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Failure investigation of in-flight separation of afterburner nozzle flap in a turbojet engine

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ABSTRACT

A turbojet fighter experienced a separation of the afterburner nozzle flap during flight. Three mounting bolts were intended to fasten the nozzle flap assembly, but complete fracture of these bolts was the primary reason of failure. One of them was lost during the incident and two shank parts of the mounting bolts remained in the engine component. Laboratory investigation of the failed components of the nozzle flap assembly indicated that the mounting bolts were improperly installed during the last maintenance. Detailed fractographic study and metallurgical analysis focused on the fractured bolts and revealed fatigue striations with an overload dimple morphology in all fractured surfaces of the bolts. The investigation established sufficient evidence of improper installation of the primary flap assembly due to deformation of the alignment hole which inevitably resulted in higher operational loads on the bolt. It is concluded that the missing bolt had failed first, and other bolts fractured in succession in the manner of fatigue fracture. In response, preventive measures regarding inspection strategy have been improved to avoid similar failures.

1. Introduction

A turbojet fighter experienced a separation of the afterburner nozzle flap during flight. The pilot took timely appropriate action to return to the base and completed an emergency landing. In general, afterburners and augmentation systems were added to gas turbine engines to increase their thrust during take-off for brief periods of acceleration and supersonic flight. The extra thrust is also essential for combat situations. The afterburner is often used during air-to-air combat training mission. The mishap turbojet fighter has variable nozzles with 2 stage variable-area throat which is necessary to accommodate the significant temperature changes produced by afterburn. The components of the afterburner and the location of the separated primary nozzles are illustrated in Fig. 1. The mishap engine had operated for approximately 950 h since new, and 370 h from the last engine overhaul. On-site examination revealed severe burning damage of the skin where the afterburner nozzle was mounted and one section of nozzle flap among a total of 16 sections was completely lost, as shown in Fig. 2. Also, the stabilator has been severely damaged. The damaged area of the stabilator was aligned with the possible trajectory of the separated flap parts. It is suggested that the stabilator damage was likely caused by the impact of separated parts during flight. Disassembly and examination of the incident engine was conducted at overhaul facilities under the supervision of investigation board members. The visual inspection of disassembled parts confirmed that the three mounting bolts of the primary nozzle to the afterburner duct flange were completely fractured and one of them was lost during flight. According to the maintenance log, the mounting bolts were installed with new bolts 75 flight hours previously during the primary

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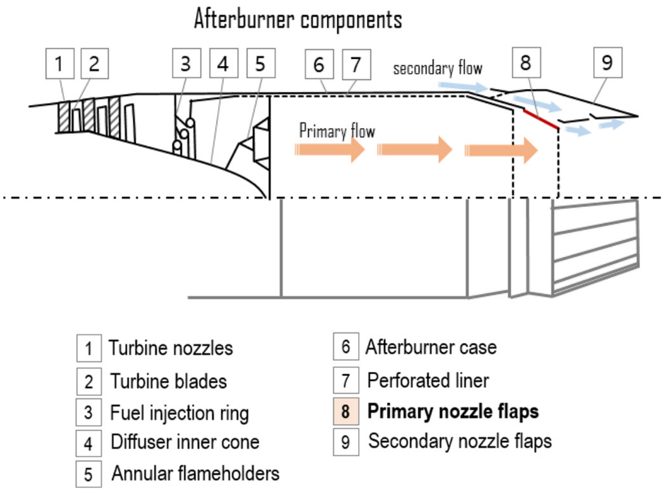

Fig. 1. Schematic of afterburner components of the turbojet engine.

Fig. 2. (a) Damaged afterburner nozzle components and (b) stabilator.

flap replacement due to mechanical defect of the flap. The maintenance specifications require that the mounting bolts must be tightened by applying a torque moment of 55 to 70 lb-in and safety wire must be installed. This study presents a failure analysis of mounting bolts of the primary flap of the afterburner nozzle in the turbojet engine. Several studies [1–6] have been reported in the literature for the fracture of mounting bolts during aircraft flight. Many of the problems encountered with fasteners in the systems are not really a fault of the fastener itself. Based on the investigation, the bolt failures were attributed to incorrect installation, specifically damage to the internal threads. Loss of the load carrying capability of one bolt resulted in fatigue fracture in the other remaining bolts. This maintenance error was attributed to either organizational or individual factors. Based on findings obtained from the investigation, maintenance strategy has been improved to conduct a proper installation to minimize maintenance errors.

2. Failure investigation

2.1. Visual observation

On-site visual examination of the damaged area revealed that two mounting bolts were completely fractured into two pieces and one bolt was missing, as shown in Figs. 3 and 4. There were 16 primary flaps in the afterburner nozzle assembly and each primary flap was attached to flange duct through a hinge tang with pin. The hinge was fastened to the flange duct with three bolts, Fig. 4b. Both bolts fractured in the vicinity of the root of the first engaged thread of the flange duct, