Construction of Armored Vehicle Diesel Engine Maintainability Evaluation Index System Based on Expert System

Lianjun Zhu[a], Xiao Kong[b]

Drill Training Center, Army Academy of Armored Force, Beijing, China

[a]zljun8888@sina.com; [b]jiningkx@qq.com

Keywords: diesel engine, expert system, maintainability evaluation, index system.

Abstract: Improving the timeliness of diesel engine maintenance for armored vehicles is an important goal of conditional maintenance. How to increase the working time of diesel engines and reduce the downtime are the key issues to be solved in order to improve the equipment readiness rate under the required reliability. When the task is performed in a harsh environment, when a large number of diesel engine failures occur, it is particularly important to improve the timeliness of maintenance to ensure that the task is completed. This article proposes the concept of the maintenance depth of armored vehicle diesel engines, builds an index system of armored vehicle diesel engines maintainability evaluation based on expert system, and elaborates on the evaluation indicators in detail.

1. Introduction

The maintenance in-depth assessment is based on the diesel engine maintainability assessment, and combines the results of the diesel engine failure probability assessment to evaluate the complexity and ease of maintenance of the diesel engine under the current performance state. Maintainability assessment requires the establishment of a systematic assessment parameter system, combined with assessment methods, and the assessment results can be used to guide the maintenance of diesel engines.

Taking the reparability assessment of ship equipment as an example, Zhang [1] evaluated the ship's maintainability through fuzzy analytic hierarchy process based on the ship's maintenance design criteria. Through the verification of an example, the method can achieve the qualitative to quantitative assessment. Wu [2] established regression assessment model and fuzzy comprehensive evaluation method for ship equipment's maintainability evaluation model, which can realize reasonable assessment of maintainability. Gao [3] integrated the indicators of ship maintenance evaluation, and established a reasonable evaluation system at different levels. The research results can be used as the criteria for the maintenance decision of the enterprise. Jin [4] summarized the existing methods for evaluation and analysis of maintainability, combined with the characteristics of the ship, proposed a method for assessing the maintainability of ship equipment. Gong [5] proposed to use the fault tree method to evaluate the maintainability of marine nuclear power plants, and elaborated the specific modeling method and process, and modeled the waste heat removal system of marine reactor as an example.

In terms of other equipment, Zhang [6] comprehensively analyzed the maintainability of military construction machinery and built an evaluation model through the fuzzy comprehensive evaluation method and the analysis of the index system. Tao [7] studied the evaluation of vehicle maintainability design and the evaluation of repair quality, and evaluated the engine with an example. Xiao [8] described qualitatively and quantitatively the steam turbine's maintainability, and proposed a method for establishing the maintainability model, and did a lot of work for the steam turbine's

maintainability assessment. Wu [9] established an evaluation system for the maintainability of civil aviation aircraft through the method of virtual reality.

Based on the analysis and analysis of the structural characteristics of the diesel engine of armored vehicles and the technical standards and specifications of engine maintenance, this paper proposes the concept of the maintenance depth of diesel engines of armored vehicles, builds an evaluation index system for the maintainability of diesel engines of armored vehicles based on an expert system, and evaluates the indicators.

2. Armored Vehicle Diesel Engine Maintenance Depth Concept

2.1 Definition of Diesel Engine Maintenance Depth

With the change of the maintenance method of the diesel engine of armored vehicles from preventive scheduled maintenance to timely and conditional maintenance, the state detection mode, maintenance timing, and maintenance plan should also be adjusted accordingly. In preventive maintenance, the maintenance interval of motorcycles is defined by motorcycle hours, and the maintenance method of diesel engines that are overhauled after use to maintenance intervals requires a large amount of equipment and spare diesel engines for turnover and replacement; the replaced diesel engines need to be sealed, transported, disassembled, inspection, repair, acceptance test and other processes cause part of the maintenance process and work overlap, long cycle, and poor economic benefits; when a large number of diesel engine failures occur in the army, the equipment integrity rate cannot be guaranteed, which affects the completion of combat and training tasks; the timeliness requirements of battlefield repairs are not compatible. Therefore, in the decision-making of the condition-based maintenance of armored vehicle diesel engines, the timeliness of maintenance should be considered, and the impact of comprehensive factors such as maintenance workload, manpower, and time on different maintenance programs should be considered. In order to solve the above problems reasonably, this paper proposes and defines the maintenance depth of the armored vehicle diesel engine as one of the decision goals.

