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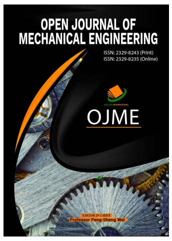

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GENERAL MODELS AND APPLICATIONS OF SPARE PARTS CONSUMPTION FORECASTING

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ABSTRACT

On the basis of various unit maintenance polices when the equipment is under inspection or under different levels of repair, the multi-maintenance policies based consumption rule of spare parts is studied. In addition, the spare parts consumption for the next year is predicted, which solves practical problems. Through improving the generalized model established in this paper, spare parts consumption of equipments group can be further analyzed based on the multi-maintenance policies, resulting in solution to problems including prediction of spare parts consumption of equipments group and the strategy optimization of spare parts stock amount.

KEYWORDS

Maintenance strategies, regular maintenance, inspection, spare parts consumption

1. INTRODUCTION

Many scholars have conducted in-depth studies of methods of spare parts consumption forecasting. 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 method, the method proposed can improve the accuracy of spare parts consumption estimation and has good steadiness. Study showed the more rational spare parts scheme can be formed [1]. A researcher 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]. One of the researcher analyzes the multiple failures of components, studies the component control model based on multi-tier technology, and establishes spare parts consumption forecasting models as Mod- METRIC, Vari-METRIC, Dyna-METRIC through improvement [3]. Others also have done scientific researches on spare parts consumption forecasting [4-8]. Through the analysis of the previous literature, it can be found there are few undertaken research works of the models and methods of spare parts forecasting based on a variety of maintenance strategies.

A certain type of equipment is maintained with a combination of inspection and regular maintenance. There may exist there may exist three maintenance strategies called “non-replacement”, “certain replacement” and “condition based replacement” at the regular maintenance of equipment and there may exist two maintenance strategies called “non- replacement” and “condition based replacement” in the inspection of the equipment component. The determination of the storage capacity of spare parts should be based on the consumption law of the spare parts. How to scientifically predict the spare parts consumption of the equipment under the circumstance of various maintenance is a key issue in this text.

2. ANALYZING OF THE PROBLEM

The maintenance strategy of components determines how the component will be replaced in the next year, therefore it is closely associated with the spare parts consumption generated by the equipment in the next year. In addition, the four main factors including the age of the equipment, next year’s operation time, components lives and remaining lives of components have a direct impact on the spare parts consumption generated by equipment in the next year.

Replacement of equipment components may occurs during regular maintenance or inspection. Possibly it will be replaced at both regular maintenance and inspection, or not replaced at regular maintenance and inspection. Therefore, in order to forecast spare parts consumption in the next year, the number of components replacement at regular maintenance and inspection should be calculated. It is necessary for us to establish a general model for forecasting of spare parts consumption under various maintenance strategies.

3. GENERAL MODELS OF SPARE PARTS CONSUMPTION

3.1 Description of Symbols

θ_i——Unit life span before the i time replacement in the next year, i = 1, 2, 3 ; θ'——Unit residual lifespan before the first replacement in the next year; T_s——Equipment service time; T ——Equipment usage time in the next year; x ——level of equipment repair; x = 1 means minor repairs, x = 2 means medium repairs, x = 3 means major repairs ; L_0——Unit maintenance policy when equipment is under inspection; If non-replacement upon unit maintenance, $L_0 = 0$; If condition based replacement upon unit maintenance, $L_0 = 1/2$; L_x——Unit maintenance policy when equipment is under the x level repair; if non-replacement is upon the x level equipment repair, $L_x = 0$; if certain replacement is upon the x level equipment repair, $L_x = 1$; if condition based replacement is upon the x level equipment repair, $L_x = 1/2$.

3.2 Unit Replacement Number When the Equipment is Under Inspection

The equipment is repaired within the time period of [0,T) , (1) if the result is non-replacement i.e ($L_0 = 0$), the unit replacement number $q_0 = 0$; (2) if the maintenance policy is condition based replacement i.e ($L_0 = 1/2$) , according to the theory of random processes, the probability of unit replacement number $q_0 = 0$ is $P(q_0 = 0) = P(\theta_1' > T)$; the probability of unit replacement number $q_0 = 1$ is $P(q_0 = 1) = P(\theta_1' < T) - P(\theta_1' + \theta_2 < T)$ [9]; the probability of unit replacement number $q_0 = k$ (k = 2, 3, 4,) is

$$P(q_0 = k) = P\left(\theta_1' + \sum_{i=2}^{k}\theta_i < T\right) - P\left(\theta_1' + \sum_{i=2}^{k+1}\theta_i < T\right)$$

The average value of unit replacement numbers when the equipment is under inspection can be obtained, so

$$q_0 = \sum_{k=2}^{+\infty} P\left(\theta_1' + \sum_{i=2}^{k}\theta_i < T\right) + P(\theta_1' < T)$$

As a result, the generalized formula for unit replacement number when the equipment is under inspection can be expressed as

$$q_0 = 2L_0\left[\sum_{k=2}^{+\infty} P\left(\theta_1' + \sum_{i=2}^{k}\theta_i < T\right) + P(\theta_1' < T)\right] \qquad (1)$$

3.3 Unit Replacement Number When the Equipment is Under Various Levels of Repair

Various levels of repair are given to the equipment at T moment, (1) if non-replacement policy is adopted, i.e ($L_x = 0$) , the unit replacement number upon various levels of equipment repair $q_x = 0$; (2) if the policy of certain replacement is adopt, i.e ($L_x = 1$) , the unit replacement number $q_x = 1$; (3) if the result is condition based replacement, i. e ($L_x = 1/2$) , the unit replacement number is

$$\bar{q}_x = P(\theta_1' > T) + \sum_{k=2}^{+\infty} P\left(\theta_1' + \sum_{i=2}^{k}\theta_i = T\right) = 0$$

