

# Research and Optimization of Marine Diesel Engine Index System

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**Abstract.** Aiming at the quality evaluation of diesel engine, this paper analyzes the influence factors of diesel engine quality from the function and general quality of diesel engine, and establishes the detailed index system of diesel engine quality evaluation, which covers all aspects of diesel engine quality. Finally, the degree of discrimination is sorted by the entropy weight theory, and the indexes are optimized and screened.

## 1 Introduction

Due to the wide range of power coverage and low fuel consumption, diesel engine is widely used in small and medium-sized ships. Diesel engine in the process of inhalation of pure air and diesel mixing, and ignition to form high-temperature high-pressure gas, gas pushing the piston downward movement to make the crankshaft rotate and work and drive the propeller to promote the ship. Since the 1980s, with the rapid development of the world diesel engine technology, modern diesel engine has reached a high level of technology, marine diesel engine with high thermal efficiency, low fuel consumption in the whole operating conditions, power and rotational speed range, a lower power volume ratio and power quality ratio, less air consumption, lower temperature, etc., which dominant in small and medium ship power plant [1]. At present, the world's marine diesel engines are mainly high-power high-speed diesel engines, with the development of large-scale ships, more and more high-power medium-speed diesel engine was selected as a ship host, diesel engine is currently the most widely used power plant [2].

As an important part of the marine power plant, the quality of the diesel engine has great influence on the overall operational effectiveness of the ship. Therefore, the quality performance of the diesel engine has become a concern of the development side and the user side, so it is necessary to take effective evaluation method to evaluate the quality performance of the diesel engine.

## 2 Establishment of diesel Engine index system

The first and most important point in the quality evaluation of diesel engine is to establish the corresponding quality evaluation index system, because a good index system is the prerequisite of quality evaluation.

At present, there is a big problem in quality evaluation, that is, there are missing, small, wrong, uncertain phenomena in the research data[3]. However, based on the principle of quality evaluation index system, the overall target of quality assessment should be considered, therefore, when establishing the index system, it is more important that after the establishment of the index system, the quality evaluation of this index system can comprehensively reflect the quality of the system, as for some indicators of data acquisition difficulty to be discussed, can be processed by some data processing methods, when necessary, using qualitative and quantitative methods to evaluate indicators, But not from the data to manufacture indicators.

Depending on whether the parameters of diesel engine are changed with the time of use, the indexes can be divided into static indexes and dynamic indexes. The static index mainly refers to the diesel engine size, the weight, the purchase expense and so on, but the dynamic index refers to the power, the failure rate, the service life and so on index. In view of the complex and changing characteristics of the ship, the requirements of the power system pay more attention to the daily use, so we pay more attention to the dynamic index of diesel engine, so the main object of this paper is the dynamic quality index of diesel engine.

According to the dynamic quality index of diesel engine, it can be divided into diesel function quality index and equipment general quality index. The so-called diesel engine function quality index mainly refers to the diesel engine using functional characteristics of the indicators set up, which is different from the other systems of the non-power system, such as the main drawback of diesel engine is noise, especially low-frequency noise, which poses a great threat to the concealment of ships. In the study of diesel engine quality problem, the noise reduction performance of diesel engine is an important index of diesel engine, which should be included in the quality

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evaluation index system. But for the equipment general quality index, then mainly refers to "six performances" index [4].

### 3 Functional indicators

#### 3.1 Concealment

Concealment is a characteristic that ships avoid being detected by enemy reconnaissance equipment. As a diesel engine, it is the main source of ship heat and underwater acoustic emission, and has the first role in influencing the stealth of ships. For the hidden nature of the ship, it is hoped that the power system noise and external radiation of the less heat the better, the more difficult to detect the better. In the modern war of high technology, with the increasing of electronic, underwater acoustic detection means and infrared reconnaissance means, the requirement of the concealment of the warship is higher, the concealment has a direct influence on the survivability and combat ability of the warship, so it is necessary to classify the concealment as the quality evaluation index of the diesel engine. For ships, there are many kinds of physical fields in navigation, which should be considered in the application of mechanical structure noise, air noise, exhaust temperature and cooling water temperature of diesel engine system.

