Borescope inspection for HPT blade of CFM56-7B engine

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Abstract. CFM56-7B engine has had several ruptures of HPT blades since its service, resulting engine failure during the flight. Through borescope inspection for HPT blade can detect the damage of blade on the front and rear edge effectively, and avoid the use of damaged blades. This paper briefly summarizes the experiences of borescope inspection for HPT blade, mainly using hose to check the defect of leading edge for blade.

1. Introduction
In all parts of engine, the working environment of HPT blade is the worst, working in high temperature [1] and high speed and high speed, bearing high thermal stress, centrifugal force and torque [2]. According to statistics, the HPT blades of CFM56-7B engine have been broken several times, causing the engine to stop during the flight.

The HPT blade of CFM56-7B engine has been modified by SB several times since its service. So far, it seems that the problem of blade fracture [3] has not been solved completely. According to the statistics, of all the engine into the factory reason, whether planned overhaul or unscheduled repairs, HPT blade soft deadline management or damage levels are the top cause, sometimes even in the first place.

In the daily maintenance, the borescope inspection [4] can detect the defects of HPT blades so as to prevent the occurrence of engine failure event caused by blade fracture. But not all faults can be detected by borescope inspection, and the cracks inside the blade can't be detected by borescope inspection. The borescope inspection is more about the ablation and crack in the outside of the blade.

By borescope inspection and maintenance scheme provided by Boeing MPD, HPT blades are inspected by 1600 cycles. Use a hard tube to check the trailing edge of the blade when working, and then use the hose to check the leading edge of the blade if there is any damage. In actual work, the trailing edge of HPT leaves is seldom defective, leading to less inspection of blade leading edge, but blade fracture occurs frequently in front edge of blade [5]. The method of trailing edge inspection may leak many defects of leading edge.

2. Analysis of defect statistics of HPT blades
Some more common defect statistics are shown in figure 1 to figure 3.
The relationship between defect and use time can be clearly seen from the statistical defect. The normal defect expansion process of blade leading edge is the loss of the leading edge insulation layer, then oxidation discoloration and the ablation material are lost. And the use of color change is around 12,000 cycles.
The oxidation and discoloration of HPT leaves is related to the working environment. The high temperature airflow hits the leading edge of the blade repeatedly, the leading edge insulation layer gradually falls off, and the protection of the insulating layer is lacking, the material of the base body begins to oxidize and change.

At the beginning, the oxidation is slight, the material is not lost, the outline of the front edge has not changed significantly. After longer use time, the material begins to lose, the front contour outline will occur to the internal concave change. The first area of oxidation discoloration may be related to the temperature distribution of air flow and the cooling mode inside the blade.

According to the AMM inspection procedure, a hard tube is normally used to inspect the blades from the trailing edge (the hard tube is relatively small in temperature). But this method can only see a small part of the blade leading edge, and not from a positive observation. It is difficult to observe the defect of initial oxidation discoloration on the front edge.

But there are some engine defects that are not conventional oxidation discoloration [6]. It's the indentation and crater on the leading edge. And the main thing happened in zone A and B. The time distribution of these defects is random. The shape of the defect is likely to be caused by the breakdown of hard objects, while the front edge of the blade has not had a large area of insulating layer to fall off. Some nicks and pits have been oxidized and discolored due to the loss of heat insulation. There is no obvious expansion trend for these defects.

3. Technique of HPT borescope inspection
Using a hard tube to check the HPT blade, it is possible to check the HPT blade with a high temperature, which does not require too long cooling time. If you use a hose to check, the temperature requirement is high. Take Welwyn XLG3 hole as an example, its within 6 mm video to spy out the work of the highest temperature is 80 °C. It takes 3 to 4 hours for normal engine to cool off. The use of dry and cold rotation can effectively reduce the temperature. The engine will naturally cool for an hour or so after the engine is off, and the temperature will be reduced. Opening the inner C function on cold turn can improve the cooling effect. Generally cold turn twice, each cold turn for 2 minutes.

