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Application of The Optimization Decision Model of Discrete Random Events in the Lathe Management

Lepeng Chen*, Ruiming Yu, Yuhao Deng, Chen Zhan, Yingqian Yu and Zhiyu Shang

College of Electrical Engineering & New Energy, China Three Gorges University, Yichang, 443002, China

**Corresponding Author: 2282166878@qq.com*

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Abstract: *This paper solves the optimization decision problem of inspection cycle and tool change cycle in automatic lathe management. The historical data is used to verify that the number of produced parts obeys the normal distribution when the lathe is faulty, and the corresponding model is established for the two problems to optimize the solution. An optimization decision model for discrete random events is established, and the advantages and disadvantages of the model are objectively evaluated and the model is popularized and applied.*

1. Problem Background

After the establishment of the People's Republic of China, especially in the past 30 years, the development of machinery manufacturing technology has been accelerated, and the trend of large-scale, precision, automation and complete sets of mechanical products has reached or exceeded the world's advanced level in some aspects. Automated lathes have replaced labor, which has greatly improved production efficiency and quality. For an industrialized enterprise, the lowest cost and maximum benefits are the goals they are pursuing all the way. Therefore, based on this social background, this paper aiming at the problem of automated lathe management., established a cost-effective production strategy and management method [1-4].

There is a continuous process of machining a certain part with an automated lathe. There are two reasons for the failure of the process. Among them, the tool damage accounts for 90%, and the non-tool failure accounts for 10%. It is assumed that the failure of the process is completely random, the probability of non-tool failure is the same when any part is manufactured. The staff checks the part to determine if the process has failed. The cost of the production process is derived from the cost of the wastage parts during the failure, the cost of the inspection, the average cost of the failure to adjust to the normal recovery, and the cost of replacing the new tool when the failure is not found [5-7].

2. Problem to be solved

It is assumed that all parts produced in the event of failure of the process are non-conforming and those produced under normal conditions are qualified. It is necessary to work out the best inspection interval for the design benefit of this process (the number of parts to be inspected once) and the tool replacement strategy.

In the automated production process, failures are inevitable for various reasons, resulting in the production of unqualified parts, tool damage and other factors will lead to this result. The failure of the process is completely random. The probability of non-tool failure is the same when producing any part. When the process fails, it should be checked in time and repaired in time to minimize the loss. After analysis, if the inspection cycle is too long, the failure cannot be detected in time, the cost of loss of parts will be increased, and if the inspection cycle is too short, the cost of inspection will be increased. Therefore, we further analyze the parts produced in the process, establish relevant models, and eliminate faults in time to improve production efficiency and reduce costs.

The problem to be solved is that under the condition that the parts produced during the process failure are non-conforming and the parts produced under normal conditions are qualified, the check interval and tool replacement strategy are optimized for the design of this process. We solve the problem by taking the cost of producing the same number of qualified parts as the objective function. If the defective part is inspected, it can be judged that the process has failed. However, if the tool is replaced only after checking the unqualified product, the unqualified product will be produced during the inspection cycle, which will cause huge losses. Therefore, the tool should be changed after machining a certain number of parts.

We take a tool change interval as a period and consider it in two cases, one is the failure after the tool change, the other is the failure before the tool change. The expectation of the total loss cost of the parts is obtained, and the cost of loss of each part is expected to be obtained as a ratio to the production of the qualified parts.

The second question is the same as the objective function of the first question, and the object of the study is still a tool-changing period, the cost of checking the cost of failure, and the cost of changing the tool. There is also the cost of stopping and consumption of unqualified parts if they are produced.

In the case where there is a fault, there are six items of expenses, namely, the cost of inspection in the absence of a fault, the cost of loss and loss of unqualified parts resulting from the normal process in the case of no failure, and the cost of stopping that. If a failure occurs but the inspection costs are not checked, there is also the adjustment cost in the case of the failure, and the cost of loss and loss of the unqualified parts caused by the failure. The final quantity of qualified parts is divided by division to get the cost of unit quantity parts consumption.

