Application of analytic hierarchy Process in abnormal vibration of Marine machinery

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Abstract: This paper will use analytic hierarchy process to evaluate abnormal vibration of diesel engine in operation. The possible abnormal vibration factors of diesel engine in use are further analyzed to ensure the normal operation of diesel engine in use. Combined with analytic hierarchy process, the hierarchical structure model is determined, and the problems are analyzed from different angles to reduce the influence of subjective factors.

1. Introduction

Diesel engine, as one of the commonly used machinery, precision and its component structure is relatively complex. In the work under the condition of high temperature and high pressure to work for a long time, the frequency of breakdown. For ships, as the main power of diesel engine fails, the consequences will be serious. thus timely and accurate diagnosis of diesel engine fault becomes extremely important [1-3].

By studying the causes of abnormal vibration of diesel engine, this paper qualitatively analyzes the main factors causing abnormal vibration and the corresponding sub-factors by using the improved analytic hierarchy process. Determine its hierarchical structure model, and analyze the problem from different angles to reduce the influence of subjective factors [4].

2. Causes of abnormal vibration of diesel engine

The causes of abnormal vibration of diesel engine are complex and diverse. Marine diesel engine often has abnormal vibration phenomenon, such as relatively high vibration frequency and irregular vibration frequency, etc. Vibration components mainly include valve seat and piston percussion [5]. Abnormal vibration of diesel engine is mainly caused by the following factors:

1. Equipment factors: from the damage degree of equipment and components and the intensity of vibration. The main reason for abnormal vibration of diesel engine is the rotation of the crankshaft related to the abnormal parts, such as unit coupling damage, too large.

2. Human factors: in addition to equipment factors will cause abnormal vibration of diesel engine. Human factors are also inevitable. These include operational errors, lack of concentration, weak safety awareness, poor adaptability, poor professional skills, and violation of management systems.

3. Environmental factors: the environmental factors leading to abnormal vibration of diesel engine are mainly influenced by wetting degree and other factors, which lead to abnormal vibration for a long time.
Management factors: they should be considered in the study, including equipment management, personnel management and system management. For example, equipment maintenance and maintenance are not in place and preventive measures are weak.

3. Analytic Hierarchy Process and its application

3.1. Establish the hierarchical structure model
According to the above drawing happened abnormal vibration of diesel engine, and then combined with the hierarchical structure model. The principle of which is a qualitative analysis of the whole system is divided into three layers. The top layer (A) for the abnormal vibration of diesel engine, the middle layer (B) for the four main factors, the bottom layer (C) 13 main factors for the following factors, as shown in fig 1.

![Hierarchical model of abnormal vibration of diesel engine](image)

3.2. Construct the judgment matrix
After the establishment of hierarchy, the factors subordinate to or affecting the upper layer and each factor at the same layer are compared in pairs to judge its influence on the accident. Then, the corresponding matrix, namely the judgment matrix, is quantified according to the scale specified in advance.

3.3. Calculate the weight vector
The relative weight of each factor in each judgment matrix to its criterion is calculated. The feature vector $W$ composed of the maximum eigenvalue $\lambda_{max}$ in the judgment matrix $A$ is normalized, so the ranking weight of the relative importance of the corresponding factor in the same level and that of A factor in the next level can be obtained.

3.4. Consistency index test
In order to prevent the judgment matrix from being interfered by other factors. It is required that the judgment matrix basically meets the consistency requirement in the actual calculation. The consistency index test should be carried out, and the consistency test formula of the judgment matrix is as follows:
\[ CR = CI/RI \]  

Where, CR is the indicator to measure the consistency of judgment matrix. If CI<0.10, the consistency of the judgment matrix can be accepted; otherwise, the judgment matrix should be modified appropriately, where CI is the consistency indicator of the judgment matrix, which can be calculated as follows:

\[ CI = (\lambda_{\text{max}} - n)/(n-1) \]  

When \( \lambda_{\text{max}}=0, CI=0, \) it is completely consistent. The larger CI value is, the worse the complete consistency of the judgment matrix is. RI is introduced, which can be determined by looking up the table, as shown in Tab 1.

| Dimension(n) | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| RI           | 0.00| 0.00| 0.58| 0.90| 1.12| 1.24| 1.32| 1.41| 1.45|

3.5. Determine the evaluation index and establish the hierarchical structure model

According to the above analysis, abnormal vibration factors of diesel engine can be divided into four aspects: equipment factors, human factors, environmental factors and management factors. The target layer A: abnormal vibration of diesel engine, and the criterion layer: B1 equipment factors, B2 human factors, B3 environmental factors and B4 management factors.

3.6. Construct the judgment matrix and test the consistency

The judgment matrix formed between A-B is shown in Tab 2.

| A  | B1 | B2 | B3 | B4 |
|----|----|----|----|----|
| B1 | 1  | 2  | 3  | 4  |
| B2 | 1/2| 1  | 1  | 5  |
| B3 | 1/3| 1  | 1  | 5  |
| B4 | 1/4| 1/5| 1/5| 1  |

And the corresponding eigenvalues, and

\[ W = (\omega_1, \omega_2, \omega_3, \omega_4) = (0.4499, 0.2509, 0.2309, 0.0682) \]

\[ \lambda_{\text{max}}=4.1767 \]

\[ CI = \frac{\lambda_{\text{max}} - n}{n-1} = \frac{4.1767 - 4}{4 - 1} = 0.0589 \]

Look-up table:

\[ RI = 0.90 \]

\[ CR = \frac{CI}{RI} = \frac{0.00333}{0.90} = 0.0662 < 0.1 \]

Therefore, this judgment matrix is feasible. Therefore, the weight of each factor affecting abnormal vibration of diesel engine is 0.4499, 0.2509, 0.2309 and 0.0682, respectively.
4. Conclusion
1. In the qualitative analysis process, the complex factors in the abnormal vibration of diesel engine are summed up into 4 main factors and 13 sub-factors by using analytic hierarchy process, which makes the results simple and intuitive.

2. In the process of analyzing diesel engine abnormal vibration, the analytic hierarchy process can not only analyze the problem qualitatively and quantitatively, but also obtain the test results intuitively and scientifically. This method has good applicability and is worth popularizing in other fields.

At present, most of the research on abnormal vibration of diesel engine is based on the analysis and summary of the accident after the accident occurs, and the corresponding protective measures are put forward. However, few abnormal vibration may exist in the operation process before the accident occurs, and effective measures are found to reduce abnormal vibration. So it is very important to evaluate abnormal vibration of diesel engine with improved fishbone diagram and analytic hierarchy process.

References
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