Research on Application of Functional FMECA in Reverse Engineering Optimization

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***Abstract*—This paper studies how to apply the functional FMECA-a reliability analysis method in the reverse engineering process to make up for the shortcomings in reliability design. Analyze the implementation process of traditional reverse engineering; aiming at the shortcomings of the reverse engineering process such as the lack of reliability design, etc, optimize the implementation process. Failure mode effects and criticality analysis (FMECA) is one of the major methods used in reliability analysis, in which 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. Applying the functional FMECA-a reliability analysis method in the reverse engineering, we can find out the potential weaknesses of the design process in the early phase of imitation. On this basis carry on the design improvement, and realize the synchronization of reverse design and reliability design, thus ensuring the reliability of the product. Finally, with the reverse engineering of a missile as an example, the functional FMECA is conducted, and the combination of reliability design and performance design is realized according to the influence between the functional FMECA and the design of products.**

Keywords-reverse engineering; functional analysis; functional FMECA; failure mode

I. INTRODUCTION

With the development of modern science and technology, product competition is increasingly fierce in all walks of life. Reverse engineering is an effective way to learn advanced technology and achieve technological progress. How to improve the reliability while ensuring the performance of the product, has become an increasingly important issue for many product designers. Failure mode effects and criticality analysis (FMECA) is an important method for reliability analysis, of which 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. This paper studies how to apply the functional FMECA in the reverse engineering process to make up for the shortcomings in reliability design.

II. REVERSE ENGINEERING PROCESS AND DEFICIENCIES

Reverse engineering is a technology which is on the basis of the physical prototype, through the analysis of the product and its components, to determine the intrinsic relationship between different components of the product, understand its working principle and structure feature, and explore to master its key techniques and then to develop more advanced products. It's also a combination of a series of methods and applied technology adopted while digesting and absorbing advanced technology [1-4].

Modern product complexity is increasing and the product performance is realized by the interaction of different systems. When the complex product is imitated, first we need to decompose the product. For the product supported by the software and hardware to achieve its function, we need to isolate hardware parts and software modules in the decomposition process of the products. On the one hand we imitate the hardware parts, separately carrying on the data acquisition, data processing, model reconstruction, processing and manufacturing, assembling and molding, then we get the hardware support part; on the other hand we decompile or redesign the software parts, according to the function relation refactor the demand of each module, then through general design, detailed design, coding and debugging of the software we get the software parts of the product, finally forming a complete imitation product. Reverse engineering process of complex products is shown in Fig 1.

The traditional reverse engineering process is mainly focused on the representation of product appearance, and current research on reverse engineering is also focused on the rapid prototyping. The deficiencies in the product design are as follows:

(1) Lack of in-depth analysis of the product functions, the connection between functions, and the connection between the functions and the software/hardware.

(2) The research on reverse process of the complex product is less, and the issues in the product functional decomposition and assembly process have not been valued.