Therefore, the generalized formula of unit replacement number upon various levels of equipment repair can be expressed as
$q_x = 2L_x(2 - 2L_x)[(1-2L_0)P(\theta_{11}' \le T)] + L_x(2L_x - 1)$ (2)

3.4 General Models for Spare Parts Consumption Forecasting

By adding the next year unit replacement number upon equipment inspection q0 and the next year unit replacement number upon various levels of equipment repair qx , the predicted value of equipment spare parts consumption in the year can be obtained as follow:

$$q = 2L_0\left[\sum_{k=2}^{+\infty} P\left(\theta_1' + \sum_{i=2}^{k}\theta_i < T\right) + P(\theta_1' < T)\right] + 2L_x(2 - 2L_x)\left[(1-2L_0)P(\theta_{11}' \le T)\right] + L_x(2L_x - 1) \qquad (3)$$

Where in: x = 1, 2, 3 , the specific value of x is det ermined according to the equipment service time Ts. Suppose the unit purchasing price is p , the cost of spare parts of the next year is $J = pq$ (4)

4. APPLICATIONS OF GENERAL MODELS

There is a certain type of equipment in certain organization unit with maintenance cycle of 1-3-6, which has been in service for 2 years. The basic information of three kinds of components is shown in Table 1 and maintenance policies of three kinds of components are shown in Table 2. It is stipulated that when the equipment is under various level of repair, if the working time of condition based replaced unit has already exceeded its average life span, unit replacement should be conducted; otherwise non- replacement of unit is adopted. In the next year the planed training time for this equipment is 0.6 year, after training, the equipment will be given with various levels of repair, now a trial of forecasting spare parts consumption and relevant cost of 3 types of units is conducted.

Table 1: Basic information of three kinds of components.

Unit	Unit price (Yuan)	Lifespan (Year)	Service time (Year)
1	1000	$N(0.4, 0.01)$	0
2	1000	$N(0.4, 0.01)$	0.7
3	2000	$N(0.5, 0.02)$	0.1

Table 2: Maintenance policies of three kinds of components.

Unit	Maintenance policy			
	Inspection	Minor repair	Medium repair	Major repair
1	Condition based replace	Condition based replace	Condition based replace	Certain replace
2	Condition based replace	Non- replace	Non- replace	Certain replace
3	Non- replace	Condition based replace	Certain replace	Certain replace

According to the maintenance cycle of 1-3-6, it can be known that the level distribution for equipment repair is minor repair, minor repair, medium repair, minor repair, minor repair, major repair. Since the already spent service time T_s = 2 years, in the next the equipment should receive medium repair after finishing training task. The use time of the equipment for the next year T = 0.5 year. Hereby we firstly forecasts spare parts consumption of the first type unit. According to the known conditions in Table 1, it can be seen that the already spent time for the first unit is 0, in this case, the remaining service time of the first unit equals its entire service time, i.e $\theta_1' = \theta$. The probability density function of the first unit life span is $f_\theta(t) = \frac{1}{0.1\sqrt{2\pi}} e^{-\frac{(t-0.2)^2}{0.02}}$, according to the probability theory and relevant statistical theorems, the probability density function of accumulated life span of k numbers of first units is

$$f_{\sum_{i=1}^{k}\theta_i}\left(\sum_{i=1}^{k} t_i\right) = \frac{1}{0.1\sqrt{2\pi k}} e^{-\frac{(\sum_{i=1}^{k} t_i - 0.2k)^2}{0.02k}}.$$

[10]. The maintenance polices for the first unit when the equipment is under inspection or under medium repair are both condition based replacement so $L_0 = 1/2$, $L_2 = 1/2$. In the case of medium repair and condition based replacement, the time node for replacing first unit $T_0 = 0.3$ year. With the MATLAB program software, we can compute the predicted value of spare parts consumption of the first unit in the next year q = 3.2 . In addition, according to the unit price of the first unit, we can obtain the predicted value of spare part cost of the first unit in the next year J = 3200 . Based on the prediction method of the first unit spare parts consumption, we can calculate the predicted values of next year spare parts consumption amount for the second unit and the third unit, which is 2.6 and 1, respectively; Meanwhile, the predicted values of next year spare parts cost for the second unit and the third unit are 2600 and 2000, respectively. Therefore, the predicted total cost of spare parts for all types of units is 7800. Based on the spare parts consumption amount and cost of the tree types of units, and with comprehensive consideration of equipment maintenance level and maintenance cost, the maintenance personnel can formulate a further plan to store the spare parts for the three types of units.

5. CONCLUSIONS

On the basis of analyzing four factors which include components lives, remaining lives of components, the age of the equipment and next year's operation time, this paper establishes a general model of spares parts consumption forecasting based on various maintenance strategies. Through improving the generalized model established in this paper, spare parts consumption of equipments group can be further analyzed based on the multi-maintenance policies, resulting in solution to problems including prediction of spare parts consumption of equipments group and the strategy optimization of spare parts stock amount. At last, an example is taken to illustrate the applicability of the general model. The general model provides a scientific basis for choosing spares storage amount reasonably. On this basis, the military efficiency and economic efficiency of spare parts support of equipment group can be enhanced.

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