

Starting Fault Experiment of a Certain Turbo Shaft Engine

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Summary: In order to diagnose the starting fail fault of the certain turbo shaft engine which often occurs in daily use, the experiments for the micro pump and the fuel filter were carried out by the method of contrast test. Through the comparison and analysis, the differences between domestic components and French-made ones were found. The results showed that: The outlet pressure of domestic micro pump is smaller under the engine's working condition; the flux of it is significantly lower under high outlet pressure; the pressure-flux characteristic line of domestic micro pump can close to the French-made pump when the French-made fuel valve and regulating valve were installed on it; the structure size of domestic filter frame is very different from the French-made one, which leads to its greater flow resistance. According to the performance indicators of French-made components, the improvement measures were put forward in order to improve the success rate of engine ground starting.

1 Introduction

As the heart of the helicopter, the turbo shaft engine must guarantee the stability of rapid starting and health work in the whole process of tasks [1]. After the localization of the certain turbo shaft engine's fuel system components, the fault of unsuccessful starting gradually appeared with the increase of installed sets and frequency of usage, especially in the first starting after a long time placement. Over the years, the problem has not been thoroughly solved, and it increased the helicopter mission preparation time and affected the normal flight.

Aiming at the faults of turbo shaft engine, X.X. Cai [2] developed the turbo shaft engine health management system for bench test and flight test phase; S.L. Hou [3] did the preliminary analysis for the basic composition and design characteristic of a certain turbo shaft engine fuel control system; T. Wang [4] studied the surge fault in the starting process by analysis the starting control process and fuel supply rate. But the study about the starting failure fault of this certain turbo shaft engine at home and abroad is less. Most of its components were developed by surveying and mapping the French-made ones, some manufacturing imperfections which affected the engine's working performance occurred because of the technical limits the lack of accurate and reliable components manufacturing standards. In this paper, according to the starting failure fault of this type of engine, contrast experiment of the domestic and French-made components were carried out by establishing the fault tree and analyzing the main bottom events. The experimental results show that, there are some big differences between some domestic components and French-made ones in the starting fuel system and

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main fuel system, and they have great influences to the starting performance of the engine. Considering the vulnerabilities of domestic components, some corresponding improvement measures were put forward in order to improve the engine starting performance.

2 Fault Analysis

When the engine is starting, the starting fuel system is used to produce enough ignition torch to light the main combustion chamber and the main fuel system is used to guarantee the combustion stability of the main chamber. [5]In order to find out the cause of the starting failure fault accurately, the fault tree which is shown in Figure 1 were built according to the phenomenon and characteristics of it and combining with the structure and principle of the starting fuel system and main fuel system.

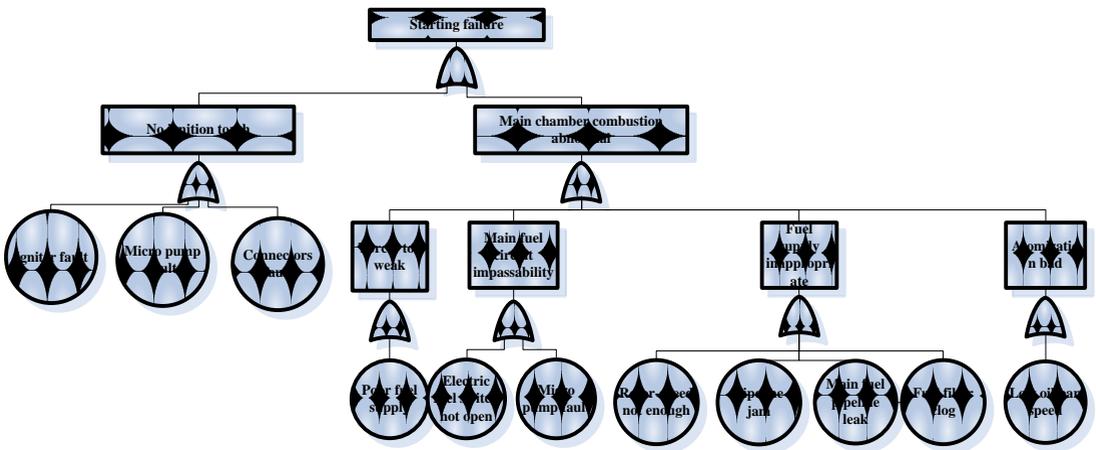


Figure 1. Starting failure fault tree of this type of turbo shaft engine.

