Research on the Combination Methods of Spare Parts Consumption Data and Consumption Models

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Abstract: Through making an analysis of the problem of lacking of spare parts consumption data in some environments, this paper combines spare parts consumption data in different environments, applies equipment reliability theory and probability theory to establish spare parts consumption combination models. The predictive precision of combined model applied to predict the short-term consumption of spare parts can be enhanced effectively by using the information of different models synthetically. The calculation method could be used to solve the difficult problem of developing a reserve program of spare parts since it is not easy to find out spare parts consumption rule. The models provide a theoretical basis for calculating reserves of spare parts scientifically and have the vital important guiding significance.

Keywords: spare parts consumption data; different environments; spare parts consumption model; combination methods

1. Introduction

Many scholars have made scientific researches on spare parts consumption. Ni Xiancun uses the concept of the repair degree and improves the proportional hazards model based on general renewal process. The parameter value is estimated by analyzing failure data and then the number rotables are calculated based on Monte Carlo simulation. An example is given and the results of various maintenance policies with and without considering covariates are compared and analyzed. Results show that the model has a larger practical value [1]. Zhao Jianzhong improves on search mode of APSO and weighted method of least squares support vector machine. Then the consumption forecasting model of missile spare parts is established based on RS, EW and WLS-SVM with APSO, and realization process is analyzed. The example results show that the combinatorial forecasting model has better forecast precision and important applied value in the course of consumption forecasting of missile spare parts [2]. Li Dawei uses the initial spare parts scheme as prior information and proposes the regulate method of spare parts in incipient operation based on the Bayes method. Finally, the simulation example shows that the method proposed is feasibility. Comparing with classical methods, the method proposed can improve the accuracy of spare parts consumption estimation and has good steadiness. So the more rational spare parts scheme can be formed [3]. According to different maintenance times, the maintenance method can be classified roughly as periodic maintenance, condition-based maintenance and corrective periodic maintenance. What’s more, periodic maintenance is preferred in the situation that failure rate of the equipment increases with the time, meanwhile other maintenances are not applicable within; Condition-based maintenance is suitable for the equipment, of which the failure rate increases slowly with the time; Corrective maintenance is well recognized in the situation that the failure rate will not increase with the time, or failure rate increases with the time but the preventive maintenance cost is more than equipment breakdown loss. Some will combine different maintenance methods for use. For example, some equipment basically adopts a combination of periodic maintenance and corrective maintenance, meanwhile, some parts of the equipment will adopt condition-based maintenance, when the equipment is under a certain level of periodic maintenance. In the case of condition-based maintenance, if the reliability of a unit falls below a certain prescribed value, the unit replacement maintenance should be adopted; if some parts are broken before condition-based maintenance, we should immediately conduct unit replacement maintenance. A certain amount of condition-based replaced units should be stocked according to equipment maintenance requirement. If the stock is too small, a completed equipment maintenance task can hardly be guaranteed; if the stock is too big, the caused backlog will affect the economic benefits [4]

However, through analyzing the scientific researches on spare parts consumption, we could find that few papers have been published as of now regarding the combination of spare parts consumption data, which is formulated by combining spare parts consumption rules under both periodic maintenance and corrective maintenance.

Based on the abstraction of above problems, a general solution is given to such kind of problems.

2. Combination of Spare Parts Consumption Data with Time Variation

Under many circumstances, the sample of spare parts consumption in a unit is small, so expanding the spare parts consumption data is an effective method to increase the fitting precision. In order to expand spare parts consumption data, this unit could draw on the experience of the pare parts consumption data in other units. It is essential to do research on the combination method of the pare parts consumption data.

At first, it is necessary to educe the reasonable environmental factor. Then according to the reasonable environmental factor, the spare parts consumption data in different environments can be transformed into the equivalent spare parts consumption data in the same environment. So the combination method of spare parts consumption data could be obtained in different environments.