If in the winter, the cockpit EGT instructions will be closer to 50 °C, and in summer EGT instructions will around 60 °C. EGT indicates that the temperature is lower than the temperature of the leading edge of HPT. According to the experience, if EGT instructions below 60 °C when cold turn, using Welwyn XLG3 hole finder normal inspection (10 minutes) will not be grainy and overtemperature warning, and if EGT instructions close to 50 °C, can use Welwyn XLG3 hole finder defects inspection measurement for a long time.

From the back edge inspection, it is better to use the angle of direct view lens to observe the concave and convex surface of the trailing edge area [7]. The convex surface of the posterior half can be observed with proper angle adjustment. It is also better to look at the lens from the front. The frontal area and most of the concave surfaces can be observed. Sometimes the defect of the front edge is closer to the convex surface, the defect can be found with the angle of direct view lens, but it can't be observed in detail, and the side view can view well. For the defects of concave and convex surfaces, such as using the 6 mm probe, it is not easy to approach, but with the 4 mm probe, it can be observed at long distance and close range, which is helpful for judging defects.

It is divided into two segments [8], with tip, zone A and zone B on the side of blade tip, and on the side of leaf root including zone B, zone C and platform of blade. Two views overlap and can be seen clearly. Turning on the opposite direction, the blade moves from a distance to near place, which is helpful for finding defects. Partition schematic of HPT blade is shown in figure 4.
4. Conclusion
Repeat the inspection for the location of the defect. You can use different distances, different angles, different lighting levels, and then determine the type of defect, the area and size of the defect, and whether the plane can fly according to the standard. From the point of view of flight operation, it is concerned whether it can work, but the maintenance can not only consider the flight, but also how to monitor these defects.

Borescope inspection is a job that requires both technology and accountability. The internal structure of engine is very complicated and we can’t see it directly with naked eye. If testing personnel are familiar with the internal structure of engine, then the spatial structure can be imagined in the brain. When they see the picture, they can clearly know where the camera is now, and observe the location, area, angle and size of the target. It is helpful to judge the defects accurately and quickly. The work of borescope inspection is not observed by the naked eye directly, and it is easy to form fatigue attentions and miss the defects in the eye. This requires the accountability of the agents. Every time have to be responsible for checking an engine.

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References
[1] Guo Jianting, Yuan Chao, Yang Hongcai, et al. Creep-rupture behavior of a directionally solidified nickel-base superalloy [J]. Metallurgical and Materials Transactions, 2001, 36(5): 38-39.
[2] Liang Chunhua. Overview of advanced fan and compressor blade in high performance aero-engine [J]. Aero-engine, 2006, 32(3): 48-52.
[3] Li Jing, Sun Qiang, Li Chunwang, et al. Study on the vibration fatigue life for aero-engine compressor blade [J]. Chinese Journal of Applied Mechanics, 2011, 28(2): 189-193.
[4] Ke Chenghe, Gong Mengxiang, Zhao Xin. Fracture failure analysis of sixth-stage stator blade for an aero-engine HP compressor [J]. Aero-engine, 2012, 38(2): 55-58.
[5] Fan Shunchang, Tang Xiaohui, Zhang Yindong, et al. Failure analysis of third-stage rotor blade of high-pressure compressor in aero-engine [J]. *Failure Analysis and Prevention*, 2014, 9(2): 110-114.

[6] Wang Jing, Wang Deyou, Han Qingkai. Mechanism analysis and treatment on loss corner faults of compressor blades [J]. *China Mechanical Engineering*, 2008, 19(9): 1048-1050.

[7] He Shengshuai, Chen Liwei, Qiang Xiaohui, et al. High stress vibration fatigue test technology of aero-engine blade [J]. *Equipment Environmental Engineering*, 2013, 10(4): 41-46.

[8] Wang Huawei, Gao Jun, Wu Haiqiao. Reliability analysis on aeroengine using Bayesian model averaging [J]. *Journal of Aerospace Power*, 2014, 29(2): 305-313.