

## Reliability Study of Aviation Equipment

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**Abstract.** It is well-known that reliability of equipment is the most important of all performance to all equipments. In order to make the equipments which include mechanical equipments, electrical equipments and so on work normally, reliability theory FMECA is applied in an aviation equipment to study its reliability and improve operational reliability of the product. Through its reliability mathematical model, average of operational time is predicted based on calculating failure probability of all electrical components. According to the process of FMECA, all kinds of the failure mode, reasons, effects and criticality of the products can be determined completely. By comparing these criticality data as shown, the paper analyses adopted method by that the contents, accents and operating process of maintenance may be instituted finally. FMECA-based method for reliability study of the equipment and the equipment maintenance perform well. The results indicate that application of FMECA method can analyze reliability in detail and improve operational reliability of the equipment. Therefore this will supply theoretical bases and concrete measures of maintenance of the products to improve operational reliability of products. FMECA can be feasible and effective for improving operational reliability of all equipments.

### Introduction

With the development of electronic technology, the performance of the aircraft equipments tends to be growing better. In order to ensure their working order and enhance their performance, the operational reliability of the aircraft equipments should be guaranteed. Low failure probability and long time work are required to plane-carried products [1]. Thus, it is necessary to analyze the reliability of products and do a good maintenance to the aircraft equipments under the guidance of proper theories. Failure Mode Effect and Criticality Analysis (hereafter called FMECA) is one of the methods for reliability analysis and valuation [2]. FMECA is designed to analyze all sorts of the potential failure in each component by analyzing and computing criticality, FMECA may tell the incoming failure and its effect, that is, FMECA can tell the staff the exact service job [3]. According to what has been produced by FMECA, a well-scheduled job list may be done to enhance the reliability of the plane-carried equipments.

Aiming at the plane-carried equipment of a certain type of aircraft and applying FMECA, we conducted its reliability modeling and prediction of average of operational time [4] and pointed out the issues which should be paid attention to in maintenance while using the equipment. So the operational reliability of the plane-carried equipment has been improved. In the following part, this equipment is used as an example to introduce the process and effect of using FMECA method.

### The Modeling of the Aircraft Equipment Reliability

The reliability modeling of the aircraft equipments is conducted by dividing the whole working process into different functional system and sub-system, each of which fulfills its respective function. The systematic functional diagram is designed finally. Based on this systematic functional diagram, the reliability model with one-to-one clear administrative levels is built, that is the reliability diagram of the aircraft equipment [5].

**The Main Structure and Functions of the Equipment.** According to the design and application characteristics of the equipment, the systematic functional diagram is formed. Based on this, this equipment can be divided into eight functional modules: microcomputer system, pulse width regulating D/A converter, volt-control vibes system, digital trigonometric function generator system, D/A transition network system, numerical control gaining system, power magnification system and display system [6]. The main function can be further divided into the sub-systems which fulfill the most basic functions. For example, D/A transition network system, used to realize the production and output of the analog quantity, consists of R/2R transition network and operational amplifier unit. Each sub-system can also be divided into parts and components and other apparatus. This kind of division is in accordance with units of the equipment while designing and manufacturing.

**The Reliability Diagram of the Equipment.** Based on the systematic functional diagram, those parts and components which have the same function are used to form a sub-system. Many sub-systems form the reliability system of the equipment. The reliability modeling is conducted according to the function each part fulfills. And then the whole system is divided into many sub-systems which are further divided into individual part and component. The reliability diagram is drawn according to this. The reliability diagram should be in accordance with the schematic diagram of the whole equipment. Then, the encoding process is conducted according to the hierarchy relation of system and sub-system. The eight functional modules are seen as eight systems and are encoded as microcomputer system (01), pulse width regulating D/A transmitter (02), Volt-control vibes system (03), digital trigonometric function generator system (04), D/A transition network system (05), numerical control gaining system (06), power magnification system (07) and display system (08). The sub-systems, parts and units in each system are also encoded. For example, RAM (010310), etc. The reliability diagram is shown in Figure 1.

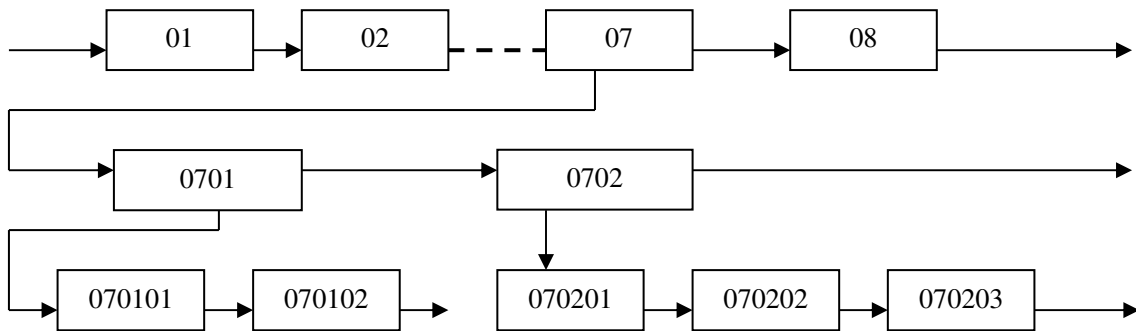


Fig. 1 Reliability diagram of the aircraft equipment

**The Reliability Mathematical Model of the Equipment.** The reliability mathematical model of the equipment while working is shown in equation (1) and (2).

$$\lambda_s = \sum \lambda_i . \tag{1}$$

$$MTBF_s = 1/\lambda_s . \tag{2}$$

$\lambda_s$  — failure probability of the equipment.

