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Investigation of failure in main fuel pump of an aeroengine

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ABSTRACT

There was an accident to a fighter aircraft. Investigation revealed that the accident was caused due to loss of power in the engine as a result of failure in the main fuel pump (MFP). The MFP was multi-plunger type. On dis-assembly, the MFP was found severely damaged and there were fractures in one plunger and four springs. Through systematic metallurgical investigation and analysis, the sequence of events leading to the failure in the MFP was established. The primary failure in the MFP was the fatigue fracture of springs. The fatigue crack initiation could be attributed to pitting corrosion on the surface of the springs. Because of multiple fractures in one of the springs, there was impact load on the corresponding plunger, which resulted in generation of an overload crack. This crack had further propagated progressively by fatigue mechanism culminating in fracture and loss of material from the side wall of the plunger. Subsequently, there was fuel leakage internally in the MFP with the resultant reduction in the fuel delivery pressure. Due to insufficient fuel supply, there was winding down of the engine RPM leading to loss of thrust. After establishing the sequence of failure in the MFP, investigation was carried out to identify the cause for the corrosion on the surface of the springs. It was established that the raw material (wires) used for the manufacture of the springs had developed corrosion pits on the surface due to improper storage.

1. Introduction

The components in an aeroengine always operate under most arduous conditions and the application demands working of the components in tandem. Failure in any of the components leads to catastrophe with resultant loss of the aircraft and also, loss of valuable lives. Aeroengine being a safety critical system, is normally manufactured, serviced and maintained to the highest standards. Yet, aircraft accidents do take place due to engine failures. Failures in aeroengines are more likely the result of a chain of events rather than due to a single cause. Investigation of aeroengine failures is, therefore, complex and challenging [1,2].

The components of aeroengines are subjected to cyclic loading during their operational usage. Because of this, the components experience fatigue leading to initiation and propagation of cracks at highly stressed areas. Statistics show that fatigue is the predominant mode of failure in aircraft components and it accounts for nearly 60% of the total failures [3,4]. If one considers the failures in engine components alone, the percentage of fatigue failure is still higher.

Generally, the components of aeroengines are designed for safe life with the minimum probability of fatigue cracking during the life span. In spite of this, fatigue failures of the components are common. Fatigue cracks generally initiate at locations

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of high stress concentrations. Study shows that the stress concentrators are invariably related to defects of various types, introduced mostly inadvertently, at various stages of the life cycle of the components, starting from manufacturing to service retirement [4–6]. Stress concentration also arises because of corrosion during service due to interaction of the components with the operating environment. In these cases, the failure generally does not take place due to loss of substantial amount of material by corrosion. Instead, the stress concentration arising from the corrosion facilitates premature fatigue crack initiation in the component and its eventual failure by fatigue fracture. In this paper, investigation of a failure in the main fuel pump of an aeroengine has been reported. The failure resulted in loss of power in the engine, leading to an accident. Through systematic investigation and analysis, the primary cause of failure in the MFP and the sequence of events that led to the accident were established.

2. Information

A fighter aircraft met with an accident during a practice sortie with parallel taxi track overshoot and landing. The pilot had carried out two overshoots during the flight of 1320 s. During the final circuit while on turn, pilot suddenly felt loss of thrust and observed winding down of the engine RPM. Thereafter, finding no response to the throttle movement, the pilot ejected safely and the aircraft crashed onto the ground. Since the aircraft was flying at low altitude, the impact was not very severe. Also, there was no post-accident fire.

The engine was removed from the aircraft and strip examined. Most of the components of the engine were in good condition. Based on the pilot's statement and flight data recorder (FDR) analysis, it was decided to carry out functional test on the main fuel pump (MFP). During the test, the maximum fuel pressure build-up in the pump was recorded to be 1.5×10^6 Pa, which was significantly less than the required limit of 6.9×10^6 Pa. On dis-assembly, the MFP was found severely damaged.

3. Construction and working of MFP

Schematic of the MFP is shown in Fig. 1. The MFP in the present case is multi-plunger type and had nine plungers. The plungers are housed in the cavities or chambers of the rotor. For facilitating unobstructed up and down movement, each plunger is assembled in the rotor chamber with a guide and a spring. The plunger heads are crowned and in the assembly, they remain flushed with a swash plate. One end of the swash plate is fixed while the other end is operated by a servo piston. The angular position of the swash plate ensures up and down movement of the plungers when the rotor is on rotation. This facilitates the fuel to enter into the plungers and to deliver to the respective ports. At the bottom of the rotor, a plate having two kidney ports is fixed for the fuel to enter and to exit during each rotation of the rotor.

4. Observations during dis-assembly of MFP

After dis-assembly of the swash plate, deep score marks were observed on the outer conical surface of the rotor and the corresponding inner surface of the pump body casing. It was found that two plungers (at cavity Nos. 3 and 4) were in

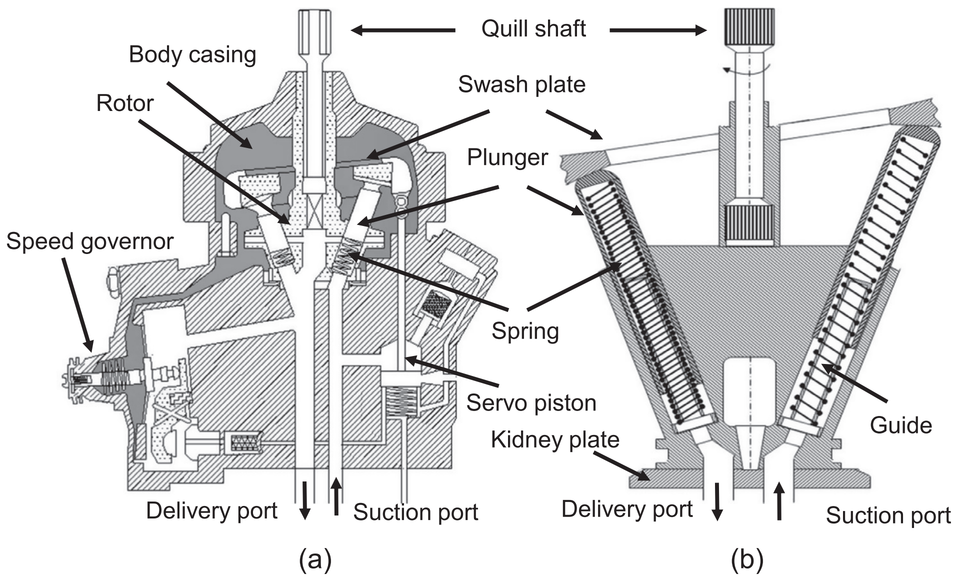

Fig. 1. Schematic of (a) MFP in assembly, and (b) components of MFP.