The maintenance depth of the armored vehicle diesel engine is based on the maintainability of the diesel engine, and according to the diesel engine's condition-based maintenance program, the amount of work required to implement the diesel engine maintenance process is measured.

The concept of maintenance depth is based on maintainability: The definition of maintainability in GB3167 is: "Use the product under specified conditions, and maintain or restore the ability to complete the specified function when performing maintenance in accordance with the prescribed procedures and methods within the prescribed time." Maintainability is the inherent performance of a design that is easy to maintain. It is a measure taken by the designer to incorporate the characteristics of improving maintenance convenience into the design during the development of weapons and equipment. Its role is to ensure that the weapons and equipment equipped to the army can be used. Minimal life cycle costs and minimal downtime for repairs. Maintainability is a design consideration. It is an inherent characteristic of a completed design. This characteristic determines the type and amount of maintenance required to maintain or restore the weaponry to a specified state. The maintenance depth of armored vehicle diesel engine is based on the maintenance degree of armored vehicle.

The depth of armored vehicle diesel engine maintenance is closely related to the condition-based maintenance plan for armored vehicle diesel engines: The condition-based maintenance plan for the diesel engine of armored vehicles in this article includes: complete disassembly maintenance, partial disassembly maintenance and replacement. The maintenance workload for each maintenance method is different, especially under the premise of maintaining a certain reliability. The smaller the time, the better the timeliness, the less time and manpower used, the better the economic benefits.

The maintenance depth of an armored vehicle diesel engine is a measure of the amount of maintenance work performed: In the definition of maintainability, the prescribed constraint conditions are intended to facilitate the quantification and verification of maintainability. Depth of

maintenance is the workload generated by the implementation of operations on the basis of maintainability. According to the prescribed process standards and the maintenance staff trained by standard maintenance, the hours, resources, and manpower used to repair it are related to the parts, components, and components of the diesel engine to be repaired. The system is more or less relevant.

2.2 Model of Diesel Engine Maintenance Depth

In order to facilitate the measurement and quantitative calculation of the maintenance depth, this article gives a preliminary model and calculation method for the maintenance depth of the armored vehicle diesel engine. For the armored vehicle diesel engine maintenance level, it can be divided according to the sub-system or parts. The target parameters in this article are calculated by the sub-system, and the maintenance depth calculation is also divided by the sub-system.

$$D(n) = \sum_{i=0}^{n} V_i / V \quad \square\ \square\ \square$$

Where: n represents the number of parts (sub-system) that need maintenance;

i represents the i-th member in need of repair parts (sub-system), which is in the range $0 \le i \le n$;

V represents the workload measurement required to complete the maintenance of all parts (sub-system);

V_i represents the measure of the amount of work required to complete the repair of the i-th repairable part (sub-system);

The maintenance depth in the above formula increases with the increase of maintenance parts (sub-system), that is, the maintenance workload increases, the time and manpower increase, and the overall maintenance difficulty increases; when all parts are repaired, the maintenance depth is 1.

3. Diesel Engine Maintainability Evaluation Index System

According to GJB/Z91-97 Maintenance Design Technical Manual, combined with the structural characteristics of the armored vehicle diesel engine and the actual characteristics of maintenance, an index system for the maintainability evaluation of the armored vehicle diesel engine is proposed, as shown in Fig.1. The maintainability evaluation index system is divided into three layers, of which the middle layer is: maintenance complexity, maintenance time, maintenance tools, maintenance staff, and maintenance safety. The middle layer is composed of their own bottom events. The components of maintenance complexity include: maintenance accessibility, maintenance visibility, universality of maintenance components, and error prevention of maintenance components; maintenance time includes fault location time, average maintenance time, and maximum maintenance time; maintenance tools include the generality of the maintenance tools, the portability of the maintenance tools, and the operability of the maintenance tools; the number of maintenance staff includes the number of maintenance staff, the skills requirements of the maintenance staff, and the intensity of the repair work; maintenance risk.