$\lambda_i$  — failure probability of Unit i.

MTBF<sub>s</sub> — average of interval between failures of the equipment.

**The Prediction of the Reliability**

The prediction of the reliability of the equipment starts with the parts and components and ends with the whole equipment [7]. The data are from the GJB/Z299-91. We also refer to the external field data of some other similar products [8]. For example, the resistance R in the numerical control gaining system, n=30, the working failure probability model of the resistance R is:  $\lambda_p = \lambda_b \times [ ]_E \times [ ]_Q \times [ ]_R$ . Since

$S=0.3$ , according to Chart 2.4.1—5, 2.4.1—1, 2.4.1—2 and 2.4.1—3,  $\lambda_p=0.056 \times 10^{-6}/h$ ,  $\prod_E=1$ ,  $\prod_Q=0.3$ ,  $\prod_R=1.0$ , thus,  $\lambda_p=0.056 \times 10^{-6} \times 1 \times 0.3 \times 1.0=0.0168 \times 10^{-6}/h$ , the failure rate of all the resistance  $\lambda=\sum \lambda_i (i=1,2,\dots,30)=0.504 \times 10^{-6}/h$ . By using this method, we can get the failure rate ( $\lambda_s$ ) of the equipment:

$$\lambda_s=\sum \lambda_i=(1.45+2*0.01188+8*0.01133+\dots)=985.7 \times 10^{-6}/h \tag{3}$$

$$MTBF_s=1/\lambda_s=1/(985.7 \times 10^{-6})=1014.5(h) \tag{4}$$

**The FMECA Analysis of the Equipment**

**The Work of FMEA.** FMEA is a bottom-up failure analysis method. According to the FMECA working program, the FMEA analysis of the aircraft equipment is conducted [9].

**List the Equipment Failure Model Checklist.** According to the national military standard GJB299, the reliability estimation handbook of electronic equipments and working experience of maintenance, the typical failures of this equipment are as listed below.

**Reasons Analysis.** Analyze the reasons causing the failures. Careful analysis should be conducted to judge every possible failure or problem, such as the reason of joins and quality.

**Possible Effect.** Analyze the possible effect of each problem to the part or component itself, to the upper level and to the whole equipment.

**Measures.** Propose some possible preventive measures according to each kind of problem model, reasons and effect.

**Degree of the Seriousness of the Failures.** The degree of seriousness can be classified into the following four types: Type I (disastrous), Type II (fatal), Type III (critical) and Type V (slight).

Take D/A transition network system for example, FMEA analyzing table of some parts and components is shown in Table 1.

Table 1 D/A Transition network system FMEA

Code	Failure mode	Failure cause	Failure effect			Compensation Measure	Severity
			Oneself	Upper	Last		
050201	Loose contact or break	Solder-off	Amplifier no-working	System not work	Equipment no-working	Choose product Improvement of the welding quality	III
050202	Open circuit	Solder-off	Capacitor no-function	$\beta$ change	Equipment no-working	Improve welding quality	III
	Short circuit	Lower quality	Capacitor short connection	$\beta=1$	Equipment no-working	Choose product	III
	Parameter drift	Long-use	Value of capacitor change	System work	Equipment work	Improve daily maintenance	IV

**The CA Analysis of the Equipment.** Under a specific degree of seriousness, the criticality value of a certain failure model in those failure models is  $C_{mj}$ . As for a given degree of seriousness and a given phase of mission, the  $C_{mj}$  of the number  $j$  of the product can be calculated by using the following formula:  $C_{mj}=\lambda_p * \alpha_j * \beta_j * t$ . In this formula,  $\alpha_j$  shows the percentage of failure displayed as model  $j$ . If all the failure models of a product are listed, the totality of  $\alpha_j$  would be  $\beta_j$ . Number  $\alpha$  got by analyzing faculty from their working experience is the conditional probability of the systematic mission when the product breaks down as model  $j$ . The working time can be calculated from the definition of the system. Generally, it is shown by the hours used to finish each mission or by the times of the working

circle. The  $C_r$  (the destructive degree of a product) refers to the estimated failing numbers of a certain type of product caused by this failure model of the product. As for a given degree of seriousness and a given phase of mission,  $C_r$  is the totality of  $C_{mj}$  under this degree of seriousness.  $C_r$  can be calculated according to the following formula:

$$C_r = \sum_{j=1}^n C_{mj} = \sum_{j=1}^n \lambda_p * \alpha_j * \beta_j * t \tag{5}$$

Take the example of power amplification, and the table of CA is shown as Table 2.