2.1. Environmental Factor

Suppose the spare parts consumption rule of equipment unit is a distribution function concerning the parameter t , and the probability of spare parts consumption at the t_1 time is $F_1(t_1)$ in the first environment; the probability of spare parts consumption at the t_1 time is $F_2(t_2)$ in the second environment; the type of distribution function in the first environment is the same with that in the second environment; the probability of spare parts consumption at the t_1 time in the first environment is the same with that at the t_1 time in the second environment. The formula is

$$F_1(t_1) = F_2(t_2) \tag{1}$$

If the type of distribution function of the spare parts consumption rule of equipment unit is normal distribution, i.e., T_1 ~ $N(u_1, \sigma_1^2)$; T_2 ~ $N(u_2, \sigma_2^2)$, $u_1, \sigma_1^2, u_2, \sigma_2^2$ are respectively the average values and variances of T_1 and T_2. According to the formula (1),

$$\Phi\left(\frac{t_1 - u_1}{\sigma_1}\right) = \Phi\left(\frac{t_2 - u_2}{\sigma_2}\right) \tag{2}$$

According to the stochastic values t_1 and t_2, it is not hard to educe the relation between T_1 and T_2 [5],

$$T_1 = K_N T_2 + B_N \tag{3}$$

In the formula (3), $K_N = \frac{\sigma_1}{\sigma_2}$, and it is name is flex factor; $B_N = u_1 - K_N u_2$, and it is name is translation factor. According to the formula (3), the conversion of the spare parts consumption data in the two different environments, is called the environmental factor method.

When the parameters of normal distribution in the two different environments are known, the environmental factor could be solved and it is a certain value. When the parameters of normal distribution in the two different environments are unknown, the estimation value of the environmental factor could be solved via the spare parts consumption data, then the estimation value of the environmental factor could be used to transform spare parts consumption data.

The distribution function of the environmental factor is also suitable for other types of distribution function of the spare parts consumption rule, for example, uniform distribution and triangle distribution. K_N and B_N are certain values via the parameters of distribution, and they are not stochastic values; K_N and B_N are all have functions of expression, and they are not hard to be calculated and used.

2.2. Combination of Data

Suppose the spare parts consumption data of equipment unit in the two different environments has been obtained. The sample of spare parts consumption in the first environment is z_1, and the sample of spare parts consumption in the second environment is z_2. When the parameters of the distribution in the two different environments are unknown, the conversion and combination of the spare parts consumption data are as follows:

(1) The maximum likelihood estimate method could be used to calculate the parameters of the distribution, then the point estimation values K_N and B_N could be calculated.

(2) According to the point estimation values K_N and B_N , the spare parts consumption data in one environment can be transformed into the equivalent spare parts consumption data in another environment. When the spare parts consumption data in the second environment is transformed into the data in the first environment, the formula is [6]

$$t'_{1j} = \hat{K}_N t_{2j} + \hat{B}_N \qquad j = 1,2,\cdots,z_2 \tag{4}$$

(3) Composite the spare parts consumption data in the two different environments, the combination of the spare parts consumption data are

$$t_{11}, t_{12}, \cdots, t_{1z_1}, \; t'_{11}, t'_{12}, \cdots, t'_{1z_2}$$

In this way, the sample of the spare parts consumption data of equipment unit could be expanded into $z_1 + z_2$.

3. Combination of Spare Parts Consumption Models

Based on the different models, The predictive combined models could be established.

$$\begin{cases} \hat{x}_t = \sum_{i=1}^{m} w_i (f_{ti} + \alpha \varepsilon_{ti}) \quad t = 1,2,\cdots,n \ and \ 0 \le \alpha \le 1 \\ \sum_{i=1}^{2} w_i = 1 \end{cases} \tag{5}$$

where w_1 and w_2 are weight values, and f_{t1}, f_{t2} and $\hat{x}_t$ denote the predictive values of the first model, the second model and the combined model respectively. Assuming that the predictive error drifts around a fixing value, $\alpha\sum_{i=1}^{m} w_i \varepsilon_{ti}$ can be denoted as the constant a, then $\hat{x}_t = a + \sum_{i=1}^{2} w_i f_{ti}$, $t = 1,2,\cdots,n$. Actually, a is the weighted average value of each single prediction model.

4. Conclusion

Through making an analysis of the problem of lacking of spare parts consumption data in some environments, this paper combines spare parts consumption data in different environments, as well the simplification of related problems, using reliability theory and probability theory. The method proposed in this paper can help equipment management personnel to grasp the spare parts consumption rule under condition-based maintenance, and to accurately predict spare parts consumption amount, which provide theoretical basis for proper stock amount of spare parts. The predictive precision of combined model applied to predict the short-term consumption of spare parts can be enhanced effectively by using the information of different models synthetically

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