According to the former troubleshooting conditions of this kind of engine, faults such as electric fuel switch not open, pipeline jam and main fuel pipeline leak are very rare, they are not the main events of starting fault, so we don't take them as the research object. [6] But the components such as micro pump, igniter, starting fuel filter are close to the bottom events and they require in-depth research and analysis. In this paper, the experiments for the micro pump and the fuel filter were carried out by the method of contrast test. Through the comparison and analysis, the differences between domestic components and French-made ones were found, and the improvement measures were put forward in order to improve the success rate of engine ground start.

3 Experiments and analysis

3.1 Micro pump experiments

RCB-4 micro pump was produced by surveying and mapping the French-made pump. The purpose of it is to supply fuel to the igniter and switch on the fuel cock in the main fuel system. Its main components are one-way valve, regulating valve, fuel valve, etc. The structure of it is shown in Figure 2.

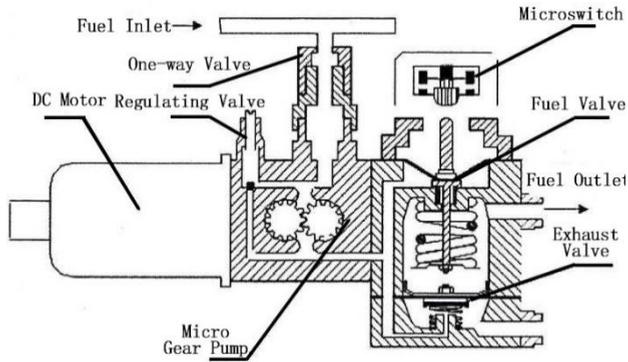


Figure 2. Structure of RCB-4 micro pump.

3.1.1 Micro pump-igniter experiment

Select French-made micro pump (NO.05AT) and domestic micro pump (NO.1011017), and connect them to the domestic and French-made igniter respectively. Connect them with other starting fuel system components through cross valve and fuel pipe to simulate the engine working condition. Set the inlet pressure of micro pump to 40kPa and carry out the atomization experiment under the voltage of 28V, measure the outlet pressure of it. The Table 1 is the experiment data.

Table 1. Micro pump outlet pressure.

Micro pump	Igniter	Outlet pressure (kPa)
05AT	Domestic	555
05AT	French-made	555
1011017	Domestic	523
1011017	French-made	530

Through the table we can find that when the same micro pump is connected to the different igniter, the outlet pressure of it are almost the same, it is obvious that the fuel holes in French-made and domestic pump have the similar throttling ability. When connected to the same igniter, the outlet pressure of French-made pump is about 550kPa, it is obviously higher than the domestic one, which is about 525kPa.

3.1.2 Pressure-flux experiment

Set the inlet pressure of the two micro pump above to 40kPa, perform the pressure-flux experiment under the voltage of 28V, and measure the flow rate of them under different outlet pressure.

Figure 3 shows us the pressure-flux curve of these two micro pumps. It can be seen that: when the outlet pressure is less than 400kPa, the domestic micro pump has the similar flux with the French-made one; when it is greater than or equal to 450kPa, the flux of French pump is greater than the domestic pump.