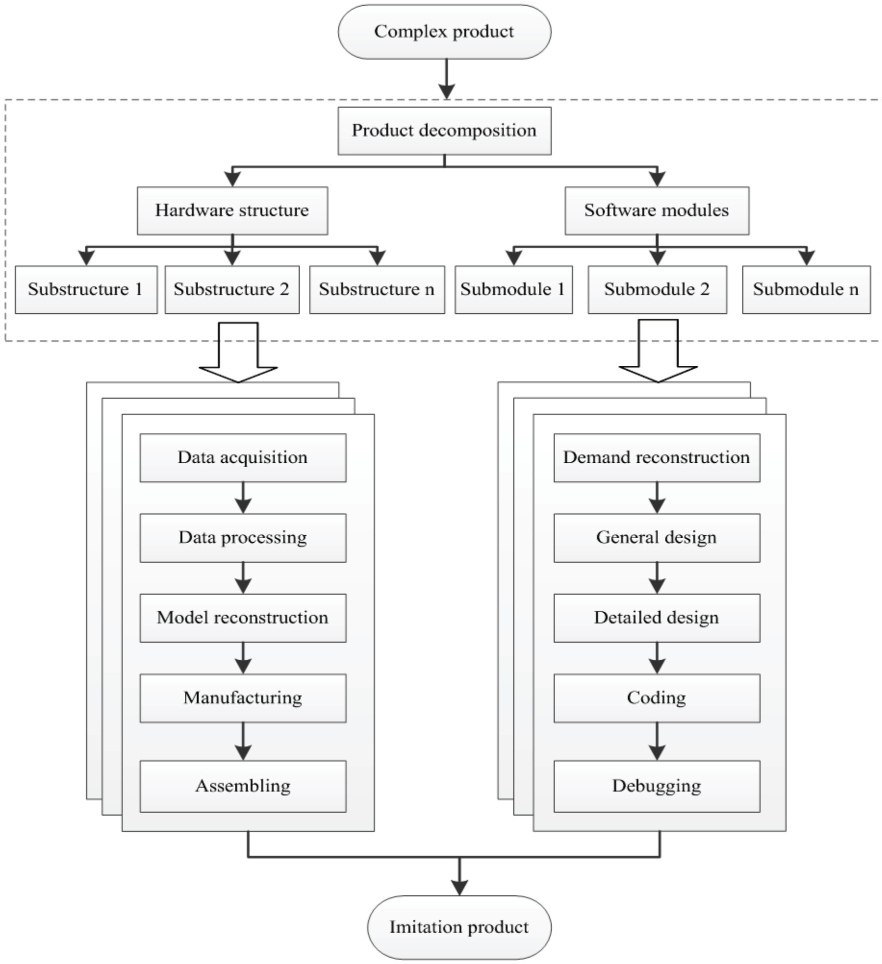

Figure 1. Reverse engineering process of complex product

(3) Lack of the application of reliability design method, and ignore the product's ability to maintain its performance.

III. FUNCTIONAL 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 [5-7]. 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 Fig 2.

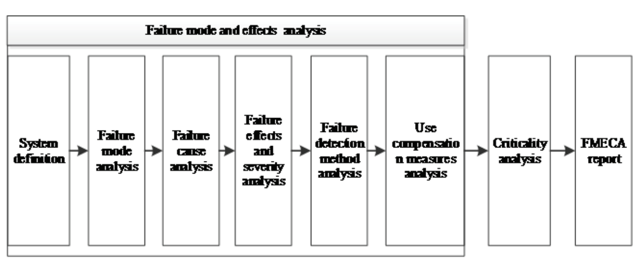

Figure 2. The functional FMECA process

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 Detectio n**	**Current Controls Preventio n**	**Actions Taken**

In engineering practice, the functional FMECA is often combined with the hardware FMECA. They are generally carried out by filling the FMECA form [8], and the commonly used FMECA table is shown in Table 1.

IV. REVERSE ENGINEERING PROCESS OPTIMIZATION

This paper integrates functional FMECA into reverse engineering process. Firstly, conduct in-depth functional analysis of the generic object while disassembling the product to obtain the functional connection of the generic object as an input preparation for the functional FMECA. Then study each functional failure mode and solving measure of the generic object through initial functional failure mode analysis, explore product design concepts and design methods, and store the failure mode list of the product and product design knowledge into the product knowledge base, to form the accumulation of product failure modes and solving measures. Lastly, based on user demand improve the functional connection that has been established and determine the function of the target product. Through the analysis of each functional failure effect and the severe degree find key objects, and put forward the functional design requirements and fault detection requirements to improve the product design before determining the hardware structure.

After the software/hardware FMECA we conduct the functional criticality analysis to verify whether the risk of serious failure mode is under control. If it is not we need to return to improve the design; if it has reached an acceptable level production and manufacturing can be performed to get new products. The optimized reverse engineering process is shown in Fig 3.

