management system [13]. British scholar Dr. Tanncok put forward the strategy of quality management integration, the quality of information into system integration [14].

In this paper, we study the application of statistical process control in multi variety and small batch production environment. Bayesian theory is used to estimate the parameters of the production process. Based on Bayesian parameter estimation, Bayesian model is used to control the production of many varieties and small batches.The basic method is based on the Bayesian theory to establish a double boundary Bayesian control model, the critical value and the allowable deviation as the evaluation criteria . When the probability of fluctuation in the allowable range is greater than the critical value, the process is in the controlled state and continues to run. When the probability of fluctuation in the allowable range is less than the critical value, the mean value of the process is offset. Finally, an example is given to verify the feasibility of the method.

II. BAYESIAN ESTIMATION OF PROCESS PARAMETERS FOR MULTI VARIETY AND SMALL BATCH PRODUCTION

It is assumed that the mean of the quality characteristics of the machining process monitored in the small batch production is θ_n. However, θ_n is an unobservable random variable in the actual production process.However, in practice, we can get a set of observation values of process quality characteristics $x_{n1}, x_{n2}, \ldots, x_{nm}$ Its mean value is $\overline{X}_n = \sum_{i=1}^{m} x_i / m$ For a stable machining process, we can use the constant average linear model [15,16] to characterize the quality of the manufacturing process.

$$\text{Observation equation: } \overline{X}_n = \theta_n + \nu_n \quad (1)$$

$$\text{Equation of state: } \theta_n = \theta_{n-1} + u_n \quad (2)$$

$$\text{Initial information: } \theta_0 \sim (\mu_0, \ \tau_0^2) \quad (3)$$

Among them：

$\overline{X}_n$ --Mean value of observation of N moment mass characteristics ；

θ_n --The mean of the quality characteristics of n process ；

ν_n --Observation error of manufacturing system $\nu_n \sim N(0, \sigma_0^2)$；

u_n --State error of manufacturing system $u_n \sim N(0, \sigma^2)$；

μ_0 --Initial time a priori mean ；

τ_0^2 --Initial time a priori variance；

Based on Bayesian theory, we can see that the posterior distribution is normal distribution, and the posterior mean and the posterior variance are [17]:

$$\hat{\mu}_{n2} = K_n \mu_{n-1} + (1 - K_n)\overline{X}_n \quad (4)$$

$$\tau_n = K_n(\sigma^2 + \tau^2_{n-1}) \quad (5)$$

N stage coefficient,

$$K_n = \frac{\sigma_0^2}{\sigma_0^2 + \sigma^2 + \hat{\tau}^2_{n-1}} \quad (6)$$

For example, after obtaining the first sample value, the following parameters can be obtained:

First stage coefficient:

$$K_1 = \frac{\sigma_0^2}{\sigma_0^2 + \sigma^2 + \hat{\tau}_0^2}$$

The first stage posterior mean: $\hat{\mu}_1 = K_1\mu_0 + (1-K_1)\overline{X}_1$
The first stage posterior variance; $\hat{\tau}_1 = (1-K_1)\sigma_0^2 = K_1(\sigma^2 + \tau_0^2)$

III. CONSTRUCTION OF BIAS CONTROL MODEL

Based on Bayesian parameter estimation, Bayesian model is used to control the production of many varieties and small batches. The control idea of this method is: Remember M as tolerance center,Calculating the posterior probability of the process mean value θ_n according to the sample information in phase n The critical value c and allowable deviation d are used as the evaluation criteria, Specific judgments are as follows:

If $P(M-d \le \theta_n \le M+d \ \overline{X}_n) > c$ that is, the probability of fluctuation in the allowable range 2dis greater than the critical value c, the process is in a controlled state to continue to run; if $P(M-d \le \theta_n \le M+d \ \overline{X}_n) < c$, the process average deviation occurs to take corresponding measures here

$P(M-d \le \theta_n \le M+d \ \overline{X}_n)$, the calculation formula is as follows:

$$P(M-d \le \theta_n \le M+d \mid \overline{X}_n) = \phi\left(\frac{M+d-\hat{\mu}_n}{\hat{\sigma}_n}\right) - \phi\left(\frac{M-d-\hat{\mu}_n}{\hat{\sigma}_n}\right) \quad (7)$$

For the selection of allowable deviation d, can be determined according to the requirements of process capability, the minimum value of a given process capability index is given by a as follows $c_{pk} = \frac{USL - LSL - 2\Delta}{3\sigma} = a$ among them Δ is Process deviation.Then Maximum allowable deviation $d = \frac{(USL - LSL) - 3\sigma a}{2}$ USL and LSL are the tolerances of the process itself.

IV. QUALITY CONTROL METHOD

The Bias and the Bias control model for the process parameters of multi batch and small batch production is establish.The specific steps are as follows: first of all, we can use a constant average linear model to describe the quality fluctuation of a manufacturing process.Initial equation, equation of state and initial information.Then based on the Bayesian theory, we can get the coefficient K and the posterior mean and the posterior variance Then based on the Bayesian theory, we can get the coefficient K and the posterior mean and the posterior variance. Based on the above information, the Bayesian control model is established, the A is calculated according to the process capability index and the maximum allowable deviation is obtained by a d. The probability p is calculated according to the discriminant method, and then compared with the C value. By comparing whether the process is controlled. If P is greater than C, the process is controlled to continue, if P is less than C the process average deviation occurs to take corresponding measures.

