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Study of Evolution Mechanism on Aircraft Sudden Failure

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Abstract

Sudden failure of aircraft is a transient failure, always difficult to prevent for its quick and random occurrence. However, it has an evolutionary process from gradual change to sudden change, therefore the sudden failure of aircraft can be reduce or eliminate through the understanding its evolutionary mechanism. In this paper, the fatal accidents of aircraft are analyzed, produced causes of aircraft sudden failure are researched, and the formed process of aircraft sudden failure can be divided into three stages including gradual change, sudden change and sudden occurrence. It has important meaning to know evolution laws of aircraft sudden failure and prevent its occurrence.

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Keywords: Aircraft; Sudden failure; Produced causes; Formed process

1. Introduction

Aircraft is a main tool for air traffic. In case of aircraft failure during the flight, it would bring about influence to the aircraft performance, or serious threat to the flight safety, or even fatal crash, especially the sudden failure, which has created many catastrophic accidents due to its sudden occurrence and seriously destructive effect. Therefore, research of the sudden failure has aroused great concern [1-3]. In order to know the mechanism of aircraft sudden failure and its evolutional laws, produce causes of aircraft sudden failure are analyzed，and the form process of aircraft sudden failure can be divided into three stages including gradual change, sudden change and sudden occurrence. It provides a new and new method to know evolution laws of aircraft sudden failure.

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2. Statistics and Analyses of Aircraft Fatal Accidents

The sudden failure of aircraft is a transient failure. It is difficult to prevent for its quick and random occurrence [4-5]. The fatal accidents and fatalities of world airline from 2000 to 2009 are shown in Fig.1.

Fig.1.The fatal accidents and fatalities of world airline from 2000-2009

Sudden failures of world airline from 2000 to 2008 are shown in Fig.2.

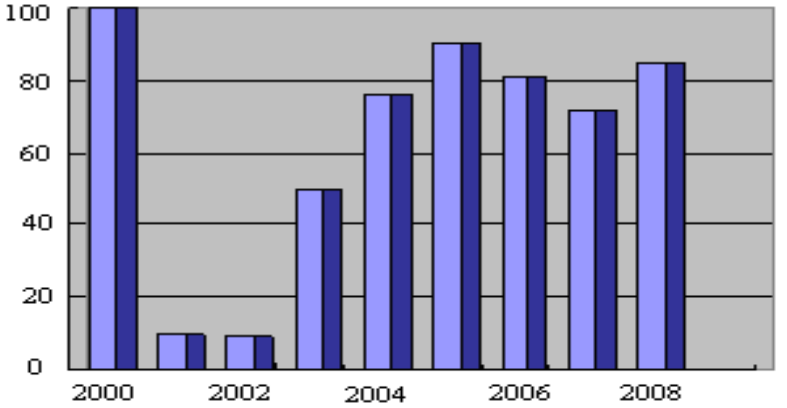

Fig.2. Sudden failures of aircraft from2000-2008

Ratio of aircraft sudden failure from 2000 to 2008 is shown in Tab.1.

Tab.1. Ratio of aircraft sudden failure from 2000-2008

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Fatal accidents	1126	34	37	363	151	178	156	136	108
Sudden failure	100	10	9	50	76	90	81	72	85
Ratio %	9	29	24	19	50	50	52	53	79

The causes of fatal accidents and its ratio are shown in Tab.2.

Tab.2. Causes of fatal accidents and its ratio

Accident causes	Accident number	Ratio %	Death number	Ratio %
Crew error	37	65	824	68
Collision ground	21	37	523	43
Weather	17	30	287	24
Lose control	8	14	419	34
Engine fault	9	16	90	7
Structure fault	6	11	152	13
Operation error	6	11	18	0.5
Maintenance	1	1.7	1	0.1
Air fire	1	1.7	15	1.2
traffic control error	1	1.7	2	0.2

We can know from Fig.1, Fig.2 and Tab.1,Tab2 that the fatal accidents of aircraft are caused by main sudden failure and the sudden failure is a result of comprehensive function on human-machine-environment

3. Produced Reason on Aircraft Sudden Failure

Besides the design and quality problem, the produced reason of aircraft sudden failure mainly includes the following aspects.

- Energy Accumulation

During flight, the aircraft has to keep material and energy exchange with the outside to maintain internal balance and work properly. Once the balance is broken, it may induce the sudden failure, while the destruction of balance is usually the result of various energy accumulations. For example, the in-flight shutdown of engine by surging is formed since the air flow inside the compressor and the compressor speed deviate too much from the designed conditions, bringing about drastic fluctuation of the total outlet pressure, flow and velocity of compressor, followed by flameout of the combustion chamber, i.e. in-flight shutdown of the engine, which is exactly the result of the pressure, flow, temperature and other energy accumulation.

- Structure Damage

As the aircraft is composed of thousands of structures, once the structural damage occurs in the course of operation, the normal operation of aircraft would be influenced, or the sudden failure will be induced, causing serious threat to the flight safety. The structural damage in the early form mainly refers to the mechanical fretting damage.

Mechanical fretting damage means the mechanism surface damage due to fretting wear, fretting friction, micro-extrusion, micro broaching, collision, attacking, fretting adhesion and slight slipping among all the fitting piece, which can induce the mechanical fatigue fracture. Generally, there are three stages from the fretting damage to the fatigue fracture, including initiation of crack source, micro-crack propagation and fatigue buckling. It usually spends long courses for crack formation and development, and it's difficult to be aware especially in the early stage. As the micro-damage enters the propagation and buckling stage, it will lead to sudden failure. For example, once the aircraft wing fittings have the structural damage, when strong turbulence impacts the aircraft in the flight, the wing may be broken, causing the calamitous accident.