#### 3.2 Maneuverability

The maneuverability of the ship is mainly determined by the maneuverability of the power plant. Maneuverability is a measure of the capability of the ship to perform navigation and maneuvering tasks, it is an important part of the warship's technical performance. The maneuverability of a ship is mainly reflected in the flexibility of the ship and the time it takes to generate power. For the small and medium ships, the diesel engine is the source of its maneuverability, the maneuverability of the diesel engine influences the survival and combat ability of the whole ship, so maneuverability should be one of the important indexes in the quality evaluation of diesel engine. As a measure of mobility, it mainly considers the maximum speed of warship and the preparation time of diesel engine. The dynamic index of diesel engine can be divided into indicator index and effective index, mechanical efficiency and speed and average speed of piston, and the indicator can be mean indicator pressure and indicator power, effective index can be effective power and average effective pressure.

#### 3.3 Survivability

The survivability of warship is the foundation of the warship's combat capability, and the ship's dynamic system is the carrier of the ship's driving force, its vitality and survival performance naturally affect the whole survival performance of the warship. A dynamic system with good survivability will still be able to provide dynamic support for the successful completion of the

attack or the escape mission in the event of a certain degree of attack, thus survivability is evident in the power system and even the ship's overall importance. Therefore, survivability should also be regarded as an indispensable factor in the quality evaluation system of diesel engine. When considering the survivability index of diesel engine, the probability of stability of diesel engine and the probability of the diesel engine being destroyed (resisting damage) are mainly studied.

#### 3.4 Economical efficiency

Based on the evaluation index of the dynamic quality of the marine diesel engine, the cost of the diesel engine is not considered in the economic index, and the operating maintenance and repair costs of the diesel engine are mainly considered. The operation maintenance cost mainly considers the fuel consumption of the diesel engine in the daily use and the warship endurance. For economic indicators, it can also be divided into indicators and effective indicators. The indicators are divided into indicator fuel consumption rate and indicator thermal efficiency, effective oil consumption rate and effective thermal efficiency. The data of these indexes can be obtained by instrument.

### 4 General indicators

#### 4.1 Reliability

Reliability usually refers to the ability of the system to perform the specified functions within the prescribed time and the prescribed time [5], simply put, the power system is reliable, whether it can be at work for a long time or to work status. For marine diesel systems, the "prescribed function" refers to the diesel engine to generate power and transmission power, the "Specified time" refers to the diesel engine generated this part of the power of the time interval, can be specific to start time, cruise time and reversing time, the "prescribed conditions" can refer to the conditions of the external environment, such as ambient temperature, humidity, salinity, etc., as well as their own conditions, such as the state of cooling or the degree of damage. Considering the specific indicators, we can use the mean time between failures (MTBF) and mission reliability to evaluate the reliability and quality of diesel engine.

#### 4.2 Maintainability

The definition of maintainability is somewhat similar to the definition of reliability, that is, the ability of the system to maintain or restore its prescribed functions during the prescribed conditions and in the specified time, when the system is maintained in accordance with the prescribed procedures and methods. Maintenance is related to whether the system is well repaired, whether it is repaired quickly and whether it can be successfully repaired. The procedures and methods specified here refer to the contents, procedures and methods of maintenance work

according to technical documents, which are not included in the research scope of this paper. In view of the time and function specified by the diesel engine, this paper mainly considers the two indexes of diesel engine's average repair time and maintenance degree (M (T)).

### 4.3 Supportability

Supportability is the system's design characteristics and planning of the resources to meet peacetime readiness and wartime use of the capacity of the requirements. It is mainly reflected in whether the diesel engine system is easy to guarantee, the complete degree of spare parts and the guarantee delay during the use stage. The design characteristic of the diesel engine is to provide power for the ship or other system, and the work done by the diesel engine can provide the power as the prerequisite to make it better and faster and more stable. In order to comprehensively reflect the supportability of the diesel engine, the selected index is comprehensive and not redundant, taking the key index as the principle, considering the average guarantee delay time (MLDT) and the spare parts satisfaction rate as the security index.

### 4.4 Safety

As the security of "six nature", with the improvement of modern science and technology, ship power system is becoming more and more complex, and the safety considerations are gradually getting into people's field of vision. Because in some accidental or extreme circumstances, the factors of personnel are difficult to grasp and evaluate, not easy to study the human activity characteristics, and the operation of the system more or less will have an impact. Some of the usage habits of personnel are often not operated according to the rules and regulations, which often result in accidents that are large or small. This has made a great demand on the security of the system. Safety can be defined as a performance of the system that is used to demonstrate a system's ability to resist dangerous generation and eliminate disasters, thus ensuring that the system does not endanger people's lives and other systems. As a power system of the diesel engine system, a large feature is the energy produced by the large, if not consider its safety factors, the harm caused by immeasurable. And the power system is the lifeblood of the ship's survival, the diesel engine as a representative of the power system, its own security and other systems and

personnel of the potential harm must be considered as the object. Therefore, this paper takes the probability of accident occurrence and the degree of damage as the safety evaluation index.

