Research on Consumption Law of Equipment Maintenance Spare Parts

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Abstract: Nearly all the segments about spare parts include acquisition, storage, supplying and management have close connections with the spare parts consumption information. This paper analyzes the basic concept of the consumption law of equipment maintenance spare parts, and demonstrates the influencing factors of equipment maintenance spare parts consumption from three aspects: design factors, use factors and maintenance factors. By analyzing the consumption data of equipment maintenance spare parts, the calculation formula of equipment maintenance spare parts consumption is established. Finally, the validity of the formula is verified by example analysis. Through making an analysis of the maintenance method of maintenance spare parts in some complex equipment and application of the spare parts consumption models based on the calculation method after analying the influencing factors, it could be extended and the spare parts consumption models could also be improved aiming at solving different problems.

Keywords: maintenance spare parts; consumption law; calculation formula; example analysis

1. Introduction

Many scholars have made scientific researches on spare parts consumption prediction. Zhao JZ improves on search mode of APSO and the weighted method of least squares support vector machine, the combinatorial forecasting model has better forecast precision and important applied value in the course of consumption forecasting of missile spare part [1]. Ni XC uses the concept of the repair degree and improves the proportional hazards model based on general renewal process [2]. LI DW 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 [3]. What's more, improved models for spare parts consumption prediction based on exponential smoothing methods or grey models have been developed to avoid the limitations of traditional prediction methods, utilize all the information, and improve the precision of spare parts consumption prediction [4-7]. Through the analysis of the models, it can be found that solving equipment maintenance spare parts consumption problems needs the higher prediction accuracy calculation formula. To improve the equipment maintenance spare parts support military and economic benefit, this paper analyzes the consumption data of equipment maintenance spare parts, and apply the mathematical statistics method to establish calculation formula of equipment maintenance spare parts consumption. The example indicates that calculation formula has high prediction accuracy. Scientific spare parts consumption prediction methods could enhance the equipment maintenance spare parts support efficiency and effectiveness.

2. Analysis of Influencing Factors of Equipment Maintenance Spare Parts Consumption

(1) Design factors

The higher the reliability of the equipment, the less the variety and quantity of maintenance spare parts consumed by the equipment is. Similarly, the stronger the reliability of the equipment unit, the less the variety and quantity of maintenance spare parts consumed by the equipment unit is. Therefore, in the design and development of equipment and its units, the corresponding reliability design is an important factor affecting the variety and quantity of spare parts consumed by equipment and its units [8].

(2) Use factors

The longer the use time of the equipment, the more the number of uses and the greater the use intensity is. Among them, the service time of the equipment may be measured by the number of years and the boot time may be measured. In addition, when the equipment is used, whether it is used continuously or intermittently also has a certain impact on the variety and quantity of maintenance spare parts consumed by the equipment and its units.

(3) Maintenance factors

Since the organized units often contain multiple sets of the same type of equipment, the maintenance levels of different equipment over the years are not the same, in the same year, some equipment does not carry out grade maintenance, some equipment carries out minor repairs, some equipment carries out middle repairs, and some equipment carries out major repairs [9]. When the equipment is in minor repair and middle repair, the repair method is not the same for a certain unit.

3. Statistics and Analysis of Equipment Maintenance Spare Parts Consumption Data

Firstly, the consumption data of various types of equipment are classified and counted. For example, the construction unit may be equipped with multiple types of equipment, so for the same type of power equipment, the

variety and quantity of maintenance spare parts consumed by each equipment over the years, as well as whether the equipment has undergone grade maintenance over the years, and if grade maintenance is carried out, whether minor repair or medium repair is carried out can be obtained through the equipment history book.

Note: For a certain type of equipment, in the i th year, the average time of equipment use is T_i, the amount of equipment used is N_i, the amount of equipment entered into minor repair is N_{Xi}, and the amount of equipment entered into middle repair is N_{Zi}. Taking the data statistics of the past 5 years as an example, the information statistics of the use and maintenance of a certain type of equipment over the years. The actual consumption of certain maintenance spare parts produced by a certain type of equipment over the years is y_{ij}.

The amount of equipment used over the years, the amount of equipment entered into minor repair over the years, and the amount of equipment entered into medium repair over the years are also dynamically developing and changing due to the dynamic development and change of influencing factors [10]. Inevitably, the number of maintenance spare parts consumed by equipment over the years is also dynamically developing and changing. Therefore, it is necessary to establish a mathematical model of the consumption law of equipment maintenance spare parts, and analyze the essential relationship and inevitable development trend between the variety and quantity of equipment maintenance spare parts consumed over the years, the average time of equipment use over the years, the amount of equipment use over the years and other factors.

4. Establishment of Calculation Formula for Equipment Maintenance Spare Parts Consumption

There are many factors that affect the maintenance consumption of equipment, among which the main factors include the use time of equipment over the years, the amount of equipment used over the years, the amount of equipment entered into minor repair over the years, and the amount of equipment entered into middle repair over the years.

