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Research on Reliability Management Mechanism of Material Testing Equipment

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ABSTRACT: With the continuous development of scientific research, the term reliability has been infiltrated into the industrial and technological blood of the society. In the product life cycle, the whole process from product design to production and use has many factors affecting the reliability of the product. Therefore, it is necessary to comprehensively consider these factors and take appropriate management measures to improve the reliability level of the product. Taking the reliability management of the material testing equipment as the research object, this paper analyze the reliability of the instrument design process, uses FMEA and FTA methods to identify the links prone to failure and the corresponding failures, and establishes the reliability management mechanism for these failures and links to form the overall solution of reliability management.

KEYWORDS: Reliability management; FMEA; FTA, Reliability Engineering.

I. INTRODUCTION

Reliability management is a discipline based on system management. Its purpose is to make plans, organize the whole life process of the system or product by using management science and corresponding technical means with the minimum resources, so as to improve the reliability of the system or product.

The current research direction of reliability management is mainly to cross-consider reliability with other disciplines and analyze and apply new reliability methods[1].Reliability management is often associated with quality management, lean, and systems engineering. In fact, they are interdisciplinary disciplines, and reliability management methods and tools are often used in the control and analysis of supply chain in lean[2].At present, the reliability management is no longer simply driven by management, but more considers the application of technology management as the driving force of reliability management.In the field of production, more diversified reliability management methods emerge from decision-making, production, inventory, risk, maintenance, resources and systems, such as the application of statistical distribution function to achieve production reliability, Amin Khadem and Burak Eksioglo put forward a new reliability-based spare parts inventory management mode in inventory [3].In the field of risk management and control of enterprises,the big data analysis method of quality, reliability and risk management proposed by Chiovanni Maz, the big data analysis method is applied to reliability and risk analysis [4].As for the selection of maintenance strategy, fuzzy analytic hierarchy process and ideal solution are newly proposed specific application methods, which have strong practical operability [5].In terms of production resources, it is a relatively cutting-edge study to include resource reliability into the key chain project management buffer scale [6].Finally, in terms of systems, Yi-Kuei Lin et al. explained how reliability and quality management in stochastic systems can be done [7].The above research provides a variety of theoretical methods for the reliability management mechanism of material testing instruments. The research contents of this paper are as follows:

[1].Use FMEA method to analyze the design process of the material testing instrument, establish FMEA analysis table and identify the easily occurred faults.

[2].Fault tree analysis (FTA) is used to sort the level of easily occurring faults and establish the reliability management mechanism for these faults and links.

Reliability management is the integration of scientific plan and action plan. Reliability management mechanism is established through the above process to ensure that the reliability of the product reaches the expected target and finally improve the reliability of the produced material testing instrument.

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II. APPLICATION OF FMEA IN MATERIAL TESTING INSTRUMENT DESIGN STAGE

Fundamentally speaking, FMEA method is to summarize and classify the logic, and make a certain prediction of the possible situation according to certain laws and development trends. The result of this method is not to obtain a high-precision data, but a nature, a law or a trend.The principle of FMEA is fundamentally to establish a database, including design process, process technology and other related documents, customer actual needs, historical data of faults, etc.The steps of FMEA usually include nine steps and have certain flexibility. Not every step is impossible, but determining unknown failure modes and their effects, establishing FMEA table, and analyzing failure causes are necessary processes and cannot be omitted. The application process is as follows:.

[1].Clarify system tasks. That is to improve the reliability of material testing instrument design stage and select the appropriate FMEA method. This paper selects “GJB 1391-19926 requirements and procedures for failure mode, effect and hazard analysis”.GJB 1391-19926published in 1992 in China as the reference method. It enumerates and defines the severity category, failure probability level, failure impact probability and other analysis items of FMEA.

[2].Determine the degree of decomposition: divide the design process into four levels according to the current design process of the enterprise. They are preliminary preparation stage, scheme design stage, working drawing design stage and product production stage.

[3].Draw the reliability block diagram: according to the above decomposition of the design process, draw the reliability block diagram as shown in Figure 1.

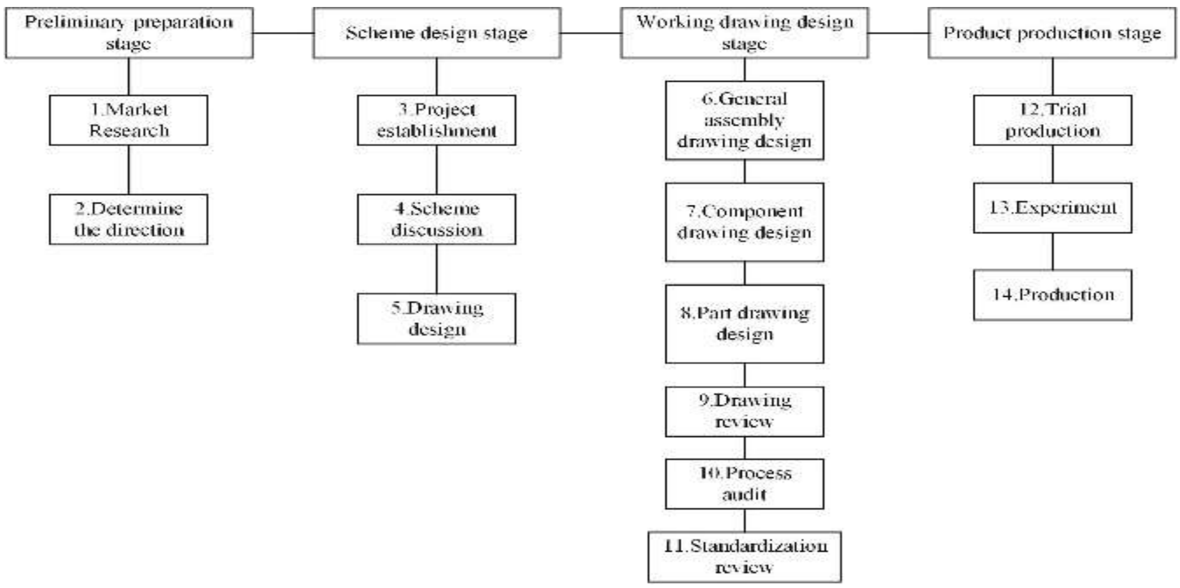

Figure1 Reliability block diagram

[4].List potential failure modes: failure modes are generally divided into six categories: personnel, machinery, methods, materials, environment, etc

[5].Analyze the impact of failure on the system: at this stage, not only the failure cause should be determined, but also the effective level should be determined according to the criteria defined by the severity in advance.

[6].Establish FMEA analysis table: the FMEA analysis table is shown in table 1, 2, 3 and 4 below.The fault level determination method is shown in table 5below.

[7].Analyze the potential failure causes and propose improvement measures. From the above FMEA table, it can be seen that market research, determination of R&D direction and project approval have the highest fault level, which can lead to the abortion of R&D projects. The potential failure causes play a guiding role in the subsequent research and development process.

The improvement measures in the management mechanism are to set up a reliability management committee at the leadership, which is supervised by the general manager of the leadership and the Reliability Assurance Department of the

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management. The fault level of scheme discussion, drawing design and review is level II, which will lead to significant economic losses or serious damage to the system. The potential failure reason is that these items serve as a connecting link between the preceding and the following. They not only undertake the guidance of the upper level, but also play a guiding role in the production stage of the lower level. The improvement measures in the management mechanism are to set up a reliability assurance department after the scheme discussion stage, in which the post of reliability engineer is specially set up to provide the reliability report to the upper reliability Committee, and at the same time to supervise whether there are reliability problems in the mission statement transmitted to the lower level, so as to guide the subordinate executive level.

Set up the post of Reliability Engineer in the design department of the executive level, and carry out reliability management throughout the whole life cycle from design to audit. The fault level in the production stage is level III, which will lead to certain economic losses or slight damage to the system. The potential failure is due to the error in the processing site. The improvement measures in the management mechanism are to set up the post of Reliability Engineer in the production department and report to the reliability assurance department together with the design department.