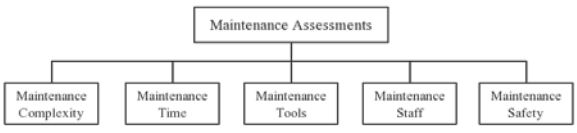

FIG1. Evaluation Index System of Diesel Engine Maintainability

3.1 Maintenance Complexity

The maintenance complexity index is composed of four indicators: maintenance accessibility, maintenance visibility, maintenance component universality, and maintenance component error prevention. Among them, the maintenance accessibility refers to the difficulty level of the maintenance staff to access the parts to be repaired during the maintenance process of the equipment. For a diesel engine of an armored vehicle, it is a highly compact and complex system with poor

accessibility to many components, especially the internal crank-link mechanism, which requires disassembly and disassembly during maintenance. Maintenance visibility refers to the ease with which certain parts can be seen by maintenance staff during the maintenance process. Visibility for parts with poor accessibility is generally poor, but good accessibility does not mean that visibility is good Although some parts do not need to be dismantled for maintenance, they need to be touched and felt by their hands, but they cannot be seen. The universality of repair parts refers to the general performance of standard parts of the parts to be repaired. Some systems have many common parts and can be replaced directly if they are difficult to repair during the maintenance process. Some parts are non-universal parts and they are expensive and difficult to reserve. They have a large impact on maintainability. The connecting rods, pistons, cylinder heads, camshafts of the valve train, etc. are all poorly versatile. Repair component error prevention refers to the ability to avoid and eliminate human error caused by the different shapes and sizes of some components due to different installation positions. For example, during the disassembly and assembly process of the piston and the connecting rod of the crank connecting rod mechanism, due to the different wear of the piston and the cylinder liner, the original cylinder liner should be replaced during the disassembly and assembly process. The shapes are the same, so it is easy to make mistakes during disassembly.

3.2 Maintenance Time

The maintenance time index consists of four indexes: fault location time, average maintenance time and maximum maintenance time. The fault locating time refers to the time required to determine the failure of the component to be repaired and the location of the failure after reaching the component to be repaired. For systems with good visibility, simple structure, and obvious faults, the fault locating time is short, but the fault locating time will be longer. For example, the gas distribution mechanism is a more complex system. The cause of the failure is relatively difficult. For the crank link mechanism, if there is a fault such as the pull cylinder or cylinder head ablation, the fault location will be relatively simple, and if a crack or mild wear occurs, the fault location time will be longer. The average maintenance time refers to the average maintenance time obtained through statistical analysis after multiple failures are synthesized after a failure, which reflects the ease of repair after a system failure. The maintenance time for parts repaired by replacement parts is generally shorter, while the maintenance time for non-replacement repairs is generally longer. Replacement repairs are generally used after failure of connecting rods, pistons, etc., and the process is faster. Some failures of the gas distribution mechanism may involve more parts that need to be adjusted during the maintenance process, and the average maintenance time may be longer. The maximum maintenance time, as the name suggests, refers to the longest time required for its repair through statistical analysis, which can also reflect the ease of repair.

3.3 Maintenance Tools

The maintenance tool index consists of three indicators: the universality of the maintenance tool, the portability of the maintenance tool, and the operability of the maintenance tool. The universality of maintenance tools refers to the degree of standardization of maintenance tools. For armored vehicle diesel engines, especially older diesel engines, the maintenance tools are less versatile, requiring specially customized maintenance tools. The portability of maintenance tools refers to the difficulty of carrying tools with maintenance teams during the wartime repair. Some special maintenance tools are difficult to carry due to their large size and weight. With the change of the maintenance system, the repair of wartime has been. It is mainly based on the replacement of the entire engine, so the impact of the portability of the maintenance tool is relatively small. The operability of a maintenance tool refers to the degree of difficulty for maintenance staff to use during the maintenance process. For large and heavy tools, the operability is relatively poor.

3.4 Maintenance Staff

The maintenance staff index consists of three indicators: the number of maintenance staff, the skills requirements of the maintenance staff, and the intensity of the maintenance work. As the name

implies, the number of maintenance staff refers to the number of people required during the maintenance process. For good accessibility, the number of maintenance staff for simple components is small, such as the maintenance of transmission systems. On the contrary, it requires a large number of people, such as the maintenance of the crank link mechanism. The technical requirements of maintenance staff refer to the level of skills that maintenance staff need to master. For the diesel engine of armored vehicles, because of its complicated structure and principle, the technical requirements of maintenance staff are relatively high, such as fuel supply system, gas distribution mechanism, crank The maintenance of the link mechanism and the like requires strong professional skills. Maintenance work intensity refers to the work intensity of the maintenance staff during the maintenance process. For the maintenance of components that need to be disassembled, the work intensity is relatively large, and vice versa.

