Depth Evaluation of Armored Vehicle Diesel Engine Maintenance Based on Expert System

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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 paper proposes the concept of the maintenance depth of armored vehicle diesel engines, establishes a maintenance evaluation index system, and establishes an armored vehicle diesel engine maintenance depth assessment based on an expert system.

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.

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 article constructs an index system for the maintainability evaluation of diesel engines of armored vehicles. Based on the failure probability assessment, combined with the expert system, a method for assessing the maintenance depth of a diesel engine is proposed. The evaluation process is illustrated by examples, and the maintenance depth of the diesel engine under three maintenance decisions is evaluated.

2. Deep Maintenance Overview of Armored Vehicle Diesel Engine

2.1 Armored Vehicle Diesel Engine Maintenance Depth Concept.

2.1.1 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.

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.

$$\mathrm{D}(n) = \sum_{i=0}^{n} V_i / V \tag{1}$$

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.

2.2 Diesel Engine Maintainability Evaluation Index System

According to GJB / Z 91-97 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.

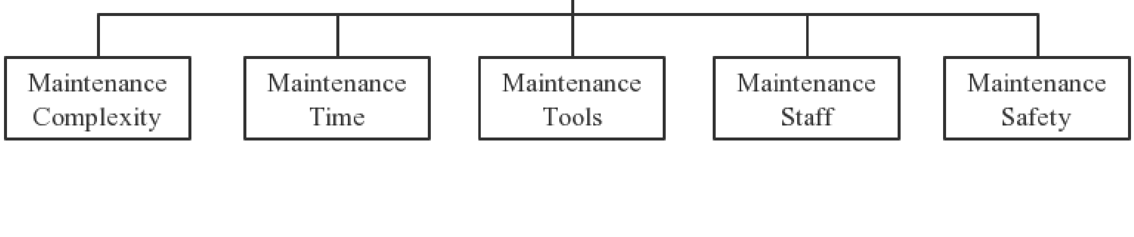

Fig. 1 Evaluation Index System of Diesel Engine Maintainability

2.2.1 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.

2.2.2 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.

2.2.3 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.

2.2.4. 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.

2.2.5 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.

2.3 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.

2.3.1 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 1 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

2.3.2 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.

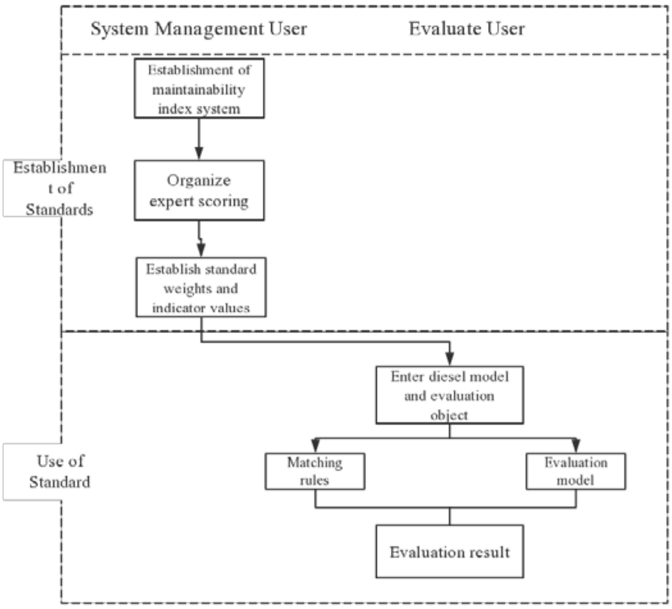

Fig. 2 Evaluation Index System of Diesel Engine Maintainability

2.3.3 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.