### 4.5 Testability

Testing is an important activity in equipment maintenance, testability is a particularly important problem in maintainability and safety, and testability becomes more and more important with the development of warship equipment and the need of modern warfare. The so-called testability refers to the ability to determine the state of the system and isolate its internal faults in a timely and accurate manner. It can be said that the testability is in the system does not stop working or before the overhaul of the forward-looking work, it can detect problems early and deal with them when the problem is not serious and uncontrollable, which plays an important role in the process of modern equipment use. For testability, we mainly consider the diesel engine normal working or sub working State of the fault detection rate and the detection of failure after the isolation rate, which is the diesel engine in the test of the key two indicators.

### 4.6 Environmental adaptability

System environment adaptability refers to the ability of diesel engine system to perform its function and performance normally under various environmental conditions during its lifetime. Generally speaking, a diesel engine that works well under harsh conditions can also work normally in a normal environment. The use of diesel engine will be affected by other factors such as low temperature environment, when the temperature decreases gradually, the internal fuel viscosity of the diesel engine increases, the quality of the formed mixed gas decreases, and the combustion process of the diesel engine is affected. For the environmental adaptability of diesel engine, most of them adopt qualitative method to consider, mainly use the feedback of personnel and expert evaluation opinion to decide the environment adaptability of diesel engine, and the environmental stress intensity and the duration of environmental stress can be the index of performance during the evaluation period.

In conclusion, the index system of quality evaluation of marine diesel engine is set up as follows:

