Research on the Equipment Support Cost Based on Maintenance Inspection

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Abstract: This paper considers four kinds of expenses: the support cost of maintenance after inspection potential faults, the cost of maintenance after functional faults, the cost of additional economic losses after functional faults and the cost of equipment maintenance inspection. When the corresponding maintenance inspection interval is ensured, the sum of cost can be ensured. Applying this method to equipment maintenance support can further reduce the risk value of equipment failure and the total cost of additional economic losses after the failure, thus greatly improving the economic benefits of maintenance support.

1. Introduction

The cost of equipment maintenance support contains the average maintenance cost in case of potential failure, the average maintenance cost in case of functional failure of equipment, and additional economic losses. In addition, it also includes the average cost of equipment failure detection. Only by reducing the total cost of additional economic loss after the occurrence of functional failure can the economic benefits of maintenance support be greatly enhanced.

Many scholars have carried out in-depth systematic research on equipment maintenance support cost and fault detection. For example, Wang Shaohua uses the strong correlation of multi-dimensional state feature parameters to equipment failure risk, and use the Weibull proportional risk model to establish the state maintenance decision model. In view of the shortcomings of parameter estimation in the typical proportional risk modeling process, the parameter estimation method based on genetic algorithm is used to improve the modeling accuracy [1]. In view of the current state maintenance detection interval decision model, Yan Jun ignores the individual characteristics of the reliability curve of a single component and did not make full use of state detection data, and proposed a state maintenance detection interval decision model based on real-time reliability [2]. Based on the research on the failure rate model of Weibull ratio, Zhang Shixin establishes a fuzzy multi-attribute state detection cycle decision-making model based on the weighted projection folding method, taking the acceptable fault risk as a constraint. The comprehensive optimal decision of state detection interval under multi-factor conditions is realized [3]. Zhang Xianglong studies the decision optimization of the detection cycle under the maintenance mode of missile weapon equipment. In this paper, a maintenance test interval model is established based on the maximum combat readiness and designated combat readiness [4].

Through the analysis of the literature in this field, it can be found that for the problem of equipment maintenance support costs and fault detection, there is no basis for relevant scholars to comprehensively consider the random characteristics of potential equipment failures and functional failures and calculate their probability of occurrence. Construction equipment maintenance support cost model.

2. Manuscript Preparation

We The state of the device includes three types: normal, potential failure, and functional failure. The initial moment of potential failure of the device is a random variable. The time interval between

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the initial moment of potential failure and the time of function failure is also a random variable. Note: The initial moment that indicates the potential failure of the device is a random variable whose probability density function is $f_1(t_1)$; Represents the time interval between the initial moment of the potential failure and the time of the function failure. It is a random variable whose probability density function is $f_2(t_2)$. Based on the potential fault probability density function and the function fault probability density function, considering the number of maintenance tests and the maintenance detection interval, we can further calculate the total probability that the equipment can detect the potential failure and the total probability of the equipment failure. Then the constraints such as the number of maintenance tests and the availability of the equipment are specified. On the basis of this, it combs the various expenses involved in the equipment guarantee process and constructs the objective function; Finally, the optimal interval value of equipment maintenance test is determined.

Firstly, the probability of potential failure can be detected when the equipment is detected within a certain period. When the maintenance test interval is, the probability that the device will detect a potential failure at the first test is

$$P_{11} = \iint\limits_{\substack{t_1<\tau \\ t_1+t_2>\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 \tag{1}$$

The probability of detecting a potential failure at the $i(i \geq 2)$ th test is

$$P_{1i} = \iint\limits_{\substack{(i-1)\tau<t_1<i\tau \\ t_1+t_2>i\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 \tag{2}$$

If the total number of device tests is n , the probability of detecting a potential failure at the n th test is

$$P_{1n} = \iint\limits_{\substack{(n-1)\tau<t_1<n\tau \\ t_1+t_2>n\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 \tag{3}$$

Therefore, the total probability that the device can detect potential failures when testing is

$$P_1 = \sum_{i=1}^{n} P_{1i} = \sum_{i=1}^{n} \iint\limits_{\substack{(i-1)\tau<t_1<i\tau \\ t_1+t_2>i\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 \tag{4}$$

Then consider the probability that the device will fail in a certain period. The probability that the device will fail before the first test is

$$P_{21} = \iint\limits_{t_1+t_2<\tau} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 \tag{5}$$

Functional failure may occur when the device is normal at the first test but before the first test. The probability of a device's functional failure between the $i-1$th detection and the i th detection can be expressed as

$$P_{2i} = \iint\limits_{\substack{t_1>(i-1)\tau \\ t_1+t_2<i\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 \tag{6}$$