V. INSTANCE VERIFICATION

This is the process of turning on the stator core, so that the size (diameter) of the size and precision requirements, the performance has an important influence on the size and precision of the stator diameter after the sequence of processing and the final motor, it is necessary factor to strict process control of the process. The stator core is small batch, which is a typical multi variety and small batch production. The process capability index c_p =2The tolerance requirement for outside diameter is 200±1.35mm The data in the table are expected to be 200Standard deviation 0.3.A set of data obtained by Matlab simulation .

Table 1 process history data (Company:mm)

Sample	X1	X2	X3	X4	X5	Sample mean
1	199.9423	199.9532	200.0037	199.9746	200.6071	200.0962
2	199.9178	200.0828	199.0912	200.4812	199.3225	199.7791
3	200.4590	199.9217	199.8629	200.0295	200.6688	200.1883
4	199.9253	200.1330	200.3727	200.0124	200.1013	200.1089
5	199.6807	200.1176	199.6800	199.7797	200.3000	199.9116
6	200.4810	199.6248	200.2801	199.9908	199.5008	199.9755
7	200.3704	199.7156	200.1051	200.0697	199.8230	200.0167
8	199.9311	199.7777	199.9913	200.1279	199.9166	199.9489
9	199.5482	199.8477	200.0547	199.8882	200.1268	199.8931
10	199.8666	199.9038	199.5305	199.9291	199.4989	199.7457

First of all, according to the above historical data to sort out the relevant information, to determine the initial mean Bias mean, first for the data to estimate the parameters, the estimated value is the average value of the data.

$$\hat{\mu}_{01}=\frac{\sum_{j=1}^{5}x_{1j}}{5}=200.0962,\quad \hat{\mu}_{02}=\frac{\sum_{j=1}^{5}x_{2j}}{5}=199.7791,\ \ldots,\quad \hat{\mu}_{10}=\frac{\sum_{j=1}^{5}x_{10j}}{5}=199.7457$$

According to the principle of conjugate prior distribution, we can know that μ follows the normal distribution,The estimation of the mean variance μ of each of the following estimates μ_0 estimate of variance τ_0^2

$$\hat{\mu}_0=\frac{\hat{\mu}_{01}+\hat{\mu}_{02}+\cdots+\hat{\mu}_{10}}{10}=199.9664$$

$$\hat{\tau}_0^2=\frac{\sum_{i=1}^{10}(\hat{\mu}_{0i}-\hat{\mu}_0)^2}{10}=0.0132$$

Combined with the subjective historical experience, process engineers and quality engineers jointly predict the mean diameter of the stator core is Φ200,Standard deviation is 0.2,according to the formula （4）（5）（6）（8）the control results of the Bias control model are shown in the table.

Table 2 Calculation of Bayesian statistics

$\overline{X}$	Mean variance	parameter Transcendental mean value （mm）	parameter Posterior mean value （mm）	parameter Transcendental variance （mm^2）	parameter Posterior variance （mm^2）	c
200.0962	0.0132	199.7457	200.0598	0.0656	0.029	0.9822
199.7791	0.0132	199.7791	199.7708	0.2572	0.030	0.9769
200.1883	0.0132	199.8931	200.0860	0.1012	0.030	0.9707
200.1089	0.0132	199.9116	200.0549	0.0226	0.030	0.9656

199.9116	0.0132	199.9489	199.9116	0.0635	0.030	0.9429
199.9755	0.0132	199.9755	199.9688	0.1393	0.030	0.8973
200.0167	0.0132	200.0167	200.0064	0.0527	0.030	0.8618
199.9489	0.0132	200.0962	199.9658	0.0129	0.030	0.8334
199.8931	0.0132	200.1089	199.9438	0.0403	0.030	0.7665
199.7457	0.0132	200.1883	199.8365	0.0360	0.030	0.7495

VI. Discussion

According to the evaluation standard (7), the probability is 0.9880、0.9029、0.9811、0.9874、0.9811、0.9892、0.9906、0.9892、0.9874、0.9551、The second sample points less than the average C value of that process quality characteristics may have deviated from the stable state to meet the requirements for process capability, so that this process should look for abnormal, the abnormal cause and to adjust the process.

VII. CONCLUSION

In this paper, we study the application of statistical process control in multi variety and small batch production environment. Using Bayesian theory to estimate the parameters of the production process, a stable process is used to describe the quality fluctuation of the manufacturing process. The observation equation, state equation and initial information are established. The posterior mean and the posterior variance can be calculated according to the given sample values. Based on Bayesian parameter estimation, Bayesian model is used to control the production of many varieties and small batches.The basic method is based on the Bayesian theory to establish a double boundary Bayesian control model, the critical value and the allowable deviation as the evaluation criteria. When the probability of fluctuation in the allowable range is greater than the critical value, the process is in the controlled state and continues to run.When the probability of fluctuation in the allowable range is less than the critical value, the mean value of the process is offset.Finally, an example is given to verify the feasibility of the method.

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