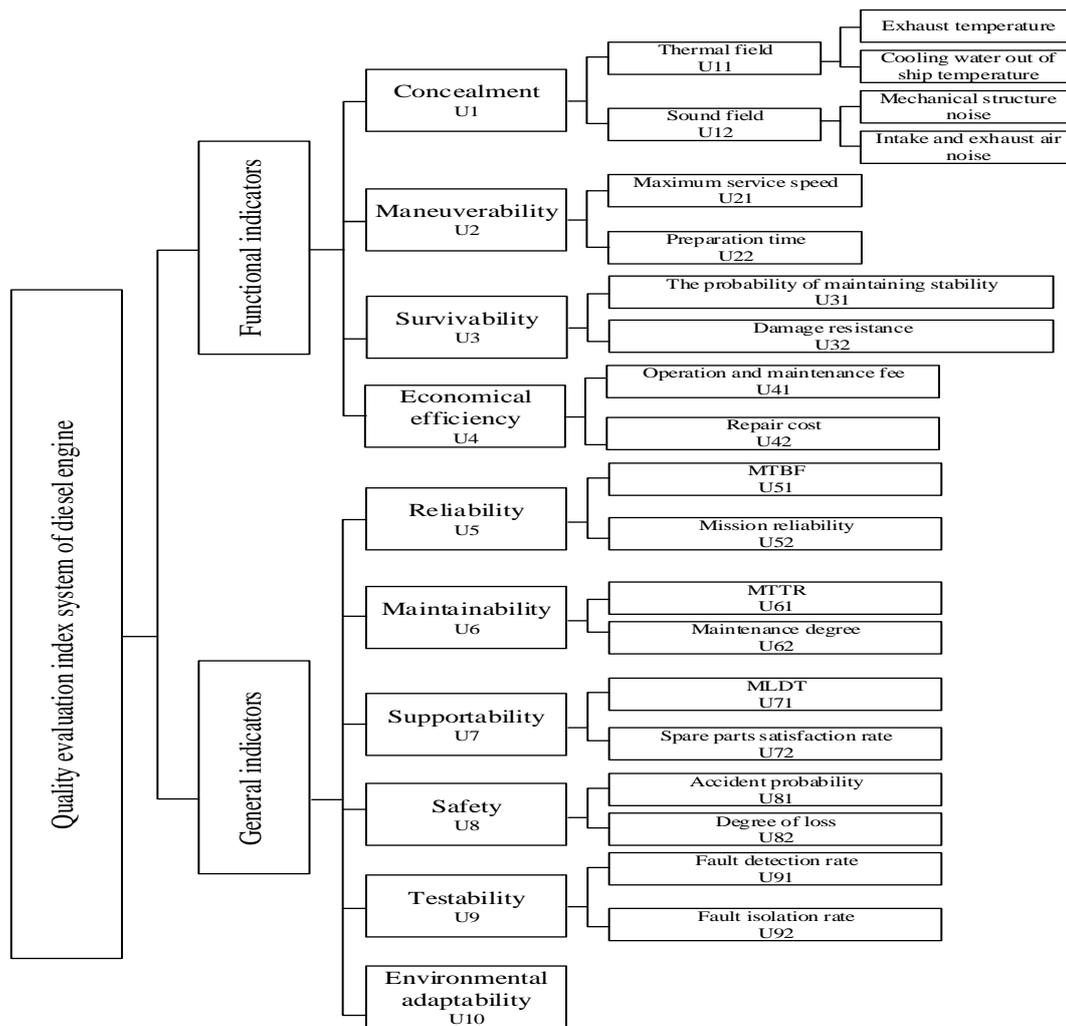


Figure 1. Quality evaluation index system of diesel engine

### 5 Optimization of diesel engine index system

This paper uses the index optimization method based on entropy weight discrimination[6], the entropy value and the entropy weight of each index are computed, then the distinguishing degree of each index is calculated, and the

sorting of the index of the diesel engine is optimized. In order to express, this paper mainly studies the optimization of the first three indexes, and according to the evaluation value of the three-grade index, the evaluation value of two-grade index is obtained, and the classification of the two-level index is actually sorted. The index original value is not present in the table, only the specification quantization value of the metric appears.

Table 1. Evaluation matrix of the quality index of a certain diesel engine

	$U_1$	$U_2$	$U_3$	$U_4$	$U_5$	$U_6$	$U_7$	$U_8$	$U_9$	$U_{10}$
1	0.732	0.604	0.601	0.776	0.631	0.722	0.812	0.817	0.656	0.824
2	0.851	0.733	0.721	0.824	0.921	0.814	0.763	0.624	0.673	0.731
3	0.735	0.819	0.811	0.805	0.701	0.914	0.910	0.735	0.722	0.841

First, the dimensionless matrix is constructed

$$R = \begin{pmatrix} 0.732 & 0.604 & 0.601 & 0.776 & 0.631 & 0.722 & 0.812 & 0.817 & 0.656 & 0.824 \\ 0.851 & 0.733 & 0.721 & 0.824 & 0.921 & 0.814 & 0.763 & 0.624 & 0.673 & 0.731 \\ 0.735 & 0.819 & 0.811 & 0.805 & 0.701 & 0.914 & 0.910 & 0.735 & 0.722 & 0.841 \end{pmatrix}$$

Then the entropy value, entropy weight and discrimination degree of each index are computed:

$$H_i = (0.997 \ 0.993 \ 0.993 \ 0.999 \ 0.988 \ 0.996 \ 0.997 \ 0.994 \ 0.999 \ 0.998)$$

$$W_i = (0.065 \ 0.152 \ 0.152 \ 0.022 \ 0.261 \ 0.087 \ 0.065 \ 0.131 \ 0.022 \ 0.043)$$

$$\rho_i = (0.065 \quad 0.153 \quad 0.153 \quad 0.022 \quad 0.264 \quad 0.087 \quad 0.065 \quad 0.132 \quad 0.022 \quad 0.043)$$

According to the calculation results, the three indices of  $U_4$ ,  $U_9$  and  $U_{10}$  are larger than other indexes, and the entropy weights are smaller, which shows that these three indexes are less important than other indexes, and can be considered in the evaluation index system in the emergency or special circumstances. At the same time, according to the index sorting of the same level, we can get the ranking of importance of each index for screening and optimizing index system.

## 6 Summary

Based on the basic properties of diesel engine, the functional quality index and general quality index are summed up in the dynamic quality index of diesel engine, the function index and general index are refined and analysed, and a multi-level detailed index system of diesel engine quality evaluation is established, which covers all aspects of the quality evaluation of diesel engine. At the same time, the index system is optimized based on the entropy weight theory, which can be used for reference to the quality evaluation of the diesel engine.

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