

Study on Structural Reliability Analysis of Aircraft Electronic Equipment

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Abstract. The aircraft electronic devices are mainly composed of plate type, the structures with so many electronic components are complex. Most electronic components are standard parts. Reliability analysis of aircraft electronic equipment is mainly focused on the circuit of electronic equipment and components and so on. However, the investigation about reliability of electronic equipment structure research is seldom. This article introduces the principle and method of structural reliability of aircraft electronic equipment. Taking the computer box of air data processing for a type of aircraft as an example, reliability analysis process is described based on Monte Carlo Method. the result of calculating the strength and stiffness reliability of the box are 99.9746% and 99.9833% respectively, while the experimental reliability are 99.9986% and 99.9918%. The good consistency between simulation and experiment results indicates that the analysis method is reasonable and effective.

Introduction

With the development of economy, the aerospace industry has also made great progress. The performance of the aircraft electronic equipment tends to be growing better as the electronic technology developed [1]. Due to the particularity of aerospace electronic equipment's working environment, they require higher reliability than normal [2]. Low failure probability and long time running are required. Because of expenses and the experimental condition, it's impossible to evaluate the structural reliability through a large number of flight experiments, therefore, in order to ensure their working order and enhance their performance, the structure reliability analyses and designs of aircraft electronic equipment are necessary. However, for recent years, the engineering studies on structural reliability analysis of electronic equipment are relatively few and lag far behind the reliability research on electronic circuit and components [3-5]. This paper summarizes the existing reliability analysis methods of aircraft electronic equipment [6-10], and illustrates the basic methods of structural reliability simulation of aircraft electronic equipment by example.

The classification of aircraft electronic equipment

The typical aircraft electronic equipment includes box, base, printed circuit board and the basic electronic components. The basic electronic components include resistor, capacitor, inductance and the magnetic components, semiconductor discrete devices, relays, electric connector, semiconductor integrated circuit, hybrid integrated circuits and so on, which are usually fixed on the printed circuit board. And the printed circuit board generally includes PSU, MBI, CPU, AFU, DFU, PSU and SFU, and then it is fixed on the box by welding, bonding and plugging. The box is used for fixing printed circuit board, power supply, display device etc, the box and base are usually made together and the base is fixed on the aircraft.

The process of the reliability analysis

Modeling. In the process of reliability analysis there must be random input variables and parametric modeling have to be done when the size of the structure, material properties are used as random variables.

Confirming the random variables. Generally, there are many random variables are involved in the process of reliability analysis, and generally they can be divided into three categories including the size of the structure, material properties and external effect(such as load, temperature change). Most of the random variables obey the normal distribution, and the statistic characteristics of random variables usually refer to the mean and variance.

Reliability calculating. Reliability analysis includes the reliability analysis of strength and stiffness.

Reliability of strength refers to that it is not allowed that stress exceeds the yield strength during work, otherwise it is considered failure. The equation of intensity state is shown in Eq. 1:

$$Z = s_s - s_{\max} . \quad (1)$$

s_s — yield strength of material, s_{\max} —maximum equivalent stress during work.

Stiffness is an ability that elastic body resists deformation, and stiffness reliability refers to that the equipment in use are not allowed to appear that deformation exceeds the material allowable displacement, otherwise it is considered failure. The equation of stiffness state is shown in Eq. 2:

$$G = g_s - g_{\max} . \quad (2)$$

g_s —allowable displacement of material, g_{\max} —maximum displacement during work.

Example analysis

A case study of computer box of air data processing of an aircraft is given to describe reliability analysis process of aircraft electronic equipment.

Finite element analysis of the computer box of air data processing. The material of the is ZL101 [11], 10-nodes tetrahedron elements- SOLID187 are deploy parametric modeling by ANSYS software. It is shown in Fig. 1.

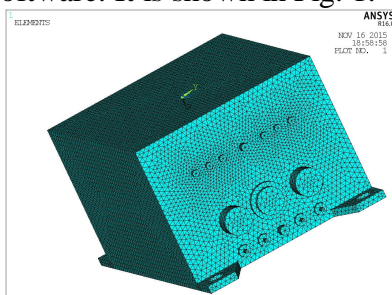


Fig. 1 The finite element model of computer box

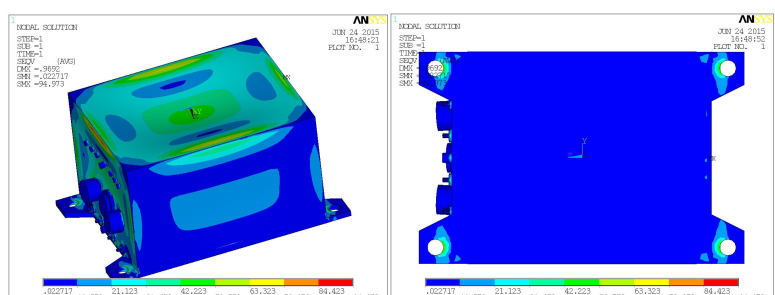


Fig. 2 The stress distribution of computer box

Stress analysis of the model is carried out after each random variable is averaged. It is shown in Fig. 2.