Table1 FMEA table for the preliminary preparation stage of material testing equipment design process

NUMBER	NAME	FAILURE MODE	CAUSE OFOCCURRENCE	EFFECT		FAULT LEVEL
				Preliminary preparation stage	New product design process	
1.1	ResearchMarket	Inaccurate product positioning	Work errors of researchers. The survey object is not representative.	Wrong direction of product development	Product development plan aborted	I
1.2	Determine the direction	Wrong R&D direction	Inaccurate product positioning. High level decision error.	New product type (reserve type Inheritance and popularization) determination fault	Subsequent new product development process Wrong direction and new product development Process abortion	I

Table2FMEA table of material testing equipment design process scheme design stage

NUMBER	NAME	FAILURE MODE	CAUSE OF OCCURRENCE	EFFECT		FAULT LEVEL
				Preliminary preparation stage	New product design process	
2.1	Project establishment	Error in project establishment	Parameter calculation error Structural design error Performance design error Costing error	Scheme design error. Drawing design error	Project failure. Drawing design error. Production failure. Cost exceeding the	I

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					outline.	
2.2	Scheme discussion	Scheme not feasible	Organizational marketing errors. Scheme design error. Poor economic status. Lack of process equipment.	Scheme design error. Drawing design error.	Drawing design error. Production failure. Cost exceeding the outline	II
2.3	Drawing design	Drawing error	Parameter and structure error. Drawing error.	Drawing design error.	Drawing design error. Production failure	II

Table3FMEA table for the working drawing design stage of material testing equipment design process

NUMBER	NAME	FAILURE MODE	CAUSE OF OCCURRENCE	EFFECT		FAULT LEVEL
				Preliminary preparation stage	New product design process	
3.1	General assembly drawing design	Error in general assembly drawing	Space position design error. Component drawing design error. Basic structural dimension design error	Component drawing design error. Part drawing design error. Increased audit workload.	Increased process difficulty. Production failure. Non conformance to standards	II
3.2	Component drawing design	Component drawing error	Functional design error. Basic dimension design error. Structural design error. Action relationship design error	Component drawing design error. Part drawing design error. Increased audit workload	Increased process difficulty. Production failure. Non conformance to standards	II
3.3	Part drawing design	Error in part drawing	Accuracy design error.Efficiency design error. Rigid design error. Processing technology design error	Part drawing design error. Increased audit workload	Increased process difficulty. Production failure. Non conformance to standards	II
3.4	Drawing review	Errors in drawing	Self review by design	Drawing review error.	Increased process	II

		review	department. Insufficient level of Auditors		difficulty. Production failure. Non conformance to standards	
3.5	Process audit	There are mistakes in process audit	There is a mistake in the processing technology. The assembly process is flawed	Process audit error	Increased process difficulty. Production failure. Non conformance to standards.	II
3.6	Standardization review	Mistakes in standardization audit	Not conforming to national standards and drawing standards	Standardization audit error	Production failure. Non conformance to standards	II

Table4FMEA table of material testing equipment design process product production stage

NUMBER	NAME	FAILURE MODE	CAUSE OF OCCURRENCE	EFFECT		FAULT LEVEL
				Preliminary preparation stage	New product design process	
4.1	Trial production	Trial production failed	Drawing design and review errors. Processing site error	Products cannot be tested and mass produced	Products cannot be tested and mass produced	Ⅲ
4.2	Experiment	Experiment failed	Parameter design error. Trial production failed	Products cannot be tested and mass produced	Products cannot be tested and mass produced	Ⅲ
4.3	Production	Batch production failed	Processing site error	Product cannot be mass produced	Product cannot be mass produced	Ⅲ

Table5Fault level table

CATEGORY	NAME	DESCRIBTION
Class I	Catastrophic	Project failure, planned abortion
Class II	Fatal	Major economic losses or serious damage to the system leading

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		to mission failure
Class Ⅲ	Critical	Certain economic loss or slight damage to the system leading to mission failure or degradation
Class Ⅳ	Mild	Certain economic loss or system damage fault, unplanned maintenance or repair

III. FTA ANALYSIS OF MATERIAL TESTING INSTRUMENT DESIGN STAGE

Fault tree analysis (FTA) is a kind of method with the guiding ideology of graphical deduction to find the causes of the events on the top of the system, that is, the events that do not want to occur, layer by layer like branches.

