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Research on Application of FMECA in Missile Equipment Maintenance Decision

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Abstract. Fault mode effects and criticality analysis (FMECA) is a method widely used in engineering. Studying the application of FMEA technology in military equipment maintenance decision-making, can help us build a better equipment maintenance support system, and increase the using efficiency of weapons and equipment. Through Failure Modes, Effects and Criticality Analysis (FMECA) of equipment, known and potential failure modes and their causes are found out, and the influence on the equipment performance, operation success, personnel security are determined. Furthermore, according to the synthetical effects of the severity of effects and the failure probability, possible measures for prevention and correction are put forward. Through replacing or adjusting the corresponding parts, corresponding maintenance strategy is decided for preventive maintenance of equipment, which helps improve the equipment reliability.

1. Introduction

With the development of science and technology and the demand of modern military struggle, the speed of equipment innovation continues to increase. Meanwhile, the fighting style changes, which brings new challenges to the quality of equipment maintenance personnel, the equipment maintenance management mode and the traditional maintenance methods. Make full use of the product information from FMECA, and apply to the maintenance decision-making of the products, which is the main content of this article. On the basis of the equipment failure mode and effect analysis, by technical analysis instead of experience, use the results of technical analysis as the basis of maintenance decision.

2. FMECA

Failure mode effects and criticality analysis (FMECA) is an inductive-type analysis method which analyzes all possible failure modes and effects of each unit in the system, and according to the probability of each failure mode and its severity classifies the failure modes [1-3]. The functional FMECA is one branch that can analyze potential failure modes and possible effects and criticality of failures in the conceptual design phase of products. It can find out the potential weaknesses of the design process to facilitate the improvement of design before the determination of product structure, which is an effective method to guarantee the quality of reliability design.

The functional FMECA is mainly used in the demonstration and project phase, as well as the early stage of the engineering development. The purpose is to analyze the defects and weak links of the product's functional design, and provide the basis for the improvements of the product's functional design. According to GJB/Z1391-2006, the functional FMECA process is shown in figure 1.
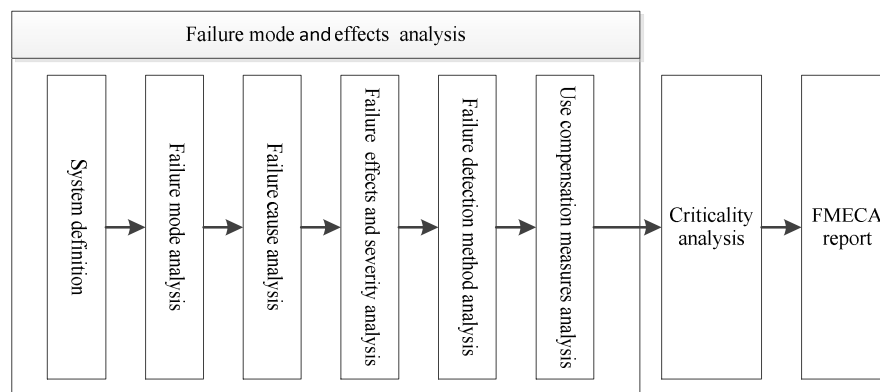
Figure 1. The FMECA process.

In engineering practice, the functional FMECA is often combined with the hardware FMECA. They are generally carried out by filling the FMECA form [4], and the commonly used FMECA table is shown in table 1.

Table 1. Function and hardware failure mode and effects analysis table.

The initial agreement level: Mission: Audit: Page:
The agreement level: Creater: Ratify: Creat date:

Number	Function	Potential Failure Mode	Potential Cause(s) of Failure	Mission Phase	Potential Effect(s) of Failure	SEV	Current Controls Detection	Current Controls Prevention	Actions Taken

3. Characteristics of missile equipment maintenance support

Missile equipment generally adopts three-level maintenance system, corresponding to three-level support. The first level maintenance is the grassroots level maintenance, and at this stage the field security personnel use outfield equipment to complete the routine testing and maintenance of missiles. The second level maintenance is the intermediate level maintenance, and at this stage the security personnel use support equipment to complete the missile's storage, packaging, transportation and preparation to be transmitted. The third level maintenance is the depot level maintenance, and at this stage the security personnel can complete a full range of missile maintenance in the repair center.

Missiles are long-term storage and single-use weapons. At storage or standby stage missiles belong to repairable system, but at launch or flight stage missiles belong to repair-free system. Therefore in the three-level maintenance system, the preventive maintenance work is completed during the first level maintenance and the second level maintenance; the corrective maintenance work is completed during the third level maintenance.

4. Missile equipment maintenance decision based on the FMECA technology

Maintenance decision-making process based on the technology of FMECA is as follows: the first step is to partition the system level; Then Failure Mode and Effect analysis is taken to determine the risk priority number; And products with or without important functions are divided according to their risk priority numbers; Then reliability-centered maintenance decision analysis is taken for products with important functions; Finally according to the severity of the failure consequences, maintenance task types and maintenance interval are determined to make up the maintenance work outline[5-7]. The flow chart is shown as figure 2.
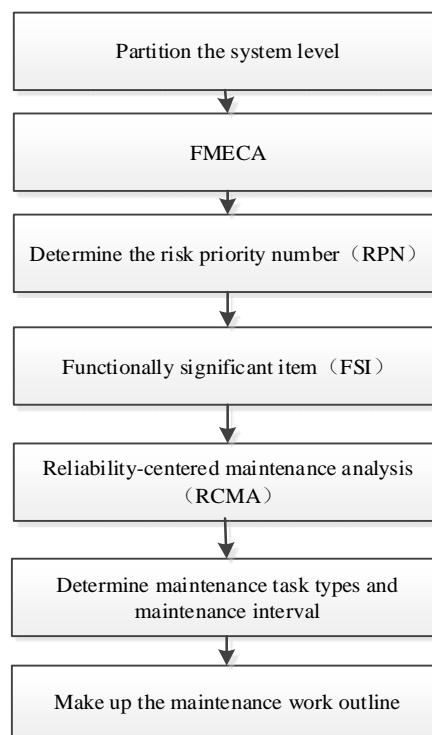
Figure 2. The maintenance decision-making process based on the technology of FMECA.