3. Model Assumptions and Symbol Description

(1) Assuming that each product is produced and the time spent is constant and equal.

(2) Assuming that random variables are independent of each other.

(3) Assuming that the tool is fault-free at the beginning of production.

(4) Assuming that the production is not stopped at the time of inspection, and the unqualified parts are inspected before the maintenance is stopped.

4. Data Processing and Analysis

The sample diagram is drawn from the data given by the title. It is found that the sample data is consistent with the cumulative probability of normal distribution, and it is further proved that the sample obeys normal distribution.

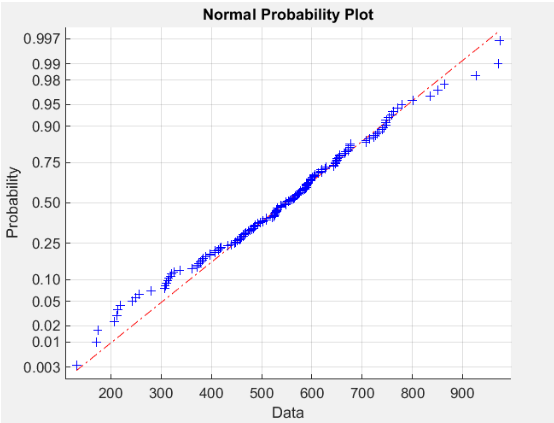

Figure 1: Normal distribution P-P diagram

According to the statistical data of tool life (the number of parts completed when the tool fails), it can be proved that the tool life obeys the normal distribution approximately by drawing the following diagram with Matlab.

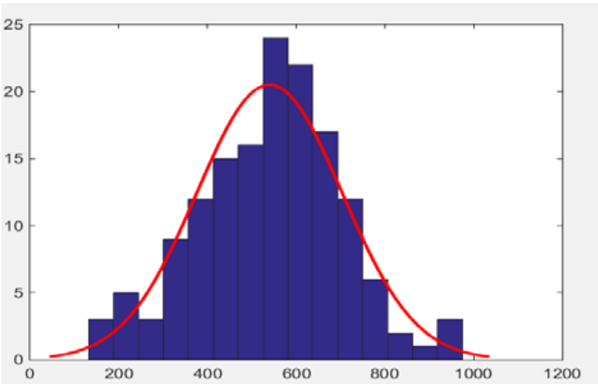

Figure 2: two-dimensional cylindrical statistical chart of tool life

4.1. The Establishment of Model 1

After analysis, it can be concluded that there is an interval between the previous checkpoint and the replacement point between the fault-free cycle and the check period. If a failure occurs during this period, there will be a huge loss. If the cycle is adjusted so that the exchange point coincides with the checkpoint, the unnecessary loss can be avoided.

In the event of a failure after the tool change, the cost of the loss is both the cost of the inspection and the cost of the tool change. The total cost expectation is the product of the cost of the inspection and the probability of failure.

Average expected cost of loss per part

$$L=\frac{U_{total}}{N_{total}}$$

The total cost expectation is the sum of the total cost of the failed and non-failed multiplied by the corresponding probability.

$$N_{\text{total}}=mP_1+\sum_{X=1}^{T_1}(xP_2)$$

Case 1: No failure before tool change

The cost of the loss is

$$U_{\text{total1}}=k+g_1t \quad (g_1=[\frac{T_1}{T_2}])$$

The probability of failure before the tool change is

$$P_1=1-\int_0^{T_1} f(x)dx/0.9$$

Case 2: Failure before changing the tool

The cost of the loss is

$$U_{\text{total2}}=(g_2+1)t+d+((g_2+1)T_2-x)f \quad (g_2=[\frac{x}{N}])$$

The probability of the xth part failing before the tool change is

$$P_2=\int_{x-1}^{x} f(x)dx/0.9$$

$$U_{\text{total}}=U_{\text{total1}}P_1+\sum_{x=1}^{T_1}U_{\text{total2}}P_2$$

4.2. The Establishment of Model 2

Average expected cost of loss per part

$$L=\frac{U_{\text{total}}}{N_{\text{total}}}$$

The cost expectation is the sum of the total cost of the failed and non-failed multiplied by the corresponding probability.