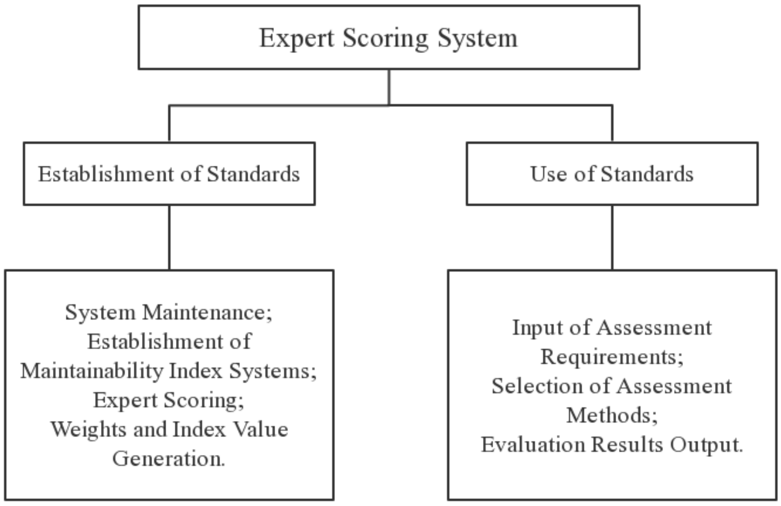

Fig. 3 Functional Composition of Expert Scoring System

3. In-depth Assessment of Diesel Engine Maintenance

3.1 In-depth Evaluation of Diesel Engine Sub-system Maintenance.

An expert scoring system is used to evaluate the maintenance depth. In order to explain the evaluation process in detail, the process of establishing the expert scoring system standards and the evaluation process are explained.

The establishment of maintenance index weights and index values is achieved through expert scoring. The fuzzy analytic hierarchy process is used in the evaluation process, and the diesel engine sub-system is used in the evaluation. The implementation steps are as follows:

3.1.1 Establish an evaluation set.

Establish a five- or seven-level evaluation set as the basis for expert scoring.

3.1.2 Expert rating.

Ask $n(n \geq 3)$ diesel engine maintenance experts to combine the evaluation index and the maintenance characteristics of the armored vehicle diesel engine to score the maintenance index of the diesel engine to obtain a score set.

$$V_{XYZ} = \left[v_{XYZ1} v_{XYZ2} \cdots\cdots v_{XYZn} \right] \tag{2}$$

In the formula:

X is the sequence number of each sub-system, where: *1* is the crank link mechanism, *2* is the valve distribution mechanism, etc.

Y is the sequence number of the intermediate events in the maintainability evaluation index, where: *1* is the maintenance safety, and *2* is the maintenance complexity.

Z is the sequence number of the bottom event.

Analyze the overall standard deviation δ_{XYZ} of the score:

$$\delta_{XYZ} = \sqrt{\frac{1}{n-1}\sum_{t=1}^{n}\left[a_t - \frac{1}{n}\sum_{t=1}^{n}a_t\right]^2} \tag{3}$$

Among them:

$$at = \lg^{v_{XYZt}} \tag{4}$$

If δ_{XYZ} is less than *1*, it means that the opinions of experts are relatively uniform, and the average value is taken as the scoring result.

$$\overline{V}_{XYZ} = \frac{1}{n}\sum_{i=1}^{n} v_{XYZi} \tag{5}$$

If δ_{XYZ} is greater than *1*, it means that the opinions of experts are not uniform. There are two ways to deal with it:

I:Find the average of the scores of all experts, remove the score that deviates the most from the average, and then calculate δ_{XYZ} until δ_{XYZ} meets the conditions.

II:Ask the experts to re-score until δ_{XYZ} meets the conditions.

3.1.3 Establish a judgment matrix for each base event and obtain the weight set after passing the consistency check.

$$A_{XYZ} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mm} \end{bmatrix} \tag{6}$$

$$W_{XYZ} = \left[W_{XYZ1} W_{XYZ2} \cdots\cdots W_{XYZm}\right] \tag{7}$$

3.1.4 Calculate the maintainability evaluation value of the intermediate event.

$$V_{XY} = W_{XYZ}\overline{V}_{XYZ} \tag{8}$$

3.1.5 Similarly, establish the judgment matrix of intermediate events, and obtain the weight set after passing the consistency check.

$$A_{XY} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1l} \\ a_{21} & a_{22} & \cdots & a_{2l} \\ \vdots & \vdots & \ddots & \vdots \\ a_{l1} & a_{l2} & \cdots & a_{ll} \end{bmatrix} \tag{9}$$

$$W_{XY} = \left[W_{XY1} W_{XY2} \cdots\cdots W_{XYm}\right] \tag{10}$$

3.1.6 Calculate the maintainability evaluation value of the top event.

$$V_x = W_{XY}\overline{V}_{XY} \tag{11}$$

3.2 Failure Probability Evaluation of Diesel Subsystem.

By using the method based on failure mode analysis to evaluate the failure probability of each sub-system, the failure probability of each sub-system is obtained.

$$P_X = \left[P_1 P_2 \cdots\cdots P_k\right] \tag{12}$$

Among them: k is the number of subsystems.