For a certain type of equipment, the average time for the use of equipment is T_i, the amount of equipment used is N_i, the amount of equipment entered into minor repair is N_{Xi}, the amount of equipment entered into middle repair is N_{Zi}, and the actual total amount of certain maintenance spare parts of the type of equipment is y_i.

Then, the calculation formula for the consumption of certain maintenance spare parts in the i th year of this type of equipment can be expressed as:

$$Y_i = \alpha_1 T_i N_i + \alpha_2 N_{Xi} + \alpha_3 N_{Zi} + \alpha_4 \tag{1}$$

By using the least squares algorithm and the Lagrange partial differential coefficient method, the specific values of each coefficient in the calculation formula of the consumption of certain maintenance spare parts in the i th year of this type of equipment can be obtained respectively:

$$\alpha_1 = \hat{\alpha}_1, \alpha_2 = \hat{\alpha}_2, \alpha_3 = \hat{\alpha}_3, \alpha_4 = \hat{\alpha}_4 \tag{2}$$

Further, the specific expression of the consumption law of certain maintenance spare parts in the i th year of this type of equipment is obtained as follows:

$$Y_i = \hat{\alpha}_1 T_i N_i + \hat{\alpha}_2 N_{Xi} + \hat{\alpha}_3 N_{Zi} + \hat{\alpha}_4 \tag{3}$$

According to the model and the actual consumption data of some maintenance spare parts in the first year of the equipment, the error of the calculation formula can be further analyzed, and the validity of the calculation formula can be verified. When the error of the calculation formula is within the allowable range, the calculation formula can be used to predict the consumption of a certain maintenance spare part on the equipment in the future.

5. Example Analysis

In the past 10 years, the average time of use, the number of equipment used, the number of minor repair and intermediate repair equipment and the consumption data of the electronic governor of a power supply vehicle of a construction unit are statistically analyzed, as shown in Table 1. According to the consumption data of the electronic governor of the power supply vehicle from 2013 to 2021, the consumption rule is studied, and the actual consumption value of the electronic governor generated by the equipment in 2022 is compared and the error analysis is made.

Table 1. Data statistics of equipment use, maintenance and consumption of certain maintenance spare parts over the years

Name	**2013**	**2014**	**2015**	**2016**	**2017**
Average time to use (h)	520	510	505	508	570
Number of equipment used	130	130	138	138	138
Quantity of minor repair equipment	29	38	39	42	48
Quantity of middle repair equipment	11	18	17	15	16
Electronic governor consumption number	22	23	23	28	29
Name	**2018**	**2019**	**2020**	**2021**	**2022**
Average time to use (h)	581	587	592	627	625
Number of equipment used	149	149	149	162	162
Quantity of minor repair equipment	59	28	27	48	42
Quantity of middle repair equipment	23	19	22	28	25
Electronic governor consumption number	32	30	31	37	35

According to formula (1), using Lagrange partial differential coefficient method, we can get the specific values of each coefficient in the calculation formula of the consumption of the electronic governor:

$$\alpha_1 = 0.000285, \alpha_2 = 0.0465, \alpha_3 = 0.1155, \alpha_4 = 0.0285 \tag{4}$$

Further, the specific expression of the consumption quantity of the electric governor in the first year of the power vehicle is as follows:

$$Y_i = 0.000285 T_i N_i + 0.0465 N_{Xi} + 0.1155 N_{Zi} + 0.0285 \tag{5}$$

According to the average time of use of the power vehicle in 2022, the number of equipment used, the number of minor repair and intermediate repair

equipment, and the above prediction formula, the consumption and estimated value of the electronic governor generated by the power vehicle in 2022 can be calculated.

$$Y_i = 0.000285 \times 625 \times 162 + 0.0465 \times 42 + 0.1155 \times 25 + 0.0285 = 33.725 \approx 34 \quad (6)$$

In fact, the true value of the number of electronic governor consumption generated by power vehicles in 2022 is 35. Therefore, the error generated by the consumption quantity of the electronic governor predicted by the formula is

$$\varepsilon = \frac{|34 - 35|}{35} = 2.86\% \approx 2.9\% \quad (7)$$

Through error analysis, it can be found that the calculation formula of equipment maintenance spare parts consumption established in this paper has high prediction accuracy and can reflect the objective law of spare parts consumption. Similarly, according to the calculation formula, the consumption of other types of maintenance spare parts can also be predicted.

6. Closing Remarks

This paper demonstrates the factors affecting the consumption of equipment maintenance spare parts, presents the methods of acquiring, sorting and analyzing the consumption data of equipment maintenance spare parts, proposes the calculation formula of equipment maintenance spare parts consumption, gives the calculation method of formula parameters, and establishes the mathematical model of equipment maintenance spare parts consumption law.

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