$$U_{\text{total}}=U_{\text{total1}}P_1+U_{\text{total2}}P_2$$

Case 1: No failure before tool change

The loss cost is divided into two parts, which are fixed inspection costs, and the other part, if another process occurs during the tool change, the process is normal and the defective parts are produced.

$$U_{\text{total1}} = k + g_1 t + (c+T_1 f)p_1'$$

The probability that the failure did not occur before changing the tool is

$$P_1 = 1 - \int_0^{T_1'} f(x)dx$$

Case 2: Failure before changing the tool

Loss cost

The cost before the failure (including the inspection cost of the normal operation, the loss of the defective parts when the operation is normal, and the loss of the operation when the operation is stopped)

$$U_{\text{total21}} = (g_2 - 1)t + c + T_1 f p_1'$$

Cost after failure

Inspection fee (If the fault is not detected, the production will continue. If the fault is detected, the adjustment will be made immediately, and one cycle will end)

The average number of inspections from g_2 to g_1 is:

$$\sum_{i=1}^{g_1 - g_2} (0.25)^i$$

So the average inspection fee is

$$U_{\text{total22}} = \sum_{i=1}^{g_1 - g_2} (0.25)^i t$$

Part loss cost (if no fault is detected, production will continue, and the cost of parts will be lost. If the fault is detected immediately, one cycle ends)

Expected value of part damage during an inspection cycle is $\frac{T_2+1}{2} p_2'$, So for the entire update cycle, the expected cost of the parts is

$$U_{\text{total23}} = T_2 \sum_{i=2}^{g_1 - g_2} \left[\left(p_2' \right)^{2n} \right] \times \left(1 - p_2'\right) f + \frac{T_2+1}{2} \left(p_2' \right)^2 \left(1 - p_2'\right) f$$

Adjustment fee

$$U_{\text{total24}} = \left[1 - \left(p_2' \right)^{g_1 - g_2} \right] d$$

In summary, $U_{\text{total2}} = U_{\text{total21}} + U_{\text{total22}} + U_{\text{total23}}$

If required N_{total}

1)The total number of qualified parts that have not occurred before the tool change: It is equal to the case where there is no failure before the tool change

The product of the total number of parts produced and the percentage of qualified parts

$$N_{total1} = T_1(1-p_1')P_1$$

2)The total number of qualified parts generated by the failure before the tool change

$$2)\ N_{total2} = \left[p_1' \int_0^{g_2} xf(x)dx + T_2 \sum_{i=1}^{g_1-g_2} \left(p_2'\right)^i \right] P_2$$

$$N_{total} = N_{total1} + N_{total2}$$

5. Model Results Analysis and Testing

We use Monte Carlo method for model checking. The specific steps are as follows:

(1) Process non-faulty working time X~N (540, 163.9864^2),using Monte Carlo method to simulate generating pseudo-random numbers with 1000 trouble-free working hours $x_i = (i = 1, 2, 3 \cdots 1000)$

(2) Given the tool replacement time and inspection interval T_1 and inspection interval T_2, the corresponding loss cost can be calculated.

Corresponding loss cost is $W_i = \begin{cases} k + \frac{T_1}{T_2} t [X_i] > T_1 \\ d + \frac{T_1}{T_2} t [X_i] = T_1 \\ d + \frac{X_i}{T_2} t + (T_2 - [X_i] \% T_2) < T_1 \end{cases}$

(3) Calculate the cost of a single part loss,

$L_i = \frac{\sum_{i=1}^{1000} W_i}{\sum_{i=1}^{1000} N_i}$, among them $N_i = \begin{cases} [X_i] \geq T_1 \\ \left(\left[\frac{X_i}{T_2}\right] + 1\right) T_2, [X_i] < T_1 \end{cases}$

(4) searching T_1, T_2, and we will find the optimal inspection interval when the average cost per part is the smallest. $T_2 = 18$, the periodic replacement of the tool cycle is $T_1 = 378$, the corresponding cost of a single part loss is 4.16 yuan. Comparing the results of Problem 1 with the

results of Monte Carlo method, it is found that the results of computer simulation are similar to those of the first question, so the first result is relatively stable.