3.3 In-depth Assessment of Overall Maintenance of Diesel Engines.

Based on the assessment of the failure probability of each subsystem and the three maintenance decisions of the diesel engine of armored vehicles, the maintenance depth of the diesel engine is evaluated. If the diesel engine is completely dismantled and repaired, the repair depth of the system is:

$$M = 1 - \sum_{X=1}^{N} V_x / NV \tag{13}$$

Among them, N is the number of systems. N is the highest value of the evaluation set.

If the system with a high failure rate is partially dismantled and repaired, the repair depth of the system is:

$$M = 1 - \sum_{X=1}^{n} V_x / NV \tag{14}$$

Among them, n is the number of partial disintegration systems.

If the renewal process is adopted, the maintenance depth of the system is *1*. The optimal value of the established maintainability evaluation value is *1*.

4. Case Study

4.1 Maintainability Assessment.

4.1.1 Establishment of evaluation set.

Based on the characteristics of armored vehicle diesel engines, a five-level evaluation set is established:

$$V = \begin{bmatrix} Excellent & Good & Medium & Poor & VeryPoor \end{bmatrix} \tag{15}$$

It corresponds to the five-level comment system:

$$C = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 \end{bmatrix} \tag{16}$$

Facilitate expert scoring and final overall scoring.

4.1.2 Establishing maintenance weight sets.

According to the maintenance assessment method described above, the weights of the first and second indexes are obtained. Among them, the second-level weight judgment matrix of maintenance safety, maintenance complexity, maintenance time, maintenance staff and maintenance tools is in order:

$$A_1 = \begin{vmatrix} 1 & 1/2 & 1/4 \\ 2 & 1 & 1/2 \\ 4 & 2 & 1 \end{vmatrix}, \tag{17}$$

$$A_2 = \begin{vmatrix} 1 & 2 & 5 & 4 \\ 1/2 & 1 & 3 & 2 \\ 1/5 & 1/3 & 1 & 1/2 \\ 1/4 & 1/2 & 2 & 1 \end{vmatrix}, \tag{18}$$

$$A_3 = \begin{vmatrix} 1 & 1/5 & 1 \\ 5 & 1 & 5 \\ 1 & 1/5 & 1 \end{vmatrix}, \tag{19}$$

$$A_4 = \begin{vmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{vmatrix}, \tag{20}$$

$$A_5 = \begin{vmatrix} 1 & 2 & 1/2 \\ 1/2 & 1 & 1/4 \\ 2 & 4 & 1 \end{vmatrix}. \quad (21)$$

The consistency check of the above judgment matrices all meets the conditions. After obtaining the feature vectors, the normalization process is performed. The weight sets obtained is:

$$\begin{cases} W_1 = [0.1429 \quad 0.2857 \quad 0.5714] \\ W_2 = [0.5068 \quad 0.2641 \quad 0.0863 \quad 0.1428] \\ W_3 = [0.1429 \quad 0.7142 \quad 0.1429] \\ W_4 = [0.33333 \quad 0.3333 \quad 0.3334] \\ W_5 = [0.2857 \quad 0.1429 \quad 0.5714] \end{cases} \quad (22)$$

The first-level weight judgment matrix for overall maintainability is:

$$A = \begin{bmatrix} 1 & 2 & 2 & 3 & 4 \\ 1/2 & 1 & 1 & 2 & 2 \\ 1/2 & 1 & 1 & 2 & 2 \\ 1/4 & 1/2 & 1/2 & 1 & 1 \\ 1/4 & 1/2 & 1/2 & 1 & 1 \end{bmatrix} \quad (23)$$

Similarly, a consistency check is performed, the feature vector is normalized after obtaining the feature vector, and the obtained weight set is:

$$W = [0.4 \quad 0.2 \quad 0.2 \quad 0.1 \quad 0.1] \quad (24)$$

As shown in TABLE 2, at the same time, five experienced maintenance workers are required to rate the evaluation indicators of each sub-system, and obtain the average after scoring.