The probability of a device's functional failure between the（$n-1$）th detection and the $n(n \geq 2)$ th detection can be expressed as

$$P_{2n} = \iint\limits_{\substack{t_1>(n-1)\tau \\ t_1+t_2<n\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 \tag{7}$$

Therefore, the total probability of a device's functional failure is

$$P_2 = \sum_{i=1}^{n} P_{2i} = \sum_{i=1}^{n} \iint\limits_{\substack{t_1 > (i-1)\tau \\ t_1 + t_2 < i\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 \tag{8}$$

During a certain period of time, during the support of the same type of equipment, the costs involved in each equipment include: average maintenance costs in case of potential failure of the equipment, average maintenance costs in case of functional failure of the equipment, and additional economic losses. In addition, the average total cost(cost) of the equipment's previous fault detection is also included in the support process of the same type of equipment. Therefore, the total cost of equipment maintenance support can be expressed as:

$$\begin{aligned} \mathrm{C} = \; & N\left[C_1 \sum_{i=1}^{n} \iint\limits_{\substack{(i-1)\tau < t_1 < i\tau \\ t_1 + t_2 > i\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 + \left(C_2 + C_2'\right) \sum_{i=1}^{n} \iint\limits_{\substack{t_1 > (i-1)\tau \\ t_1 + t_2 < i\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 \right] + \\ & N\left[C_3 \sum_{i=1}^{n} i \iint\limits_{\substack{(i-1)\tau < t_1 < i\tau \\ t_1 + t_2 > i\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 + C_3 \sum_{i=1}^{n} (i-1) \iint\limits_{\substack{t_1 > (i-1)\tau \\ t_1 + t_2 < i\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 \right] \end{aligned} \tag{9}$$

3. Example Analysis

A department is equipped with a certain type of electronic equipment. The number is 30. The main role is to implement power inspection operations. Through the statistical analysis of the collected fault data and the survey of the users, the potential fault time and the functional fault time of this type of electronic device are subject to the exponential distribution respectively. Among them, the device's potential failure probability density function is: $f_1(t_1) = 0.0005\mathrm{e}^{-0.0005 t_1}$. The device starts from the initial moment of potential failure and its function failure probability density function is: $f_2(t_2) = 0.0008\mathrm{e}^{-0.0008 t_2}$. The average maintenance cost in case of potential failure detected by the equipment is 46000, the average maintenance cost in case of functional failure of the equipment is 21000, the additional economic loss element is 32000, and the average cost of all electronic equipment fault detection is 16000. Determine the cost of equipment maintenance support.

Solution:

According to the potential fault probability density function and the functional fault probability density function, the total probability that the device can detect the potential failure is calculated separately.

The total probability of potential failure of the equipment is

$$\sum_{i=1}^{n} \iint\limits_{\substack{(i-1)\tau < t_1 < i\tau \\ t_1 + t_2 > i\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 = \sum_{i=1}^{n} \mathrm{e}^{-0.0005 i\tau} \left(\mathrm{e}^{0.0008\tau} - 1\right)$$

The total probability of functional failure of the equipment is

$$\sum_{i=1}^{n} \iint\limits_{\substack{t_1 > (i-1)\tau \\ t_1 + t_2 < i\tau}} f_1(t_1) f_2(t_2) \mathrm{d}t_1 \mathrm{d}t_2 = \sum_{i=1}^{n} \mathrm{e}^{-0.0005(i-1)\tau} \left(1 - \mathrm{e}^{-0.008\tau}\right)$$

It can be seen that when the equipment detects a potential failure, the average maintenance cost in the case of a potential failure, the average maintenance cost in the case of a functional failure of the equipment, Yuanhe's additional economic loss element, and the average total cost(cost) of the equipment's previous fault detection. yuan. Calculate the cost of maintenance support for equipment as

$$C = 30\left[46000\sum_{i=1}^{n} e^{-0.0005i\tau}\left(e^{0.0008\tau}-1\right)+\left(21000+32000\right)\sum_{i=1}^{n} e^{-0.0005(i-1)\tau}\left(1-e^{-0.008\tau}\right)\right]+$$

$$30\left[16000\sum_{i=1}^{n} i e^{-0.0005i\tau}\left(e^{0.0008\tau}-1\right)+16000\sum_{i=1}^{n}(i-1)e^{-0.0005(i-1)\tau}\left(1-e^{-0.008\tau}\right)\right]=5.46\times10^{6}$$

4. Conclusion

On the basis of considering the randomness of the potential failure of the equipment and the function failure, this paper calculates the total probability of potential failure and the total probability of equipment failure. Taking into account the average maintenance cost in case of potential failure, the average maintenance cost in case of equipment failure, and the additional economic loss, in addition, the average cost of equipment failure detection is also included, and the total cost of equipment maintenance support is established. model. This method can reduce the risk of equipment failure, reduce the cost of additional economic loss, and further improve the economic benefits of equipment maintenance support.

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