For the normal distribution of $X \sim N(540, 164^2)$, we change the P(P is the proportion of unqualified products in the normal process) and the following table and P-C scatter plot:

As can be seen from the P-C diagram, the change in P affects the loss C of a single part. It can be seen from the P-C diagram that the relationship between P and C is linear and the effect of P on C is significant, and C is sensitive to P. Therefore, in actual management, it is necessary to control the size of P to better control the expected loss of individual parts. We should minimize P and minimize C, so that the benefit is the highest.

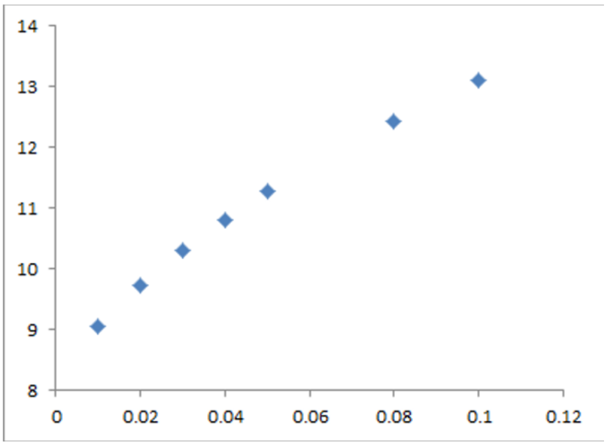

Figure 3 P-C scatter plot

7. Model Improvement

This model can be considered to take different inspection frequencies at different time periods for processing. It is suggested that the probability of failure is low in the case of one hundred parts before machining, so it is not necessary to check, and the frequency of inspection can be increased in the interval where the probability of failure is high.

Improvement 2: Use a parameter to indicate the pros and cons of the part in the qualified parts produced. This parameter (for example: score, "good, better, medium, poor, poor", etc.) is determined by many factors (length, quality), the degree of smoothness) is determined to determine the pros and cons, so that the parameters can be designed more accurately and conveniently to design a check and tool change strategy.

8. Advantages of the Model

①Since there is no specific research scope, the model is cleverly designed to study with a regulation cycle, or a tool change cycle as the research cycle. Make research more convenient.

②The model cleverly uses Monte Carlo method to verify the model and verify that 150 data are normally distributed.

③When designing the objective function, we did not study how to design the scheme to minimize the loss, but to study the cost of the individual parts. The target function setting is very accurate

④In this model, the expected method is used to calculate the value repeatedly, which ingeniously avoids the integral operation when calculating a single statistic, which simplifies the programming process.

9. Shortcomings of the Model

1. Direct adjustment without considering the specific problem of non-tool failure, the cost is too high, you can consider the size of the non-tool problem, and then adopt the optimal way to adjust.

2. Did not take into account the impact of external conditions such as temperature, and some actual discrepancies, if the corresponding data is given, the corresponding research can be carried out.

3. Compared to the inspection of the failure of the downtime, the time to replace the tool and check the parts is negligible, and this will have an impact in the actual production, this idealized processing will bring errors to the model.

10. Promotion of the Model

The model establishes relevant models by applying normal distribution, which is the improvement and promotion of the unit's expected benefits. It is widely applied to the automated management system and has certain guiding significance for the production of multiple processes and multiple parts. In the case of constant production conditions, the product's strength, compressive strength, caliber, length and other indicators; the same organism's body length, weight and other indicators; the same kind of seed weight; measuring the same object error; Directional deviation; annual precipitation in an area; and the velocity component of an ideal gas molecule, and so on. In general, if a quantity is the result of many small independent random factors, then this quantity can be considered to have a normal distribution (see the central limit theorem).

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