Judging the maintainability of the *8* subsystems, the results obtained are:

$$V = [3.4147 \quad 2.5601 \quad 1.0286 \quad 2.6005 \quad 2.1243 \quad 2.6589 \quad 2.0143 \quad 2.4129] \quad (25)$$

4.2 Sub-system Failure Probability Assessment.

Based on the failure probability assessment method, the failure probability vectors of each subsystem are obtained as:

$$P(F_i) = [0.2241 \quad 0.2198 \quad 0.0475 \quad 0.1431 \quad 0.1260 \quad 0.1586 \quad 0.0397 \quad 0.1059] \quad (26)$$

4.3 General Evaluation of Repair Depth.

If the diesel engine is completely dismantled, the maintenance depth of the diesel engine is:

$$M = 1 - \sum_{X=1}^{N} V_x / NV = 0.3310 \quad (27)$$

If the crank link mechanism, valve train, and lubrication system with a high probability of diesel engine breakdown are repaired locally, the repair depth of the diesel engine is:

$$M = 1 - (V_1 + V_2 + V_6)/NV = 0.6840 \quad (28)$$

If the diesel engine is renewed, the maintenance depth of the diesel engine is *1*.

It can be seen that when complete dismantling maintenance is adopted, the repair depth evaluation value is relatively low due to many maintenance parts, difficult maintenance, and long man-hours. For partial dismantling maintenance, although only three of the eight subsystems of the diesel engine are used. Maintenance subsystem has been disintegration, but because of the toggle mechanism, and the valve gear lubrication system score of each index are high, so maintenance is difficult, the overall score is also relatively high value; maintenance renewal process when using The depth is the best and the evaluation value is the highest.

Table 2 Maintainability Evaluation results

Weights	First-level Indicators	Weights	Secondary Indicators	Evaluation Value							
				Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
0.4	Maintenance Safety	0.1429	Maintenance Temperature	3	2	1	2	2	2	2	2
		0.2857	Maintenance Noise	3	2	1	2	2	2	2	2
		0.5714	Maintenance Risk	4	2	1	2	2	3	2	2
0.2	Maintenance Complexity	0.5068	Accessibility	4	3	1	3	2	3	2	2
		0.2641	Visibility	1	3	1	4	3	3	2	3
		0.0863	Component Commonality	3	4	1	3	2	2	2	3
		0.1428	Component Error Prevention	4	3	2	2	2	2	2	2
0.2	Maintenance Time	0.1429	Fault Location Time	2	2	2	3	2	3	2	3
		0.7142	Average Repair Time	4	3	1	3	2	3	2	3
		0.1429	Maximum Repair Time	4	3	1	3	3	3	2	3
0.1	Maintenance Staff	0.3333	Number of Maintenance Staff	4	2	1	3	2	2	2	3
		0.3333	Staff Skills Requirements	2	4	1	4	2	3	2	3
		0.3334	Maintenance Work Intensity	4	3	1	3	2	2	2	3
0.1	Maintenance Tools	0.2857	Versatility	4	4	1	3	3	3	2	3
		0.1429	Portability	4	3	1	3	3	3	3	3
		0.5714	Operability	2	2	1	2	2	2	2	2

5. Conclusion

Based on the analysis and analysis of the structural characteristics of the diesel engine of armored vehicles, combined with engine maintenance technical standards and specifications, this paper constructs an index system for the maintainability evaluation of diesel engines of armored vehicles. Based on the failure probability assessment and the expert system, an in-depth maintenance assessment of the diesel engine is proposed method. main tasks as follows:

I: Through research and analysis of the structural characteristics of the diesel engine of armored vehicles, combined with engine maintenance technical standards and specifications, the maintenance index system of armored vehicle diesel engines was constructed;

II: Based on the assessment of failure probability, combined with the expert system, a method for assessing the maintenance depth of diesel engines is proposed;

III: The evaluation method is described with a numerical example, and the maintenance depth of the diesel engine under different maintenance schemes is analyzed.

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