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The Magazine Inclusiveness Problem of Aero-engine

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Abstract: Aero engines may suffer a series of damages during operation, which threaten the structural safety of the engine. This paper studies the magazine inclusiveness problem of aero engines from three aspects, namely: what is magazine inclusiveness, why the magazine suffers losses, and how to improve the magazine inclusiveness. Finally, the future outlook on the research of the aero-engine magazine inclusiveness problem is presented.

Keywords: Aero-engine, Inclusiveness.

1. Introduction

The engine is the "heart" of the aircraft, the driving force for the rapid development of the aircraft, and the decisive factor for the performance, reliability and cost of the aircraft. The development of aero-engine technology has its important role in national defense and national economy, and every major revolutionary progress of human in the field of aviation is closely related to the breakthrough and progress of aero-power technology.

The magazine is one of the important parts of the aero-engine, it is the base of the whole engine, its shape structure is complex, different engines, different parts of the engine, the shape of the magazine varies, the function of the magazine parts determine the shape of the magazine, but their basic features are cylindrical or conical shell and support plate components. Due to the difficulty and long period of magazine parts design, the design of the magazine accounts for a considerable proportion in the design of the whole engine. Improve the design efficiency of the magazine to compress the engine design cycle is of great significance.

2. The Concept of Aircraft Engine Magazine Inclusiveness

Inclusion refers to the ability of the magazine to contain the fractured fragments after some engine structures break or fall off, preventing them from penetrating the engine and causing secondary damage to other structures of the aircraft. Among the debris are mainly: broken wheel or drum ring, broken blades, etc. When it comes to the inclusion capacity of the aircraft engine, in fact, can be divided into a narrow sense and a broad sense of two:

(1) the narrow sense of inclusion capacity: above, the rotor rupture or blade failure, if the magazine is strong enough, these fragments will be "wrapped" in the engine, with the airflow to move backward. Although the interior of the engine will be hit by a mess, resulting in stalling and stopping, but no external debris, will not cause serious secondary damage to the aircraft. As long as the pilot handles it properly, it is still possible to land the aircraft safely, especially for twin-engine or multi-engine airliners. We call this tolerance capacity in the narrow sense of tolerance capacity.

(2) broad inclusion capacity: in the case of high speed, the magazine can not completely contain the debris, which requires the engine itself, such as the rotor and wheel structure has sufficient strength, fatigue life, reliability. And take effective means of crack detection, this indirect inclusion capacity is called the broad inclusion capacity.

Non-inclusive accidents occur mainly due to environmental (bird collision, corrosion, foreign object damage), manufacturing and material defects, mechanical, human and other factors (maintenance, inspection, improper operating procedures), although the engine and magazine manufacturers are now making every effort to reduce the likelihood of accidents, but there are still accidents from time to time.

According to the different materials used, the aero-engine magazine can be roughly divided into the following categories: ① high strength structural steel magazine. With good toughness. Good protection, widely used in the early engine, but the density and mass is larger. ② aluminum/titanium alloy magazine. Density and mass is lower than high-strength structural steel, but the strength and protection effect is less. ③High-strength fiber-wound reinforced magazine. Winding high-strength fiber tape in the inner layer of aluminum/titanium magazine has the feature of light mass and strong inclusion capacity. ④All-composite magazine. Two-dimensional woven fabric winding or three-dimensional woven forming, with lighter mass, but still need to further improve the strength, stiffness, stability and service life. ⑤ Fiber reinforced ceramic matrix composite magazine. Make full use of the characteristics of high hardness, low specific density and high temperature resistance of ceramic materials. But need to overcome the material defects sensitive, brittle fracture, complex shape forming difficulties and other shortcomings. ⑥Magazine of other materials.

3. Reasons for Inclusive Failure of The Magazine

Aircraft engine non-inclusive accidents can lead to extremely serious consequences, causing unpredictable damage to human life and property safety. The reason is that in the work of the aircraft engine, if the compressor and turbine rotor blades fall out of the block, the turbine wheel discs appear broken and other failures, these pieces will be thrown outward under the action of strong centrifugal force, hitting the engine magazine. If the cassette is not strong enough, the shrapnel will penetrate the cassette and damage other objects it touches, such as the aircraft's load-bearing

structures, hydraulic and fuel systems, piping and maneuvering ropes, etc., and even directly harm the human body, causing serious secondary damage to the aircraft.