3.5 Maintenance Safety

Maintenance safety is composed of three indicators: maintenance ambient temperature, maintenance environmental noise, and maintenance danger. The maintenance ambient temperature for diesel engines of armored vehicles is generally consistent with the ambient temperature, and noisy maintenance tools are used during the maintenance process. However, during the maintenance process, diesel engine components are generally heavy and need to be hoisted. During the disassembly and assembly process of the crank link mechanism, high temperature heating is required, so the maintenance risk is relatively large.

4. Diesel Engine Maintainability Expert Rating System

For comprehensive evaluation of maintenance depth, it is necessary to establish a maintainability index system, evaluate the maintainability of the maintenance object according to the indicator system, and finally calculate the maintenance depth based on the evaluation results and failure probability. Among them, the maintainability evaluation of maintenance objects based on the maintainability index system is an important part. The common practice is to complete the expert scoring, but because the expert scoring is random, and each evaluation requires scoring is a huge project, easy Informal and affect the evaluation results.

In order to solve the above problems, this paper proposes the use of expert system for maintenance assessment. Establish a maintenance expert scoring database, establish an expert scoring result recording mechanism, and form a maintenance expert scoring database for different parts of diesel engines and different sub-systems under different conditions. According to the type, parts, and sub-system of the armored vehicle diesel engine to be evaluated, intelligently match the maintenance experts the scoring results realize the intellectualization of maintenance expert scoring and reduce the influence of subjective factors in maintenance. Expert system can be used as an optimization solution for expert scoring. This article can also be called expert scoring system.

Expert system is a computer program system that can reach the level of an expert in a specialized field. If a system wants to show its expertise, it must solve the problem through reasoning and get corresponding reliable results. The system must have access to the fact set, that is, the "knowledge base", to be able to infer conclusions from the information available in the knowledge base during the consultation session, and the expert system to add new information during the conversation and have the learning function.

4.1 Establishment of Expert Score Database

The expert system provides algorithms and data support for the evaluation, and the database is an important part. The database consists of data tables. The main data tables that make up the database are shown in TABLE I below.

The maintainability indicator system table in the database stores the established indicator system, which is constructed according to the design attributes of the diesel engine. It is relatively fixed and is the basis for in-depth evaluation of equipment maintenance. The expert score table is used to record

the expert's previous score data. It can also be centralized according to needs. Expert score; evaluation optimization algorithm parameter table. After scoring the maintainability index, it needs to be optimized. This table stores the parameters of the optimization algorithm. The diesel engine maintainability index and weight table are used to store the optimized results as available indicators for a certain type of diesel engine. Weight data; evaluation matching rules are the basic rules in use for storing evaluation data.

Table 1.Composition of Expert Score Database

Serial Number	Data Sheet	Data Sheet Description
1	Armored vehicle diesel engine type table	Store existing diesel engine types and application models
2	Composition of various diesel engines	Storage diesel engine components
3	Table of maintainability index system	Storage diesel engine maintainability index system
4	Expert scoring data sheet	Store expert scoring results
5	Table of diesel engine maintainability indicators and weight values	Stores optimized indicators and weight values based on expert scores
6	Evaluation optimization algorithm parameter table	Composition parameters of various evaluation optimization algorithms used for storage evaluation
7	Evaluate matching rules	Store matching rules in use by the database

4.2 Process of Using Expert Scoring System

The use and division of the expert scoring system is divided into two parts. The first part is the establishment of standards. The system management user organizes experts to score the maintainability index system before the system is used. The model is optimized to form a standard diesel engine maintainability index and weight value. Multi-iteration optimization can also be performed in subsequent use to make the standard more reasonable; the other part is the use of the standard, which mainly evaluates the type of diesel engine and the objects to be evaluated by the user. The objects include: diesel engine parts, components, and sub-systems; The system evaluates and outputs results based on matching rules and evaluation methods.