The method commonly used to build the fault tree is the logical deductive method. The principle of this method is the same as the logic of human thinking. First of all, after thinking, select the events that do not want to happen as the top events, then analyze the events that cause the top events, then find out the next level events of these events, and then repeat this step for many times until the bottom cause is analyzed. The specific steps are:

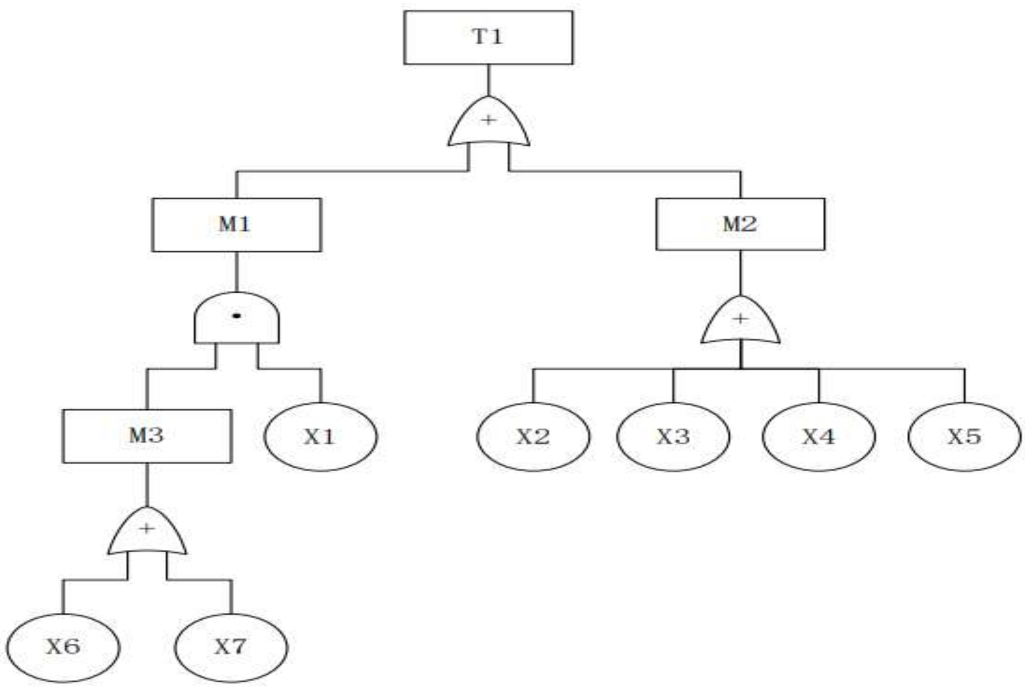
[1].Select the unwanted fault event in the system as the top event. For the design process of new products, select the event of project failure as the top event.

[2].Analyze the direct events that lead to top events. These events may be hardware failures, personnel errors, information confusion, etc., which may be either single events or combined events.

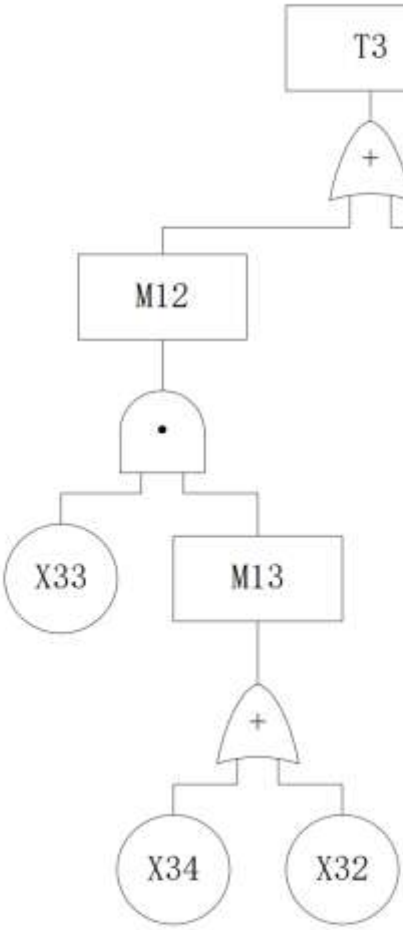
[3].In the previous step, find out the direct causes of these events, and do not omit them.