In this paper, with a certain kind of missile as research object, we choose the terrain matching function branch of the flight control stage as a case study. First conduct the functional analysis; then use functional tree to decompose the missile function forward and get the complex branch of each function. Figure 3 takes the main function of the missile as an example mapping functional tree, focusing on the research object "terrain matching function" branch with other parts omitted [8, 9].

The main task stage of the missile includes ground test stage, launch control stage and flight control stage. Terrain matching's main function is playing in the flight control stage, so below we select the flight control phase to analyze. The power-on self-test, data binding, and data loading in the figure 3 belong to the launch control stage, so they are left out in the following analysis. Analyzing the terrain matching branch we get the functional failure mode analysis table as is shown in table 2.
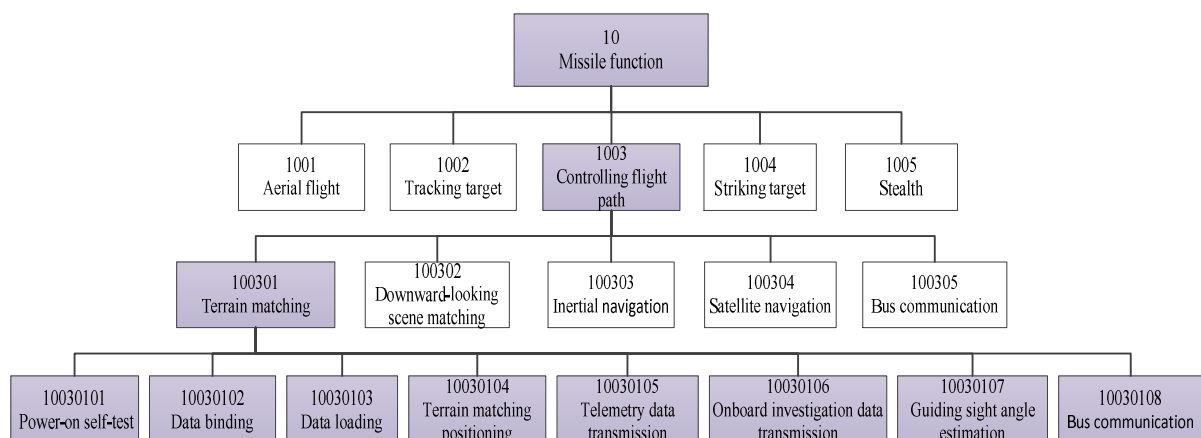

Figure 3. Missile function tree.

Table 2. The functional FMEA table of terrain matching(part)

| The initial agreement level: Missile function | | | Mission: ** | Audit: ** | Page: ** | |
| The agreement level: Terrain matching | | | Creater: ** | Ratify: ** | Creat date: ** | |

Number	Function	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Key Function	Actions Taken	Current Controls Detection
10030104	Terrain matching positioning	Terrain matching positioning failure	Terrain matching accuracy decrease	8	Yes	System software fault tolerance design	BIT
		Terrain matching positioning accuracy decrease	Terrain matching accuracy decrease	8	Yes	System software fault tolerance design	BIT
		Terrain matching positioning synchronous signal failure	Terrain matching positioning pulse output error	8	Yes	The optimization design of the hardware interface circuit	BIT

Then we conduct the functional criticality analysis of the key function in the terrain matching function branch and get the terrain matching functional criticality analysis table as is shown in Table 3.

Table 3. The functional criticality analysis table of terrain matching (part).

| The initial agreement level: Missile function | | | Mission: ** | Audit: ** | Page: ** | | |
| The agreement level: Terrain matching | | | Creater: ** | Ratify: ** | Creat date: ** | | |

Number	Function	Potential Failure Mode	SEV	Failure Mode Probability ($*10^{-6}$)	Occur	RPN	Risk Level	Achieve fault detection requirements
10030104	Terrain matching positioning	Terrain matching positioning failure	8	28.04	4	32	R3	Yes
		Terrain matching positioning accuracy decrease	8	15.10	4	32	R3	Yes
		Terrain matching positioning synchronous signal failure	8	8.71	3	24	R3	Yes

FMECA analysis of missiles can help obtain functions with larger risk priority numbers, and the corresponding Functionally Significant item (FSI) can be determined, followed what the reliability centered maintenance theory is analyzed in detail. Based on 7 types of preventive maintenance policies (including maintenance, operation personnel monitoring, inspection, functional detection,

timing overhaul, timing scrap, integrated work), and reasonable maintenance interval determined due to previous maintenance support data, a complete outline of maintenance work is made up finally.

5. Conclusion

In this paper we conduct the FMECA analysis for a certain type of missile system, and then determine the maintenance decision based on the FMECA analysis. We give the maintenance decision processes based on the technology of FMECA, which can not only improve the reliability of the missile system, also can enhance the scientific, effectiveness of maintenance work. This method improves the work efficiency and relevance of maintenance, avoiding excessive maintenance, which reduces the maintenance cost, with certain military, economic and applied value [10, 11].

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