Table 2 Power amplifier system criticality analysis (CA)

Code	Function sign	Failure Mode	Severity	$\lambda_p$ 10 <sup>-6</sup> /h	$\alpha_j$	$\beta_j$	t	$C_{mj}$	$C_r = \sum C_{mj}$
070101	capacitor	Open circuit	III	0.0048	0.13	1.00	2	0.001248	0.008348
		Short circuit	III	0.0048	0.74	1.00	2	0.0071	
		drift	IV	0.0048	0.13	0.10	2	0.0001248	
070102	paper capacitor (10uF)	Short circuit	III	0.02709	0.83	1.00	2	0.045	0.0542
		Open circuit	III	0.02709	0.17	1.00	2	0.0092	

**The Application of FMECA**

**Work Out the Content of Maintenance of the Equipment.** According to the working of FMEA, the failure models of product in each system which form the product are seen as the daily maintenance content of the equipment. The failure models of Type III and Type IV totaled up to 45 items, all of which have been written in the maintenance and using manual attached to the equipment.

**Determine the Key Maintenance Point of the Equipment.** Based on the FMEA and CA reliability analysis, the key and important parts of the equipment are CPU, crystal, LED, program and data memorizer, AD652, 74HC573, 74LS393, D/A transition system adjust resistance, and 74LS273 etc. In the work of maintenance, they are regarded as key target.

Effective measures should be taken to ensure the normal working of the equipment by considering the relative failure models.

**Work Out the Reasonable Maintenance Working Method.** Calculate the criticality of product according to the failure models of the product in all the systems. Under the principle of maintaining those parts which have high degree of destruction first, reasonable working order for maintenance must be worked out based on the order of the criticality data. Considering the destructive degrees of those failures belonging to Type III and Type IV, the maintenance working order is given.

**The Application Effect**

After investigating the same type of aircraft equipments used in two airports A and B, we collected the mean lifespan data of the equipments in the two places and they are given in Table 3 and Table 4. In airport A, the maintenance of the equipments is not conducted according to the FMECA analysis, and in airport B, the maintenance of the equipments is conducted according to the FMECA analysis.

From the two tables above, we can find: the MTBF of airport A is 869 hours which is shorter than the estimated MTBF (1014.5 hours); while in airport B, the MTBF is 1009 hours, which is very close to the estimated MEBF. From the comparison, we can also find that, for those equipments which have been maintained according to the analysis of FMECA, their MTBF is much longer than that of other equipments, the operational time of the product is longer than before and the operational reliability is also improved.

Table 3 The mean lifespan data of airport A (unit: hour)

Number	1	2	3	4	5	6	7
Interval time	810	840	1080	790	968	730	870
MTBF	869						

Table 4 The mean lifespan data of airport B (unit: hour)

Number	1	2	3	4	5	6	7
Interval time	1010	990	1070	998	1050	1000	950
MTBF	1009						

### Summary

This paper conducts the reliability modeling of the aircraft equipment and predicts its MTBF. In order to analyze and improve its reliability, reliability technique FMECA method is used to analyze its failure models and destructive degree and propose content, key point and method which should be paid attention to while using and maintaining the equipment. The result shows that reliability analysis and the application of FMECA method prolong the lifespan of this equipment and improve the operational reliability greatly. It proves that it is correct to apply this method to reliability analysis and improvement of operational reliability of a product. In the meantime, it may help to improve the reliability of all products.

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### References

- [1] Liu Luning, in: Reliability Analysis of Electric Element in Ground Tester, edited by Aircraft Design, volume 2 (1998), p. 52.
- [2] Chao Maoguo and Qian Jinshan, in: Reliability Analysis Technology on Aviation Engine, edited by Aviation Engine, volume 4 (1995), p. 32.
- [3] Gong Dequan, in: Application of FMECA Method to Improve Design Reliability, edited by Shanghai Space, volume 3 (1995), p. 25.
- [4] Establish of Reliability Model and Reliability Prediction Manual, GJB813-90, edited by National Science and Technology Committee (1990).
- [5] Ding Dinghao, in: Reliability and Maintenance Engineering, edited by Electronic Industry Press (1986), p. 362.
- [6] He Limin, in: Design of Processor System, edited by Bei-jing University of Aeronautics and Aeronautics Press (1990), p. 106.

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- [7] Chen Bingsheng, in: Electronic Reliability Engineering, edited by National Industry Press (1987), p. 71.
  - [8] Reliability Prediction of Electronic Equipment Manual, GJB/Z299-91, edited by National Science and Technology Committee (1991).
  - [9] Lu Tingxiao and Zheng Pengzhou, in: Design and Analysis of Reliability, edited by National Industry Press (1995), p. 140.