[4].Analyze layer by layer until the event is analyzed, that is, the most fundamental cause of the fault.

[5].The top events are connected with corresponding connection symbols such as logic and gate and logic or gate and connection line. After the above five steps, an inverted fault tree with several levels is built, which takes the top event as the root, the middle event as the branch, and the bottom event as the leaf. See Figure 2,3 and 4 below for details.The meanings of the codes in the three fault trees are shown in table 6 below.

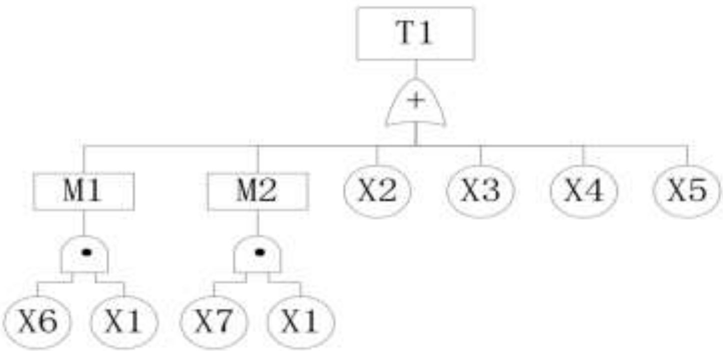


Figuer2 Take the fault with fault level I as the fault tree of top event



Figuer4 Take the fault with fault level Ⅲ as the fault tree of top event

According to the steps, after establishing the above fault tree, quantitative analysis should be carried out. The Boolean algebra method is used to simplify the same basic events that appear in different parts of the fault tree, and the fault tree equivalent diagram is made. The fault tree with fault level Ⅱ as the top event is the original fault tree diagram, and the fault tree with fault level Ⅰ and fault level Ⅲ as the top event is shown in the figure 5 and 6.



Figuer5 Equivalent diagram of fault tree with fault level I as top event

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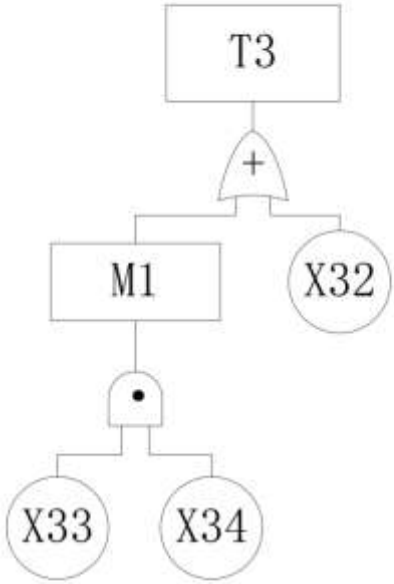

Figuer6 Equivalent diagram of fault tree with fault level Ⅲ as top event

After establishing the fault tree, the concepts of minimum cut set and minimum path set need to be introduced, which are very important for fault tree analysis. In the fault tree, a set of cut sets is the set of all basic events, which must be the origin of the top event. The concept of minimum cut set refers to the cut set that cannot be guaranteed to occur at the top after arbitrarily eliminating a basic event. The core idea of qualitative analysis is to find the fault spectrum that leads to the top event. The fault spectrum is composed of all the events that lead to the top event. The definition of all these events is the minimum cut set in fault tree analysis. In order to improve the security and reliability of the system, it is necessary to find out the weak links of the system through the analysis of the minimum cut set or the minimum diameter set. After the above Boolean algebra simplification, the minimum cut sets corresponding to the faults of the three fault levels are respectively shown in table 7 below.

The minimum cut sets of three fault levels can not only play a positive role in the specific judgment of potential fault modes, but also accumulate the basis for finding faults and making improvement plans. Since it is difficult to determine the probability of each bottom event, quantitative analysis and research are not carried out, and only the importance judgment is made for the minimum cut set obtained from qualitative analysis, and it is concluded that which link in the design process is weak needs to be arranged with reliability management mechanism.

