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Investigation report of aero engine air die hole processing

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Abstract: At present, there are a variety of problems in the aerospace manufacturing industry, especially the machining of aero-engine air film holes. In this paper, by investigating the current research status of aero-engine gas film hole machining at home and abroad, the characteristics and difficulties of the current gas film hole machining are introduced, and the comparison between ordinary laser machining and femtosecond laser machining is made.

Keywords: Air film; Hole aerospace; Process.

1. Introduction

In recent years, increasing the reliability of high temperature operation and extending the service life have become the focus of research in the field of aero engine. Turbine is the component with the largest thermal and mechanical load of aero-engine, among which the turbine blade has a particularly bad working environment and is under the impact of high temperature and high-pressure gas in the working process. Its processing technology has become the key technology of modern aero-engine. Due to its material characteristics, it is difficult to control the temperature of turbine blades, which constantly rise to the melting point of the material during operation. In order to make the turbine blades reach the melting point of the material, the engine can still work normally, which gives rise to the cooling and cooling technology, among which the gas die hole cooling technology is a representative structural improvement cooling technology. During the operation of aero-engine, air evenly passes through the gas film holes processed on turbine blades. The aperture is usually 100-800μm and the Angle is 15-90°, which can reduce the temperature of engine turbine blades and improve the service temperature and service life of the engine. In addition, as the second barrier to delay the ablation of the rear stage blades, the design of the turbine engine's in-shaft airway, in-blade airway and the gas film holes scattered on the blade has always been the research focus of the whole engine. In particular, the design of the gas film holes directly determines the key performance of the continuity of the gas film, the thermal conductivity along the curved surface normal and the heat dissipation capacity of the flow field. Therefore, the design of air film holes becomes more and more complicated. However, according to the investigation of relevant researchers, the current speed of the improvement of the processing level of the gas film hole cannot keep up with the speed of the development of the gas film hole design, which is one of the bottlenecks hindering the rapid development of domestic engines. Therefore, the processing technology of the gas die hole needs to be further studied.

2. Overview of working conditions and temperature protection mechanism of post-flight blades

2.1. Research on the highest level of shipping at home and abroad

At the present stage, China's fifth-generation fighter jets have been installed on a certain scale. However, many problems of the military turbojet engine, which is the heart of the fighter jets, have not been solved. As a result, China imports more than 200 jet engines from Russia and Ukraine every year. However, there is still a big gap between the performance of imported engines and those equipped in Western countries.

In today's world, the fourth and fifth generation fighter jets have long been the standard equipment of all-powerful countries, and the fifth-generation fighter jets have great tactical advantages over the fourth-generation fighter jets due to its "4S" performance. However, watching the NATO military exercises, it is not difficult to find that the pilots of some traditional European powers equipped with high-performance fourth-generation aircraft often exert the maneuverability advantage of fourth-generation aircraft to the extreme, and successfully suppress the advanced fifth-generation aircraft of the United States F22. "Breaking the sound barrier is not in the senses, it's just a number that rises rapidly" -- the young Rafale driver.

The first emphasis on performance of the fifth generation, and even the next six generations, must be "high mobility". This puts ever greater demands on the thrust-to-weight ratio that the engine can produce, which means that new engines will have to withstand ever higher core temperatures. At present, the self-produced fighter engine is still in the level of blade working temperature around 1350℃ and combustor temperature below 1800℃ (austenitic nickel and cobalt-based alloy). Although the blade can withstand the surface afterburning mode of 1500℃ for a certain period of time, it will greatly shorten the service life. It cannot meet the requirements of "supersonic cruise" and high mobility and large thrust. The United States has developed ceramic matrix composite material with a rated operating temperature of 1538℃, whose material density can support the improvement of the overall performance of engine design speed and so on. Moreover, the Pratt & Whitney F135 engine equipped with

F35 fighter jets has become the most advanced engine in the world. Fig1 shows the structure of a modern civil turbofan engine

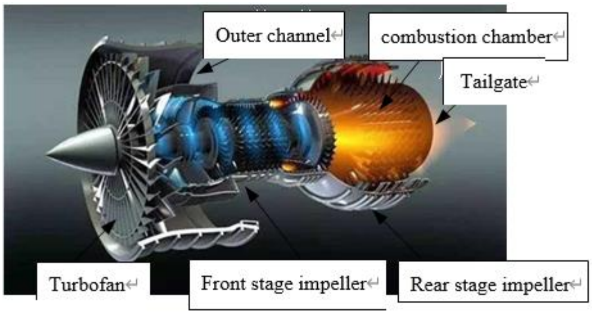

Fig. 1 Structure diagram of a modern civil turbofan engine

2.2. An overview of the force on the rear blade at work

In the process of aero operation, the rear blade is mainly subjected to the tension along the axial direction, the airflow thrust along the concave normal direction, and the high frequency impact load caused by the temporary negative pressure when the blades on the fixed rotor and the moving rotor alternate each time. The first two will participate in the interaction with high temperature creep, and the latter can generally be greatly weakened by optimized flow field design, but it always exists.

