Research on Combination Optimization of Preventive Maintenance of Mechanical Equipment

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Abstract. Modern mechanical equipment has powerful function and complex structure, which puts forward new requirements for equipment maintenance. Aiming at the new requirements of improving maintenance efficiency and reducing maintenance cost, a decision model of combined maintenance is proposed. First of all, determine the specific maintenance parts and their maintenance methods, then get the distribution of maintenance cost and service life according to the historical data, with reliability as the constraint, combined with the length of service replacement model to optimize the preventive maintenance of the action device of a certain type of mechanical equipment, which can effectively reduce the maintenance cost and improve the maintenance efficiency.

1. Introduction
With the development of science and technology, the structure of modern mechanical equipment is more and more complex, and its function is more powerful. At the same time, it puts forward higher requirements for the maintenance of equipment. After the equipment failure, it often causes great economic loss and serious consequences, so the preventive maintenance of the equipment is paid more attention [1]. According to the methods and means of maintenance, preventive maintenance is divided into group maintenance, service life maintenance and condition based maintenance [2, 3]. Because each component of the equipment usually has certain structural correlation, economic correlation and fault correlation, if the analysis is only from the perspective of a single component, it does not meet the actual needs of maintenance [4, 5]. In order to solve this problem, we should try our best to make maintenance decisions for components from the perspective of the whole equipment. By analyzing the correlation between components, we should consider the same type of maintenance work for different components at the same time, and form a combined maintenance strategy [6]. After combined maintenance, the total maintenance cost, maintenance time and downtime of the equipment will be reduced, thus improving the maintenance efficiency and saving the maintenance cost.

At present, the application research of combined maintenance decision-making model is mainly in industrial equipment and energy equipment [7-10], while the research on heavy machinery and equipment in operation is relatively less. In this paper, a typical mechanical equipment is taken as the research object. Most of the action devices of this type of mechanical equipment are of mechanical structure, so it is easier to dismantle and replace them. Therefore, preventive maintenance combination optimization is focused on this action device.
2. Repair parts and repair methods

The maintenance work should first consider to determine the key components to be maintained. The key components refer to the parts or subsystems that will have a significant impact on the operation of mechanical equipment in case of failure. Therefore, first of all, it is necessary to analyze the composition and structure of this type of mechanical equipment, and determine the important functional products of the mobile device. The structure and composition of the mobile device are shown in Figure 1.

At present, the maintenance work of the main components in the mobile device is mainly based on the failure mode and effect analysis (FMEA), so that the main functions, failure modes and failure causes of each component can be determined, and then the maintenance work type of each component can be determined according to the failure consequences of each component.

The severity level of component failure is divided based on the impact of component failure on the system, which is mainly considered from three aspects of safety, economy and task, that is, to analyze the possible harm of component failure to personnel and surrounding environment, the maintenance cost required by the failure and the impact on the normal task of the equipment. Severity can be divided into the following four levels: I - catastrophic failure, II - serious fault, III - General Fault, IV - slight fault.

According to the FMEA results of the walking device of the equipment, it can be seen that the failure of driving wheel, track, balance elbow, hydro pneumatic suspension device, and torsion shaft and load wheel in the moving device has a significant impact on the normal operation of the equipment. Among them, the equipment cannot move after the failure of the driving wheel and track as a whole. Because the track is composed of track shoes, the common maintenance method is group replacement. After the failure of balance elbow, torsion shaft and hydro pneumatic suspension device, the operation stability of the device is poor. Because the common failure mode of hydro pneumatic suspension device is the failure of sealing ring, and the maintenance is convenient, it is usually replaced in groups. The other parts are all mechanical parts, and the common maintenance work is service life replacement. For the inducer, inducer and track adjuster, the probability of failure is relatively small, and the maintenance mode of operator monitoring is usually adopted.

