Research on Failure Probability of Vehicle Equipments Based on Fuzzy Statistics Method

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Abstract. The type of vehicle equipments is varied, which usually used in complex environment. So it is difficult to statistics its failure probability. Fuzzy statistics method was proposed in this paper to subjectively analyze, statistically modeling and quantitatively calculate the failure probability of internal combustion engine forklift. The fuzzy statistics probability of the internal combustion engine forklift was obtained, which had the well consistency with the probability in actual conditions. The method purposed here can provide a basis for the vehicle equipments support, and also can provide a new method to analyze the failure probability of the vehicle equipments.

Introduction

The vehicle equipments are the important part of the military equipments, which is the indispensable material condition to constitute the vehicle support capabilities and to protect the military constructing and combating. The technical condition of the vehicle equipments is directly related to the completion of its support works. However, it is difficult to statistics the failure probability of vehicle equipments because the different using frequency and the uneven equipped number. The fuzzy probability statistical method is introduced in this paper, which is applied to the internal combustion engine forklift to subjectively analyze, statistically modeling and quantitatively calculate its failure probability. The better result is got here and can provide a basis for vehicle equipments support decision-making.

Overview of Fuzzy Statistics

Broadly speaking, failure can be understood as any system's abnormality, which makes the system exhibit the undesirable properties. In other words, failure is the event or the state that can not or will not be able to complete the intended function of the equipment or part of the equipment [1]. The failure probability of the component refers to the ratio that can be calculated by the failure times of a component and the failure times of a subsystem, and the failure probability of the subsystem refers to the ratio that can be calculated by the failure times of a subsystem and the failure times of the entire equipment [2]. The purpose to study the failure probability is to identify the subsystem which is mostly prone to failure, in order to focused strengthen the design and maintenance support process of the component or subsystem.

The type of vehicle equipments in military is varied, which is usually different in quantity and using frequency. In order to study the demand of the equipment's maintenance and support, it is necessary to statistically analyze failure probability of vehicle equipment. It can identify the weak links in the process of designing and manufacturing of vehicle equipment, in order to carry out real-time monitoring to the important parts and focus strengthening the maintenance and support work to the vulnerable parts.

Since there is no record of failure frequency in the operating process of vehicle equipment, carrying out the fault probability analysis is more difficult. In order to successfully carry out the analysis of the failure probability with avoiding the lack of actual failure record, the fuzzy statistics method is adopted in this paper. That is, marking the often faulty components and subsystems based

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on the feeling and experience of the user, and finally determining the fuzzy probability that the components and subsystems emerging failure.

Fuzzy statistics has a strong subjective. Just because of this feature, only to highlight the complementary between the fuzzy statistics and probability statistics. Psychology experiments show that there exist strict proportional relationship between the physical quantities of external stimuli and the psychological reflect quantities of human [3]. So it is scientific and feasible to statistics the failure probability of vehicle equipment adopting fuzzy statistics method.

Modeling by Fuzzy Statistical Method

To get the fuzzy probability, fuzzy statistics is needed firstly. Fuzzy statistics can carry out by the following steps:

1) Design fuzzy statistics tables. Vehicle equipment can be divided into assembly or sub-systems with the number of *R*, and then each assembly or subsystem can be broken down into components or subsystems with the number of *m.* Define the failure-possibility-describe-fuzzy-word for each component or subsystem, and give the table to the user of vehicle equipment to be filled. Failure-possibility-describe-fuzzy-word usually can be divided into five levels, as Table 1

2) Giving the fuzzy word different membership function, as Table 1.

3) Calculate the failure integrated membership function of the component or subsystem. There are multiple copies of fuzzy statistics table, so it is needed to calculate the failure integrated membership function Z_j of a certain component or subsystem according to the results of the fuzzy statistics, which is calculated as:

$$Z_j = \bigvee_{i=1}^{n} \mu(x_i) \wedge Z_i \quad \text{(j=1, 2… m)} \tag{1}$$

Wherein, $\mu(x_i)$ is the membership function given by census takers, Z_i is the weights assigned to census takers, and n is the number of the census takers.

Table 1 fuzzy word and its membership function

No.	Fuzzy word	membership functionμ(x)
1	not occur	$\mu(x)=\begin{cases}1 & x\le 0.1\\ e^{-(x-0.1)^2} & x>0.1\end{cases}$
2	less occur	$\mu(x)=e^{-(x-0.3)^2}$
3	normal occur	$\mu(x)=e^{-(x-0.5)^2}$
4	more occur	$\mu(x)=e^{-(x-0.7)^2}$
5	usually occur	$\mu(x)=\begin{cases}e^{-(x-0.9)^2} & x<0.9\\ 1 & x\ge 0.9\end{cases}$

4) Calculate the the fuzzy probability of the assembly or subsystems. Failure probability value of the assembly or subsystem can be calculated by Z_j, which can be divided into the following four steps:

① Calculate the failure possibility P_i of component or subsystem applying median method or gravity method according to Z_j[4].