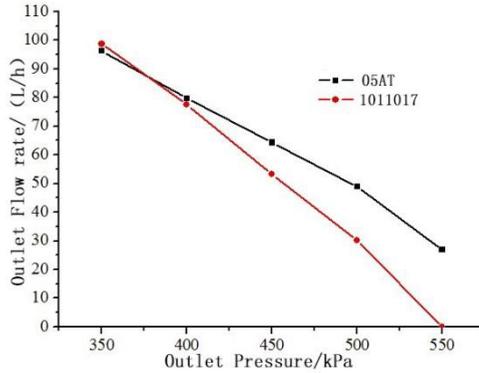


Figure 3. Flow rate of these two kinds of pump under different outlet pressure (L/h).

3.1.3 Pressure-flux experiment after adjusting regulating valve

Adjust the regulating valve of domestic micro pump, set the flux to 267L/h when the outlet pressure is 550kPa and the voltage is 28V, which is similar to the French-made pump. Then perform the pressure-flux experiment for these two pumps. The outlet flow rate of each pump is shown in Figure 4.

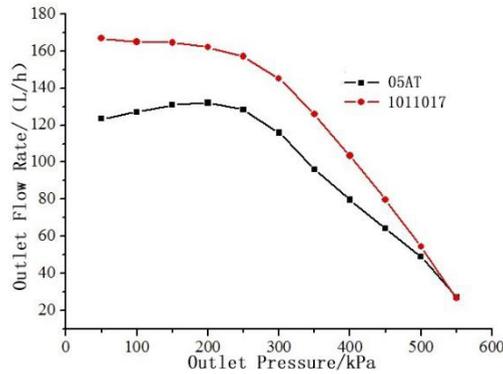


Figure 4. Flow rate under different outlet pressure after adjusting regulating valve (L/h).

After adjusting the regulating valve, the flow rate of domestic pump is promoted under the corresponding pressure, which can meet with the level of French-made pump at working point basically. But in this condition, the flow rate of domestic pump is clearly greater when the outlet pressure is under 500kPa.

3.1.4 Pressure-flux experiment when install French-made valves on domestic pump

Install the French-made regulating valve and fuel valve on the domestic micro pump and adjust them. Set the flow rate to 26.7L/h when the outlet pressure is 550kPa and the voltage is 28V, then set the flow rate to 98L/h when the outlet pressure is 25kPa. The results of this experiment are shown in Figure 5.

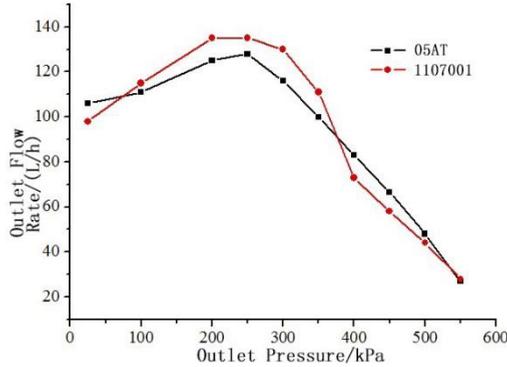


Figure 5. Flow rate under different outlet pressure after installing French-made valves on domestic pump.

The results show that after installing the French-made regulating valve and fuel valve and adjusting them correspondingly, the pressure-flux characteristic of domestic micro pump can be close to the French-made one.

3.1.5 Structure comparison

Decompose, measure and compare the domestic and French-made micro pump, then some differences can be found in the structure.

1) Regulating valve differences

There are four main differences in the structure of regulating valve, which are listed in Table 2.

Table 2. Components structural differences in regulating valve.

Regulating valve	05AT	1107001
Discharge slot size (mm)	0.8-0.9	1.2
Steel ball diameter (mm)	Φ4	Φ4
Spring elasticity coefficient (N/mm)	0.49/0.44/0.46	0.7/0.67/0.69
Valve seat shape	With convergence	Without convergence

2) Fuel valve differences

After measuring, some differences in shaft and spring was found between domestic and French-made fuel valve. These differences are very obvious and can be seen in Figure 6.