In order to determine the combined maintenance opportunity after the replacement of the service life of each component in the action device, it is also necessary to determine the relevant maintenance costs, mainly including the maintenance preparation costs, specific preventive maintenance and replacement costs and repair maintenance costs after failure. According to the relevant production and
procurement catalogue, and combined with the actual situation, the various costs of each component replaced by length of service are shown in the table below.

Table. 1 The maintenance cost of major component.

| Component          | Capstan | Torque angle | Torsion | Bogie wheel |
|--------------------|---------|--------------|---------|-------------|
| Preparation costs  | 1000    | 1000         | 1000    | 1000        |
| Preventive costs   | 8615    | 10827        | 3563    | 4518        |
| Corrective costs   | 38700   | 34955        | 11450   | 13580       |

3. Data collection and processing

In order to estimate the parameters of life distribution of key components, we searched for the historical data of mechanical equipment from relevant experts, some of which are shown in Table 2.

Table. 2 The percentage of capstan failure time in different periods.

| Interval time / 100km | 0-20 | 20-40 | 40-60 | 60-80 | 80-100 | 100-120 | 120- |
|-----------------------|------|-------|-------|-------|--------|---------|------|
| Expert 1(%)           | -    | 10    | 15    | 25    | 25     | 20      | 5    |
| Expert 2(%)           | -    | -     | 5     | 15    | 40     | 25      | 15   |
| Expert 2(%)           | 10   | 15    | 25    | 25    | 15     | 10      | -    |
| Estimation(%)         | 1    | 5.5   | 11    | 20    | 31.5   | 21.5    | 9.5  |

Assuming that the fault time of each component obeys Weibull distribution, the expression is as follows

\[ f(t) = \frac{m}{n} \left(\frac{t}{n}\right)^{n-1} e^{-\left(\frac{t}{n}\right)^n} \]  \hspace{1cm} (1)

Where \( n \) is the shape parameter and \( m \) is the scale parameter.

By substituting the collected data into the above formula, the parameter value can be estimated by minimizing the \( \chi^2 \) statistics. When this statistic is the smallest, the parameter estimates of the corresponding life distribution of each component are shown in the table below.

Table. 3 Failure parameter estimation of each component.

| Component | Capstan | Torque angle | Torsion | Bogie wheel |
|-----------|---------|--------------|---------|-------------|
| \( n \)   | 11485   | 10654        | 6570    | 12287       |
| \( m \)   | 2.76    | 2.87         | 2.17    | 2.36        |

4. Combined maintenance decision

According to the current maintenance practice, the replacement intervals of driving wheel, balance elbow, torsion shaft and load wheel are 6000 km, 6000 km, 3000 km and 6000 km respectively. The expected maintenance cost per unit time of each component can be obtained by substituting the relevant maintenance cost and failure rule parameters into the cost model of single component service life replacement.

According to the actual operation data records of a heavy machinery and equipment, it is known that the normal kilometers of each component at a certain time are 4800 km, 4900 km, 2000 km and 4650 km. According to the combined maintenance decision-making model established by [6], with reliability greater than 0.8 as the constraint condition, it can be seen that when the driving wheel has been working normally to 6000 km, if other parts can still work normally, the balance elbow, torsion shaft and load wheel shall be replaced at the same time. At this time, the actual working hours of
balance elbow, torsion shaft and load wheel are 6100 km and 3200 m respectively. Lihe 5850 kilometers, meet the relevant requirements, at this time, you can save about 3068.8 RMB.

5. Conclusion
Taking the mobile device of a certain type of heavy machinery equipment as the research object, firstly determine the important functional products through structural analysis of the mobile device, and then perform failure mode impact analysis on the important functional products, and determine the active wheel, balance elbow, The torsion shaft and road wheel mainly adopt the maintenance method of service life replacement. After collecting the maintenance cost and failure data of these components, the parameters are estimated and the combined maintenance of service life replacement is decided. Through the above application analysis, the scientificity and practicability of the combined maintenance decision-making model are verified, which is conducive to improving the level of equipment maintenance support.

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