According to public documents, on September 6, 1985, a DC 9 airliner took off from Milwaukee, Wisconsin, USA, and caused a major accident in which 431 people were killed due to the fracture of the sealing drum between the 3rd and 4th stages of the engine's high-pressure pressurizer, which broke through the cabin and damaged the aircraft. When climbing to an altitude of 3000m, the 4-stage low-pressure turbine of the engine under the tail suddenly broke. The ruptured rotor pierced through the magazine and knocked out a circular gap of about 300° along the circumference of the aircraft. Fortunately, because the engine was installed in the rear of the aircraft, the broken pieces did not hurt the aircraft's load-bearing structure and maneuvering, hydraulic and fuel systems, and the aircraft was still able to use the other two engines for power to return to Guangzhou Airport safely. Therefore, in order to ensure flight safety, to ensure the failure of the blade can be effectively contained by the turbine magazine is particularly important.

4. Improve the Inclusiveness of The Magazine

As one of the world's three largest aircraft engine manufacturers, GE Aviation often use "every two seconds there is an aircraft powered by GE engines to take off" to describe their market share. A commonly cited figure in media reports is that GE Aviation accounts for nearly half of the global aero-engine market. This includes the C919, the large aircraft developed by China, which is powered by the LEAP-1C engine developed by CFM International, a joint venture between GE and France's Safran group.

GE and other aero-engine companies have two basic types of inclusive design concepts. The first is the hardwall case concept, which uses a thick shell to contain all the pieces inside the case. The second is the Softwall case concept, where the debris penetrates the interior of the case and only a localized area is broken by the impact, leaving the case structurally intact, and the debris is recovered by the reinforced flexible composite material on the outside of the case.

Early aero-engines used hard-walled cases, which were made of high-strength stainless steel, increasing safety while greatly increasing their weight. Obviously, the performance of the hard-walled magazine is difficult to meet the design requirements of modern high thrust-to-weight ratio engines and large turbofan engines. With the improvement of technology, fiber-reinforced resin-based composite soft-wall inclusion magazine emerged, which has the characteristics of light mass and strong inclusion capacity, GE in CF6-80C2 engine early use of soft-wall magazine design, winding 65 layers of aramide fabric outside the aluminum honeycomb layer, and resin for the outer layer of protection. Then came the Kevlar containment ring, the GE90 engine wrapped multiple layers of Kevlar woven strips around the aluminum magazine, reducing weight by even more than 50% compared to the previous design. Currently, Pratt & Whitney PW4084 and Rollo Trent 900 and Trent 1000 are using Kevlar inclusion rings.

For the inclusive design of the magazine, testing is the most direct and effective way. Test verification is usually performed in four steps: target testing, component testing on a high-speed rotating test stand, bench testing and inclusion testing of real engine fan blades on an outdoor test stand. But the cost of test verification is expensive, the cycle is very long, so in the early stage of engine development is usually used to hit the target test, part test combined with numerical simulation methods to speed up the development and reduce development costs.

5. Future Development of Aero-engine Magazine Inclusiveness

On the issue of aircraft engine magazine inclusion, the following aspects can be studied in depth: the development of a new generation of aero-engine inclusion magazine with high thrust-to-weight ratio, light mass and low pollution is a top priority, try the structural shape of the metal magazine to improve its inclusion capacity; the application of advanced composite material technology to prepare the magazine, improve the impact resistance and high temperature resistance of the magazine; the blade - rotor - magazine in the blade inclusion process Coupling dynamics of the blade - rotor - magazine in the process of blade inclusion needs to be studied in depth.

With the development of science and technology, the development of a new generation of high thrust-to-weight ratio, light weight, less pollution of the aero-engine, need to further achieve technical breakthroughs in some of the following areas:

(1) fiber winding reinforced or three-dimensional woven composite magazine manufacturing process, including winding methods, the overall weave forming method, resin vacuum infusion, etc.

(2) the development of high-temperature fiber-reinforced resin-based composite magazine. Solve the high temperature resin, oxidation-resistant high-strength fibers, three-dimensional woven overall forming process, etc., the composite magazine from the fan and low-pressure compressor and other cold end to the hot end of high-pressure compressor and other applications.

(3) The whole machine coupling dynamic corresponding analysis after the blade breakage. Including the broken blade impact, rotor vortex, the whole structure of vibration and other coupling analysis.

(4) The reliability design method of magazine inclusion.

(5) Intelligent containment system (Smart containment system), the use of embedded intelligent fiber diagnosis shell debonding and other damage conditions.

The promotion and application of new materials, new processes and new technologies have reduced the incidence of non-containment accidents in aero engines, and we believe that we will make more and more progress in this area in the future.

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