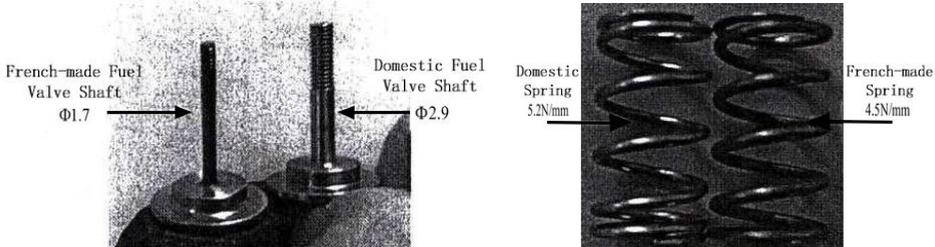


Figure 6. Structure differences in fuel valve.

3.1.6 Influence analysis

The main role of micro pump in the process of starting is to supply fuel to the igniter by pressure. The outlet pressure of domestic micro pump at the working point is lower than the French-made pump, which affects the fuel's atomization performance. This will reduce the flame intensity around the igniter and reduce the rate of lighting the main fuel successfully. The pressure-flux characteristic of micro pump is mainly determined by the motor and gear pump, and can be adjusted through the pressure regulating valve. The results confirm that, by adjusting the regulating valve and fuel valve the pressure-flux characteristic of domestic micro pump can be consistent with the French-made one at the working point. The structural differences of these two valves have great influences on the pressure-flux characteristic, so we can make the domestic pump have the performance which is as good as the French-made one by adjusting the structure of it. The specific improvement measures can be: Improve the elasticity coefficient of the spring in regulating valve and fuel valve to make them consistent with the French-made ones as far as possible; change the fuel valve shaft diameter from $\Phi 2.9$ to $\Phi 1.7$; remeasure and determine the installation compression of the fuel valve spring.

3.2 Starting fuel filter experiments

The starting fuel filter is installed between the fuel regulator and starting adjusting device. The fuel from the pump flows to the regulating device after the filtration, and the flow resistance of filter will directly affect the smooth degree of starting fuel. The fuel filter is mainly composed of shell, filter element, aprons, etc.

3.2.1 Flow resistance experiment

Select two domestic fuel filters (NO.R11-011-1, NO.RL-011-2) and two French-made filters (NO.J202B, NO.J135B). Take the RP-3 fuel as the test medium, measure the flow resistance of these filters under the flow rate of 1.7L/min, 2.2L/min, 2.6L/min and 3L/min at room temperature. The results of experiment is shown in Figure 7.

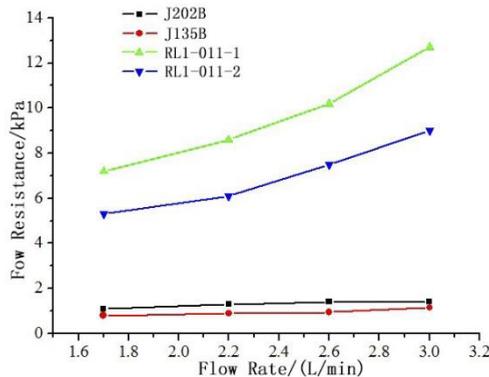


Figure 7. Flow resistance under different flow rate for each filter /(kPa).

The result confirm that, the flow resistance of French-made filter is much lower than the domestic filter in the same conditions.

3.2.2 Filtration precision experiment

Select these two kinds of filter, and measure the filtration ratio of them for the particle from 20 to 50 μm diameter. Figure 8 shows the results of filtration.

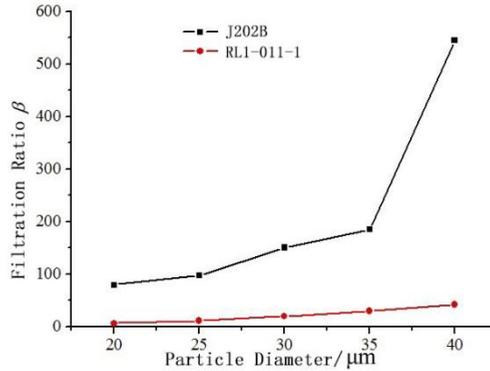


Figure 8. Filtration ratio for each diameter.

