Fatigue Research for Connecting Rod of Aero Piston Engine

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Abstract. General aviation has developed rapidly in recent years, and there is a strong demand for aviation piston engine. Aviation kerosene piston engine is the main power of general aviation in the future, with good fuel economy and high thermal efficiency. The reliability of the key parts of the engine is the key research under light weight conditions, such as the engine block, connecting rod and so on. This paper summarizes the fatigue problems in the development of lightweight aero kerosene engine, the methods we re put forward to solve these problems, so as to provide ideas for the development of aviation piston engine.

1. Introduction

General aviation is developing rapidly. By 2019, there are more than 300000 general aviation aircraft in the world, with a large demand for general aviation engines [1-2]. At present, general aviation aircraft mainly include trainer aircraft, private aircraft, agricultural and forestry spraying aircraft, etc. the engines are mainly aviation gasoline engine, such as Rotax, Continental and Lycoming, only a few aircraft use aviation kerosene engine [3-5]. In recent years, with the increasingly strict environmental protection, aviation gasoline contains tetraethyl lead, which causes serious environmental pollution. At the same time, aviation gasoline is expensive and not safe. All major airports do not have aviation gasoline, which causes many difficulties for general aircraft [6-7]. But many airports reserve aviation kerosene, which is cheaper than aviation gasoline and has good economic security. Therefore, Research and development aviation heavy oil (kerosene and diesel) piston engine can solve the difficulties caused by the use of aviation gasoline engine [9-10]. However, in the process of research and development, the reliability of the engine’s part has brought many troubles to the research and development. Meanwhile, the published paper on the reliability of whole engine is very limited [11-15], and most of the research work is focused on performance simulation. In terms of connecting rod, at present, aluminum alloy connecting rod is used in aviation gasoline piston engine, but in aviation kerosene engine, steel connecting rod is mainly used to improve the strength [16]. At present, only some research and development institute are trying to use aluminum alloy connecting rod in aviation kerosene engine.

2. Difficulties in R & D process
Although the use of aviation kerosene brings many conveniences, it is very difficult to develop an aviation kerosene engine and obtain the type certification of the Federal Aviation Administration and the European Union Aviation Safety Agency. At present, the companies that have successfully developed the aviation kerosene piston engine are mainly Continental, Austro, SMA and other companies. Their engines have been installed on the diamond aircraft. The aviation kerosene engine with type certification is shown in Table 1.

| Type   | Place of Origin | Power | Weight |
|--------|-----------------|-------|--------|
| CD135  | Germany         | 135HP | 135kg  |
| CD155  | Germany         | 155HP | 135kg  |
| CD300  | Germany         | 299HP | 260kg  |
| AE300  | Austria         | 168HP | 186kg  |
| SR305-230 | France          | 230HP | 208.6kg|

Figure 1 to figure 4 are the aviation kerosene engines that have been successfully certified.
The development process of aviation kerosene engine is very slow, which is mainly affected by the reliability under the conditions of lightweight, so it is very difficult in the development and prototype testing process. TAE Company takes the automobile diesel engine as the prototype, has carried on the research and development for many years, then obtains the engine type certification successfully. Engine block is the main target of lightweight. Reducing the weight of engine block can directly reduce the weight of engine and improve the power weight ratio of engine, but reducing the weight of the block will reduce the strength, and it is easy to cause cracks under the same pressure. Therefore, the fatigue of the engine block is a major obstacle in the development process. Figure 5 shows the equivalent stress of the connecting rod, which does not reach the yield limit of aluminum alloy, but it can cause high cycle fatigue of connecting rod. Figure 6 shows the analysis of the connecting rod of an engine under the maximum load, indicating that the strength does not meet the requirements.

3. Solutions

The working condition of aviation piston engine is very different from that of vehicle engine, and the safety requirement is very high. The aero engine loaded on the manned aircraft needs to be tested strictly before it can obtain the type certification. Therefore, in the development process, it is necessary to strictly determine the boundary conditions, test and analyze under severe conditions, and finally test according to the airworthiness regulations.

3.1. Determination of boundary conditions

Most of the time, aero engine runs at high speed, which is quite different from vehicle engine. For example, the maximum speed of Rotax aviation gasoline engine is 5800rpm, and that of CD300 aviation kerosene piston engine is 2300rpm. Therefore, the worst case should be considered in boundary analysis.

At the same time, the general aircraft has a certain flight altitude, so it is necessary to accurately analyze the stress field and temperature field of engine block and connecting rod at different altitudes. It is necessary to analyze the torque of each bolt accurately to ensure that the calculated results are similar to the actual working conditions when the simulation analysis is carried out. Fig. 7 is the connecting rod angles of engine in one working cycle. Fig. 8 is the Connecting rod bearing forces of one cylinder. In addition, the connecting rod is also affected by the temperature field. In the process of engine operation, the connecting rod is subject to mechanical stress, thermal stress, friction and so on, resulting in fatigue under the boundary of multi field coupling boundary conditions.
3.2. Process control in manufacturing process

The manufacture of automobile engine is in common workshop, but in order to ensure the accuracy of the manufacturing process, aviation piston engine is extremely demanding on the environment. The processing and manufacturing process of core components not only has strict requirements on material selection, but also has high environment temperature requirements. Most of them need to be carried out in constant temperature workshop to ensure that the performance of components will not change due to the change of temperature difference during the manufacturing process. The machining process is also very demanding, precision control, aging treatment and so on, a little deviation will cause fatigue cracks in the strict test of the aviation piston engine.

3.3. Endurance test

Each engine needs to go through strict endurance test when it gets the type certification of FAA or EASA. The longer the endurance test, the time between overhaul (TBO) of the engine will be increase. At the same time, the endurance test of aviation piston engine is not carried out directly on the test bench like that of vehicle engine. It needs to run directly with propeller. In order to better simulate the operation condition of engine, as shown in Figure 9.

At the same time, the bench-test with propeller can also complete the research work of the matching of propeller and engine, which will bring the guiding significance for the later installation of the engine.

Figure 7. Connecting rod angles

Figure 8. Connecting rod bearing forces

Figure 9. Small bench test
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