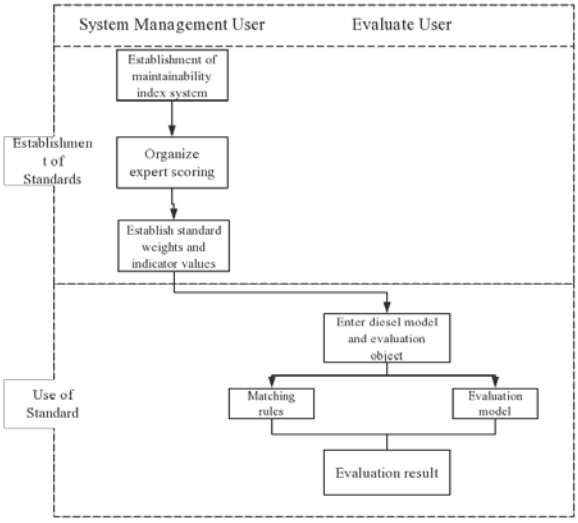

FIG.2 Using the Expert Scoring System

4.3 Functional Composition of Expert Scoring System

The function division of the expert scoring system is divided into two parts. One is the establishment of standards, including system maintenance, the establishment of maintainability index systems, expert scoring, weights and index value generation. The other part is the use of standards, including input of assessment requirements, selection of assessment methods, evaluation results output. System functions can be expanded and extended according to requirements, and can be embedded in other systems.

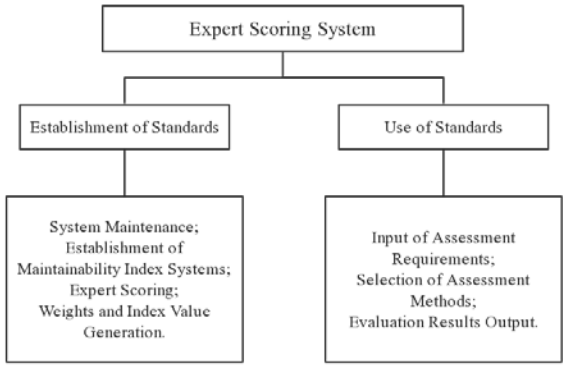

FIG.3 Functional Composition of Expert Scoring System

5. Summary

Based on the analysis and analysis of the structural characteristics of the diesel engine of armored vehicles and the technical standards and specifications of engine maintenance, this paper constructs an index system for maintenance assessment of diesel engines for armored vehicles and an expert scoring system for diesel engines for armored vehicles.

Acknowledgements

First and foremost, I would like to show my deepest gratitude to my supervisor, Dr. Cong Hua, a respectable, responsible and resourceful scholar, who has provided me with valuable guidance in every stage of the writing of this thesis. Without his enlightening instruction, impressive kindness and patience, I could not have completed my thesis. His keen and vigorous academic observation enlightens me not only in this thesis but also in my future study.

I shall extend my thanks to Mrs. Wang for all her kindness and help. I would also like to thank all my teachers who have helped me to develop the fundamental and essential academic competence. My sincere appreciation also goes to the Army Academy of Armored Force, who participated this study with great cooperation.

Last but not least, I'd like to thank all my friends, for their encouragement and support.

References

[1] Zhang Dong, Zhang Ping, Fang Qiang, Zhu Hong. Evaluation method of ship maintainability based on fuzzy analytic hierarchy process [J]. China Ship Research, 2013, 8 (1): 102-106.

[2] Wu Ling-dan, Li Fang, Yang Yuan. Research on Ship Equipment Maintenance Design Evaluation Model [J]. Ship Electronic Engineering, 2008, 28 (5): 186-189.

[3] Gao Song. Research on ship maintainability evaluation and improvement [D]. Dalian: Master's degree thesis of Dalian Maritime University, 2010.

[4] Jin Yong-ming. Research on ship maintainability analysis and evaluation method [D]. Shanghai: Master's Degree Thesis of Shanghai Jiaotong University, 2011.

[5] Gong Jian, Zhao Xin-wen, Cai Qi. Research on maintainability modeling of marine nuclear power plant based on fault tree [J]. China Ship Research, 2008, 12 (06): 74-76.

[6] Zhang Xiao-nan, Liu An-xin, Zeng Fan-yong, et al. Application of fuzzy comprehensive evaluation method in reliability and maintainability evaluation of military engineering machinery [J]. Mining Machinery, 2010, 38 (08): 42-45.

[7] Tao Yun-zheng. Research and Implementation of Vehicle Maintainability Analysis and Evaluation System [D]. Nanjing: Master Degree Thesis of Nanjing University of Aeronautics and Astronautics, 2009.

[8] Xiao Hao. Repairability Model and Application of 50MW Steam Turbine [D]. Wuhan: Master's Degree Thesis of Wuhan University of Technology. 2010.

[9] Wu X D, Liu H, Mo S. An Evaluation System of Maintainability of the Civil Aircraft Based on Virtual Reality[C].3rd International Conference on Advanced Design and Manufacturing Engineering (ADME 2013), Anshan, China, JUL 13-14, 2013.