The original filtration precision requirement is $\beta(30\ \mu\text{m}) \geq 20$, it is obvious that the filtration precision of domestic filter is much higher than this, but the corresponding data of French-made is lower.

3.2.3 Structure comparison

By surveying and mapping, the diameter of French-made filter wire is 0.093~0.1mm, it is about the same size with the RL-1-011-1, which is 0.098~0.101mm. But there are great differences in the frame structure and wire spacing. By looking under microscope (100 times magnified), these differences can be found. The microscope images are shown in Figure 9.

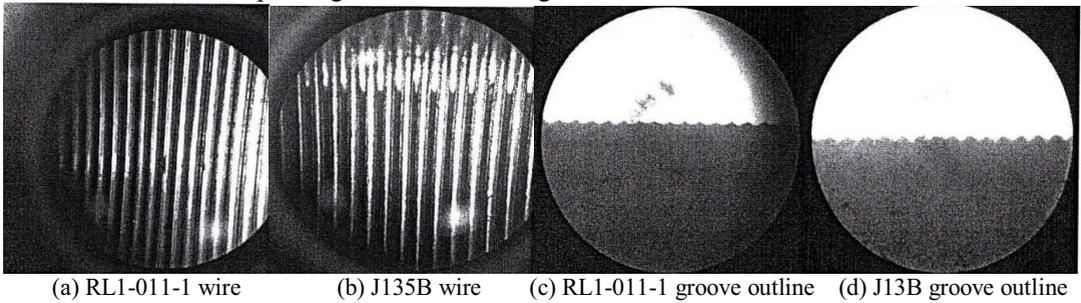


Figure 9. Filter structure comparison under microscope(100 times magnified).

And there are also some structural differences of the filters which are listed in Table 3.

Table 3. Differences in filter frame structure.

Parameter	RL-1-011-1	J202B
Groove spacing	0.105~0.11mm	0.12~0.125mm
Number of holes	8×24	6×24
Hole spacing 1	5mm	7mm
Hole spacing 2	1.5mm	2.6mm
Wire slot depth	0.024~0.03mm	0.045~0.064mm
Slot angle	80°	90°

3.2.4 Influence analysis

The starting fuel filter is used for fuel filtration, mainly to ensure the cleaning of the fuel in air pressure regulator, starting regulator and fuel regulator. Its flow resistance will directly affect the flow

rate of main fuel pipe in the process of starting, because it is installed between the starting regulator and fuel regulator. Confirmed by the manufacturer, the French-made filter is able to meet the filtration precision. The flow resistance of domestic filter is greater than the French-made one, which reduces the flow rate of fuel in the process of starting. The low flow rate of the main fuel will cause the low ignite possibility of it, which influence the starting performance. Therefore, the filtration precision can be reduced appropriately to reduce its impact on the main fuel flow rate.

4 Conclusion

In this paper, according to the starting failure fault of this type of engine, contrast experiment of the domestic and French-made micro pump and fuel filter were carried out by establishing the fault tree and analysing the main bottom events. By comparing and analysing the experiment data we can get that:

1) There are great differences in manufacturing process between domestic and French-made fuel valve and regulating valve in micro pump, which impact their performance distinctly. The outlet pressure of domestic micro pump is lower at the engine's work condition, and its flow rate is also lower than the French-made pump under high outlet pressure. This situation improves by installing the French-made fuel valve and regulation valve on it.

2) The flow rate of domestic fuel filter is much greater than the French-made filter. There are plenty of differences in filter frame structure between them, which make the filtration of domestic filter higher than the French-made one, and it's much higher than the requirement of $\beta(30\mu\text{m}) \geq 20$.

3) The structure of domestic micro pump and starting fuel filter is unfavourable to the fuel flow, and reduce the fuel supply to igniter and fuel pan in the starting process. The starting success rate of this engine can be increased by improving the accuracy of surveying and mapping and perfecting the components performance requirements.

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