The following is the qualitative analysis through the minimum cut set, that is, the determination of importance. The qualitative analysis and determination of importance using the minimum cut set require certain principles. The specific principle is that in all the minimum cut sets, the minimum cut set composed of a single basic event has the greatest structural importance. If it is only distributed in a minimum cut set, and no matter how many basic events this minimum cut set contains, it will no longer appear in other cut sets, then the structural importance of such basic events is the same. If multiple basic events occur the same number of times in different minimum cut sets, the less the basic events contained in the minimum cut set of the basic event, the greater the structural importance. On the contrary, the more the basic events contained in the minimum cut set of the basic event, the smaller the structural importance. If there are the same number of basic events in the minimum cut set, the structure of basic events with more occurrences in different minimum cut sets is more important, and the structure of basic events is more important; The structure of basic events with fewer occurrences in different minimum cut sets is less important, and the structure of basic events is less important.According to the above four principles, the order of importance of the bottom event in the fault at all levels is as follows:

Ⅰ : $I_{\Phi}(2) = I_{\Phi}(3) = I_{\Phi}(4) = I_{\Phi}(5) > I_{\Phi}(1) > I_{\Phi}(6) = I_{\Phi}(7)$

Ⅱ : $I_{\Phi}(8) = I_{\Phi}(9) = I_{\Phi}(10) = I_{\Phi}(11) = I_{\Phi}(12) = I_{\Phi}(13) = \mathrm{I}_{\Phi}(14) = I_{\Phi}(15) = I_{\Phi}(16) = I_{\Phi}(17) = I_{\Phi}(18) = I_{\Phi}(19) = I_{\Phi}(20) = I_{\Phi}(21) = I_{\Phi}(22) =$

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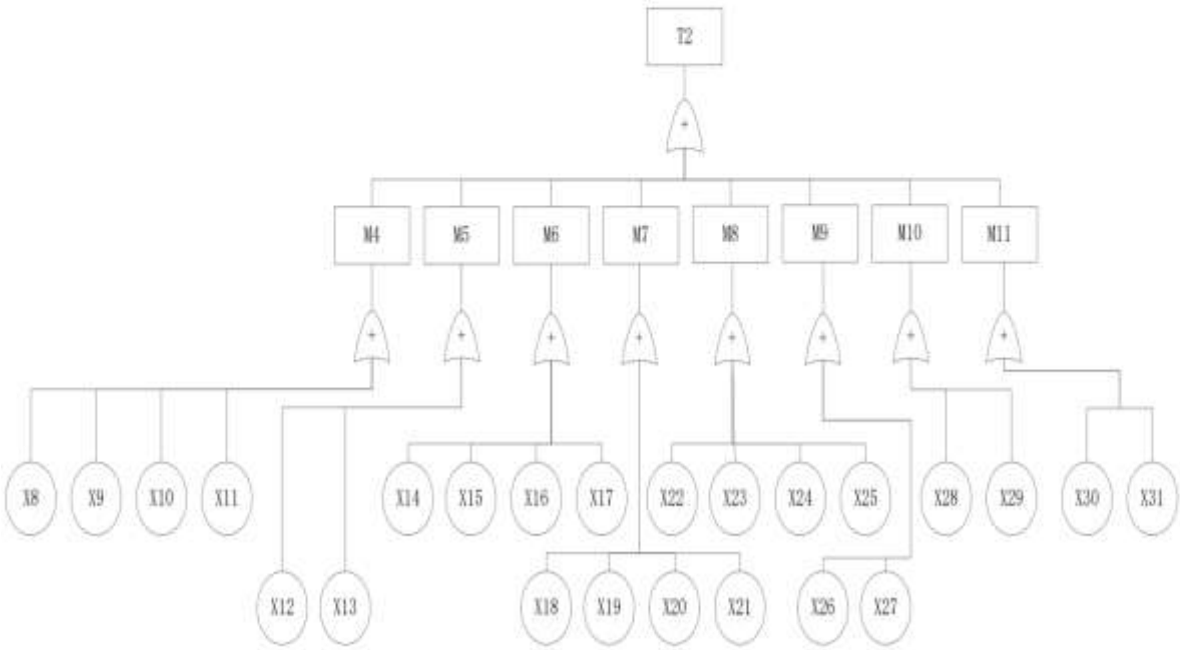
$I_\Phi(23) = I_\Phi(24) = I_\Phi(25) = I_\Phi(26) = I_\Phi(27) = I_\Phi(28) = I_\Phi(29) = I_\Phi(30) = I_\Phi(31)$