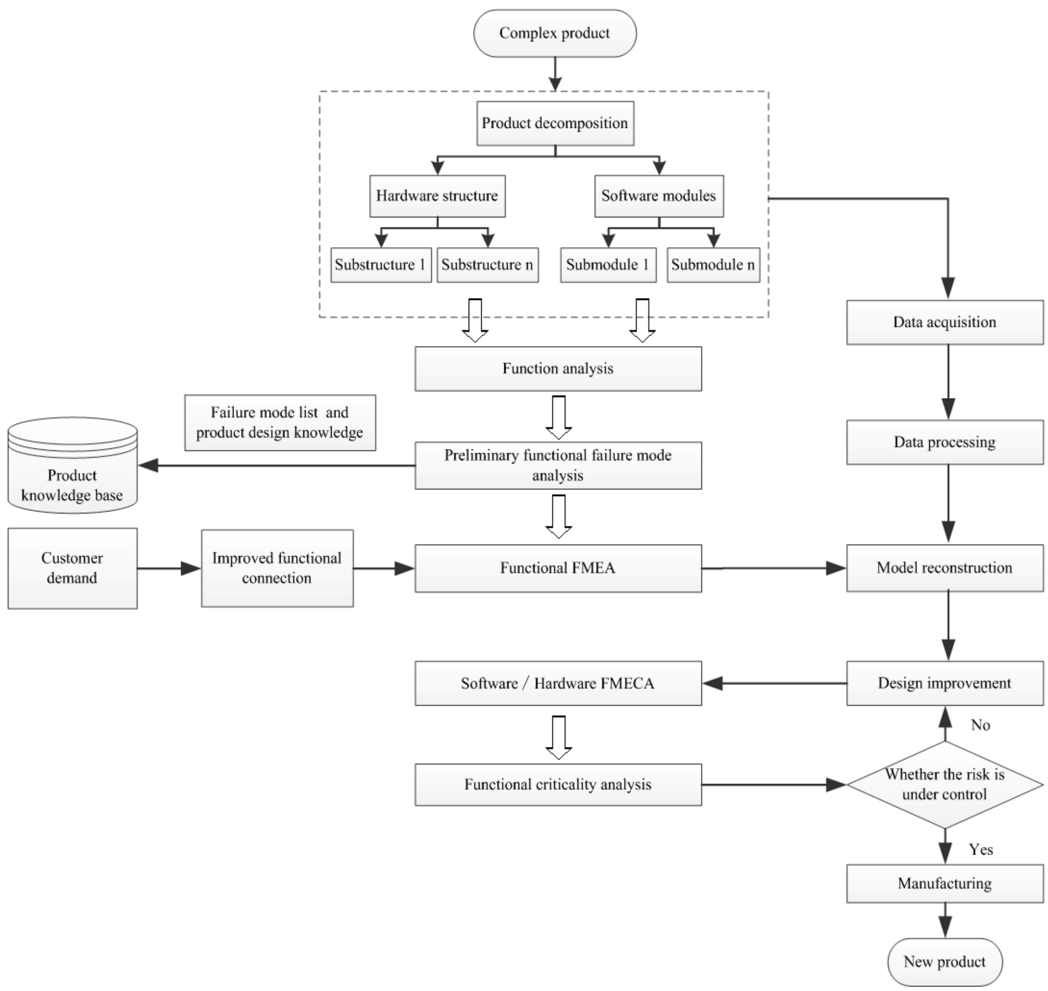

Figure 3. The optimized reverse engineering process

V. CASE STUDY

Tomahawk cruise missile which is developed by the United States is one kind of deep strike weapon launched out of the field of fire of the enemy defenses. It can be launched from the land, ship, air and underwater, and can attack ships or land targets. It is mainly used for precise attack against targets of tightly fenced area. Tomahawk cruise missile has good concealment and strong penetration ability, high accuracy and lethality, good versatility, high comprehensive benefit, etc. Tomahawk cruise missile uses inertial guidance plus terrain matching or satellite global positioning correct guidance on the voyage, and it can automatically adjust the height and speed for high speed attack [9].

In this paper, with Tomahawk cruise missile as imitation object, we choose the terrain matching function branch of the flight control stage as a case study, which provides a reference for the development of the same type equipment in China. First conduct the functional analysis; then use functional tree to decompose the missile function forward and get the complex branch of each function. Figure 4 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.

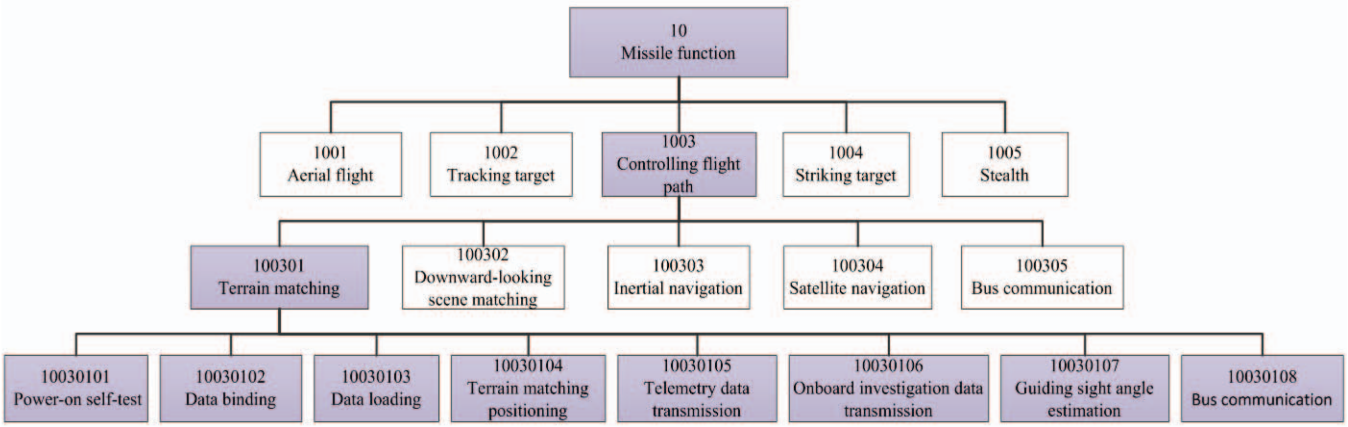

Figure 4. Missile function tree

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 Fig 4 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.

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

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

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.

By verifying analysis we can see that communication intermittent instability belongs to low risk, which can be accepted; the rest each failure mode belongs to medium risk, but we can avoid failure or reduce failure probability or harm degree by preventive maintenance, so we can accept this design which meets the requirements of reliability design. The current design state can finalize the design.

VI. CONCLUSIONS

In this paper we study how to apply the functional FMEC in the reverse engineering process，with the reverse engineering of a missile as an example. Firstly, conduct in-depth functional analysis of the generic object while disassembling the product to obtain the functional connection of the generic object. Then carry out the functional FMECA to the terrain matching function branch; after preliminary functional failure mode analysis we determine the failure mode list of the product. For the weaknesses we propose functional design requirements and fault detection requirements. Through functional criticality analysis the result shows that the risk of serious failure modes is all under control. The product has reached the reliability design requirements and the reliability level of the generic product is also ensured.

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