② Calculate the failure possibility Q of the entire vehicle equipment.

$$Q = \sum_{i=1}^{R} P_i \tag{2}$$

③ Calculate the fuzzy probability F_j of component or subsystem when the failure occurs.

$$F_j = \frac{Z_j}{Q} \quad \text{(j=1,2,…,m)} \tag{3}$$

④ Calculate the fuzzy probability V_i of entire vehicle equipment when the failure occurs.

$$V_i = \sum_{j=1}^{m} F_j \quad \text{(i=1,2,…,R)} \tag{4}$$

Though the fuzzy failure probability for each assembly or subsystem, the assembly or subsystem need to be embed the monitoring and diagnosis system or not can be obtained. At the same time, the monitoring intensity of the corresponding monitoring and diagnosis system can be obtained, too.

Examples

In order to describe the calculating process of vehicle equipments' fuzzy probability, the internal combustion engine forklift is analyzed as following.

1) The internal combustion engine forklifts can be divided into three subsystems which are mechanical devices, electrical devices and hydraulic devices [5]. Subsystem can be further divided too. For example, the mechanical devices can be divided into power unit, chassis and lifting system. Each component or subsystem can be further divided according to the composition too. Failure frequencies can be set five levels, which are not occur, less occur, normal occur, more occur and usually occur. The contents above should be made into failure frequency fuzzy statistic tables of the internal combustion engine forklift as shown in Table 2. Make the census takers to fill in the table, and there will be a number of tables when there are many peoples to participate.

Table 2 The fuzzy statistic table of the internal combustion engine forklifts' failure frequency

main function device				failure frequency
mechanical devices	power unit	diesel engine	cooling system	less occur
			lubrication system	normal occur
			fuel system	more occur
		battery electric motor		less occur
	chassis	transmission system		normal occur
		steering system		less occur
		brake system		more occur
	lifting system			less occur
electrical devices	mains system	battery		less occur
		generator and regulator		less occur
	starting system			normal occur
	ignition system			more occur
	instrumentation and auxiliary electrical			normal occur
hydraulic devices	gear pumps			not occur
	hydraulic cylinder			less occur
	relief valve			less occur
	multiple valve			more occur
	hydraulic oil			normal occur

2) Give the different membership function to different fuzzy words, as shown in Table 1.

3) Calculate the failure integrated membership function of component or subsystem. Because of the different failure possibility of the component or subsystem given by census takers in his fuzzy statistic table, the failure integrated membership function of component or subsystem needed to be calculated by the formula (1).

In the formula (1), $\mu(xi)$ is the membership function the census takers conferred. n is the numbers of census takers. Z_i is the weight value giving to the census takers, $\Sigma Z_i = 1$. When $i \geq 2$, the weight value of the census taker who gives the highest failure possibility can set be 1, and others' are 0. This calculation process catches the factor of highest failure possibility in actual operating. Due to the highest includes the lower, the emphasis is prominent, and the necessity that the component or subsystem is embedded monitoring and diagnosis system is embodied, too.

4) Calculate the fuzzy probability. According to the fuzzy probability calculation method introduced previously, calculate the failure possibility for each component or subsystem, the fuzzy probability for each component or subsystem, and the fuzzy probability for each assembly, as shown in Table 3.

Table3 calculation table of the internal combustion engine forklifts' failure fuzzy probability

main function device			failure possibility of component or subsystem Pi	failure fuzzy probability of component or subsystem Fj	failure fuzzy probability of the assembly Vi
mechanical	power	diesel engine	0.7	0.1111	0.44443

devices	unit	Battery electric motor	0.3	0.04762	
	chassis	transmission system	0.5	0.07937	
		steering system	0.3	0.04762	
		brake system	0.7	0.1111	
	lifting system		0.3	0.04762	
electrical devices	battery		0.3	0.04762	0.25398
	generator and regulator		0.3	0.04762	
	starting system		0.5	0.07937	
	instrumentation and auxiliary electrical		0.5	0.07937	
hydraulic devices	gear pumps		0.1	0.01587	0.30158
	hydraulic cylinder		0.3	0.04762	
	relief valve		0.3	0.04762	
	multiple valve		0.7	0.1111	
	hydraulic oil		0.5	0.07937	
∑			6.3	1.0	

Analyze Table 3, the following results can be obtained:

1) It can be seen from the internal combustion engine forklifts' failure fuzzy probability that, the mechanical device has the highest failure probability, followed by the hydraulic system and then the electrical equipment failures, which is consistent with the actual situation.

2) The part with the highest failure probability has been embodied in the components or subsystems, such as the diesel engine in the mechanical devices and the multiple valve in the hydraulic devices which has the failure probability with 0.1111.

Conclusions

A fuzzy statistics method to calculate the failure probability of vehicle equipments had been put forward in this paper. Fuzzy probability statistics is the method to describe the subjective things. It can provide a basis for the comparison and decision-making among things, and also can provide a new method to statistic the failure probability of the equipment without data. Although fuzzy statistics is subjective, the statistical results are scientific and have good agreement with the actual situation, due to that there exist strict proportional relationship between the physical quantities of external stimuli and the psychological reflect quantities of human. If apply the more detailed fuzzy partition, the more accurate results of fuzzy statistics can be obtained. However, the rough division can reflect the people's subjective images better.

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