As is showed in the Fig. 2, the maximum stress is 94.973MPa at the edge of the upper cover of the box, and the stress in the area where the anchor bolts are fitted on is also high relatively, which make these area vulnerable to damage in repeated impact or a huge impact.

Reform the random variables and their distribution. Random variables of computer box of air data processing include the size of the structure, material properties and external load. According to the national standard about size tolerance, the size of box should obey truncated Gaussian distribution and the others obey the normal distribution. Unified unit: size(mm), time(s), force(N), quality(t), pressure(MPa). Random input variables are shown in Table 1.

Table 1 Random input variables

Random variables	Distribution function	mean	variance	Upper limit	Lower limit
The length of box /d	Truncated Gaussian distribution	316	1	314.8	317.2
The width of box /w	Truncated Gaussian distribution	258	1	256.8	259.2
The height of box /h	Truncated Gaussian distribution	191	1	189.8	192.2
Box wall thickness / t_1	Truncated Gaussian distribution	4	0.1	3.7	4.3
Box wall thickness / t_2	Truncated Gaussian distribution	7	0.1	6.5	7.5
Box base thickness / t_3	Truncated Gaussian distribution	12	0.1	11.5	12.5
Cover thickness / t_4	Truncated Gaussian distribution	5	0.1	4.7	5.3
The density of material	Gauss normal distribution	2.7e-9	2.7e-10		
Modulus of Elasticity	Gauss normal distribution	70000	7000		
Yield strength	Gauss normal distribution	200	10		
Allowable displacement	Gauss normal distribution	2	0.2		
Pressure	Gauss normal distribution	0.08	0.008		
Overload	Gauss normal distribution	58800	5880		

Random output variables are strength performance function and stiffness performance function.

Reliability calculating. Monte Carlo method is chosen to simulate 40000 times in this example. According to the aircraft pitch test data, the biggest impact overload is about 6. The strength and stiffness reliability is got with the maximum load (impact) and 0.8 times of standard atmospheric pressure.

Analysis of calculation results. The results of reliability is shown in Table 2:

Table 2 The results of reliability		
	strength	stiffness
failure probability / p_{fs}	0.0254%	0.0167%

As is shown from results that the average probability of $Z < 0$ is 0.0254% when the confidence coefficient is 95%, which means that the strength reliability of the air data computer box is 99.9746%. The failure probability of stiffness is 0.0167%, in other words, the stiffness reliability of the air data computer box is 99.9833%, while the experimental reliability is 99.9986% and 99.9918%, which validates the good consistency between simulation and experiment results.

The impact that each random input variable have on strength and stiffness performance function is shown in Fig. 3.

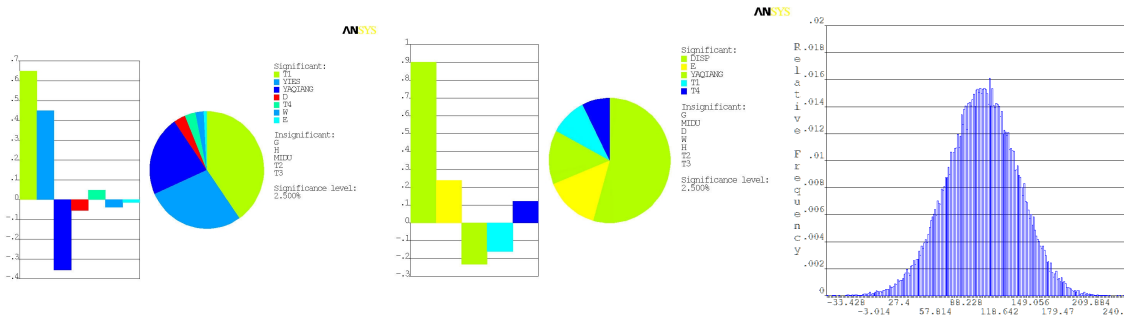


Fig. 3 Sensitivity of strength and stiffness performance function Fig. 4 Histogram of strength performance function

The Fig. 3 (left) shows that box wall thickness and yield strength YIES influence strength reliability of the box dramatically. The Fig. 3(right) shows that impact of allowable displacement have on the stiffness reliability of box is obvious, and the second one is the box wall thickness, so the basic size of box during production should obey to the standards strictly, and the high quality aluminum alloy materials should be used.

The Fig. 4 shows that it is consistent between the fitting curve of histogram of strength performance function and the distribution of the set random input variables, which indicates that the histogram curve of strength performance function is close to the normal probability density function as well as cycles sufficiently.

Conclusion

This paper introduces the principle and method of structural reliability analysis of aircraft electronic equipment, and using the reliability theory and stochastic finite element method could analyze and forecast structural reliability of aircraft electronic equipment accurately.

Technicians could early find problems by simulating structural reliability of the electronic equipment, and then optimize structure to improve the structural reliability of the products.

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