Fig2 shows the appearance and internal structure of the turbojet engine. It can be seen that both the ribbed structure and the die hole in the blade will cause stress concentration during the loading process of the above stresses, and how to reduce the harm of these stress concentrations is the focus of the research. On the one hand, the application of new materials provides greater freedom for design. The new design method further optimizes the efficiency of the inner and outer structure of the blade. On the other hand, effective and reliable processing technology can implement the advanced performance expected by the design.

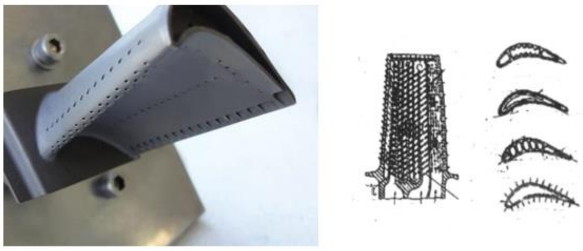

Fig.2 Appearance and internal structure of turbojet engine

3. Characteristics and difficulties of gas die hole processing

Aero engine air die hole belongs to microhole structure, the machining requirements are developing towards the direction of small size, large depth to diameter ratio, high surface quality and dimensional accuracy, so its processing technology has become a technical problem. Traditional machining is easy to lead to mechanical drill bit fracture, hole center line deflection, hole wall surface quality low, and special machining methods also have great limitations, such as: ultrasonic machining speed is low and microhole accuracy is poor. High pressure water jet method equipment investment is large, machining surface quality is not good and noise is large; Edm can only process conductive materials, resulting in low processing efficiency and high cost. There are defects such as heat affected zone, recast layer and microcracks in pore walls. Electrochemical machining is limited to metal materials. Electron beam machining needs to be processed in vacuum environment, the operating conditions are harsh, the equipment is expensive and so on. In recent years, the field of laser processing and manufacturing has attracted much attention. With the development of laser technology, a variety of laser processing technologies have emerged, such as laser cutting, laser connection, laser microhole processing, laser cladding, etc. Among them, laser microhole machining is one of the earliest and most widely used technologies in laser technology. It has a series of advantages, such as high precision, high efficiency, no cutting force, no pollution, and can process difficult-to-process materials such as high hardness and high brittleness, which is favored by researchers, especially for high-quality microholes. Compared with traditional machining methods, laser microhole machining is a more effective machining method.

Ordinary laser may cause recast layer, in the process of processing microholes, laser beam focus to the surface of the workpiece, so that the material melting, vaporization and condensation, the increase of heat makes the material steam with great pressure from the bottom of the spray, in the rapid cooling and heating process, there are some unable to spray the molten material recoagulated on the surface of the hole wall, the formation of recast layer. As shown in Figure 1-3, serious recasting layers exist in the nanosecond laser machining of microholes on nickel-based alloys. The metallurgical state, mechanical properties and base material of recast layer are very different, which is easy to cause microcracks. Therefore, the recasting layer must be strictly controlled in the process of laser machining microholes, and the thickness of the recasting layer can be reduced or even disappeared, which gives rise to femtosecond laser technology.

4. Conclusion

Femtosecond laser micromachining can process any material with extremely high machining accuracy and minimal peripheral damage. Is the aero engine blade air film hole plus? An important development trend in industry. Therefore, in order to realize the reliable application of femtosecond laser micromachining in single crystal superalloy. The formation of efficient, high quality gas film hole processing technology. It is necessary to consider the directivity of single crystal superalloy, study the damage mechanism and influencing factors of femtosecond laser processing on single crystal superalloy, and study the mechanical effect of femtosecond laser processing. It provides the theoretical basis and technical support for determining the excellent process parameters of the gas film hole of femtosecond laser plus T single product high-temperature alloy, and provides reference basis for blade application and safety evaluation.

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