Ⅲ:$I_\Phi(32) > I_\Phi(33) >= I_\Phi(34)$

According to the above FMEA analysis and FTA analysis, X2, X3, X4 and X5 are of high importance for faults with fault level I, and the corresponding events are parameter calculation error, structural design error, performance design error and cost calculation error respectively. It indicates that during the corresponding design process, special attention should be paid to the above design links, and the corresponding reliability management mechanism should be established to improve the reliability of the design process. For faults with fault level II, X8 to X31 have the same importance, and the corresponding design links are mostly drawing and process design, which also reflects that the key point of mechanical design reliability is drawing and process design. Therefore, in order to ensure the reliability of the design process, it should be carefully checked at each corresponding design process stage, focus on this part of the reliability management mechanism, and focus on enhancing the reliability management of this part of the design process. For faults with fault level III, X32 has the highest importance, and the corresponding event is the error at the processing site. In view of this result, in the establishment of reliability management mechanism, it is also necessary to supervise and manage the third operation layer to ensure that the last link of the design process will not go wrong.



Figuer3 Take the fault with fault level Ⅲ as the fault tree of top event

Table6 Fault tree code meaning

CODE	MEANING	CODE	MEANING
T1	Catastrophic failure	X10	Poor economic status
T2	Fatal failure	X11	Lack of process equipment
T3	Critical failure	X12	Parameter and structure error
M1	Wrong R&D direction	X13	Drawing error
M2	Error in project initiation	X14	Space position design error
M3	Inaccurate product positioning	X15	Component position design error
M4	Scheme not feasible	X16	Transmission relationship design error
M5	Drawing error	X17	Basic structural dimension design error

M6	Error in general assembly drawing	X18	Functional design error
M7	Component drawing error	X19	Basic dimension design error
M8	Error in part drawing	X20	Structural design error
M9	Errors in drawing review	X21	Action relationship design error
M10	There are mistakes in process audit	X22	Accuracy design error
M11	Mistakes in standardization audit	X23	Efficiency design error
M12	Experiment failed	X24	Rigid design error
M13	Trial production failed	X25	Processing technology design error
X1	High level decision erro	X26	Self review by design department
X2	Parameter calculation error	X27	Insufficient level of Auditors
X3	Structural design error	X28	There is a mistake in the processing technology
X4	Performance design error	X29	The assembly process is flawed
X5	Costing error	X30	Not conforming to national standards
X6	Work errors of researchers	X31	Not conforming to drawing standards
X7	The survey object is not representative	X32	Processing site error
X8	Organizational marketing errors	X33	Parameter design error
X9	Technological error	X34	Drawing design

Table7 Minimum cut set of each fault level

Fault level	Minimum cut set
I	$\{X6, X1\}$,$\{X7, X1\}$, $\{X2\}$,$\{X3\}$, $\{X4\}$, $\{X5\}$
II	$\{X8\}, \{X9\}, \{X10\}, \{X11\}, \{X12\}, \{X13\}, \{X14\}, \{X15\}, \{X16\}, \{X17\}, \{X18\}, \{X19\}, \{X20\}\{X21\}$ $\{X22\}, \{X23\}, \{X24\}, \{X25\}, \{X26\}, \{X27\}, \{X28\}, \{X29\}, \{X30\}, \{X31\}$
III	$\{X33, X34\}, \{X32\}$

ⅣCONCLUSION

In this paper, through the comprehensive analysis of FMEA and FTA, the fault prone links, possible faults and fault levels are identified for the design process of material testing instruments. In the design process, the events prone to failure include parameter calculation error, structural design error, performance design error, cost calculation error, etc. For these failures and links, the reliability management mechanism of organization guarantee and personnel guarantee can be established..

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