- Performance Declination

In the course of aircraft flight, with the increase of flight time, the aircraft performance is also declining gradually, once the declination is beyond the allowable performance indicator, it will cause the system function failure, leading to sudden failure. For example, after the engine performance declination, more fuel shall be provided to the engine in order to produce enough thrust force, and when the temperature of combustion chamber exceeds the limit too much, the engine part will be broken or the combustion chamber will be burnt, causing in-flight shutdown of the engine. For another example, in case of damaged oil system sealing or blocked oil filer, much oil will be lost, and as the oil cannot be transmitted normally, it's probable to damage the high-speed engine components due to lack of lubrication or poor cooling, and thus lead to the sudden failure and catastrophic accident

- Environmental effect

The aircraft in flight usually suffers from several load effect such as high temperature, high pressure, high speed etc., as well as the invasion by lightning, hail and bird, and dramatic change of flight environment will also lead to incidence of sudden failure. According to statistics, there are hundreds of engine shutdown accidents due to bird strike or suction of sand etc. during taking off or landing of the aircraft around the world every year. On January 15, 2009, the plane of Flight No. 1549 of American Airlines, which carried 155 persons, encountered the bird strike at 900 meters above, and finally escaped from the catastrophic accident thanks to properly emergent treatment by the pilot.

- Human Error

Human error includes errors of the ground maintenance personnel, flight command and management personnel and the air operator. The sudden failure of aircraft can also occurs as a result of careless work, improper command or operational errors. On April 6, 2009, the Fokker 27 aircraft of Indonesian Air Force stroke the ground building during landing, resulting into fire and crash, and five crew and 18 passengers were dead.

4. Formed Process on Aircraft Sudden Failure

Although the occurrence of aircraft sudden failure is very short, there is always an evolutionary process from the change of gradual and slight to the change of sudden and emergent. Formation of the aircraft sudden failure can be divided into three stages including gradual change, sudden change and sudden occurrence. It is shown in Figure 3.

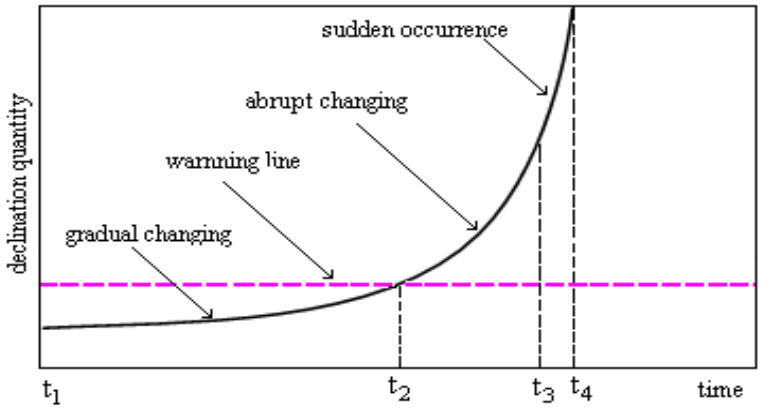

Fig.3. Evolving process of aircraft sudden failure

In the figure, section t_1-t_2 means the gradual change, during which, there is usually no significant change of the aircraft structure and performance, and the change cannot be directly observed by conventional methods, but the sensitive parameters that indicate sudden failure of the aircraft will have significant changes; section t_2-t_3 means the sudden change, the duration of which is much short, and the parameters of the aircraft structure and performance will have significant changes, such as increased vibration, aircraft flutter, etc., if the drastic measure is not taken promptly, it will soon lead to the sudden or catastrophic failure; section t_3-t_4 means sudden occurrence, as the sudden failure is to break out in a moment and make the key aircraft structure or subsystem lose all original functions, the emergency measures can only be taken at this stage, otherwise it will lead to catastrophic accidents.

The evolution model of structure rupture fatigue damage is shown in [6]

$$D = 1 - [1 - \frac{N}{N_f}]^{\frac{1}{1+m}} \quad (1)$$

Where, D Damage variable

N Circulating times of crack expanding

N_f Circulating times of damage condition

m Evolution parameter of experiment assurance

5. Conclusions

The sudden failure of aircraft is a transient failure. It has an evolutionary process from gradual change to sudden change and from slight change to abrupt change. The sudden failure of aircraft may be prevented or reduced as long as the produced causes, formed process and its evolvement rule can be known.

References

[1] Ejaz N, Salam I, Mansoor M, Tauqir A. Joining error resulted in failure of an aircraft engine radial diffuser. *Engineering Failure Analysis*, 2009, 16(1):350-357

[2] Bagnoli F, Bernabei M, Ciliberto A. Failure analysis of an aircraft auxiliary power unit air intake door. *Engineering Failure Analysis*, 2011, 18(1): 284-294

[3] Ukil A, Živanović R. The detection of abrupt changes using recursive identification for power system fault analysis. *Electric Power Systems Research*, 2007, 77(3-4): 259-265

[4] Jonathan L and Donald S. A survey of intelligent control and health management technologies for aircraft propulsion systems. *Journal of Aerospace Computing, Information, and Communication,* 2004, 1 (12): 543-563

[5] Zhao Jing, Yao Xuebin, Zhang Lei. The optimization of initial posture with avoidance of the sudden change in joint velocity for fault tolerant operations of two coordinating redundant manipulators, *Mechanism and Machine Theory*, 2005, 40(6): 659-668

[6] Zheng ZG, Cai GW, Li ZJ. A new model of fatigue damage evolution, *Engineering Mechanics*, 2010, 27 (2):37-40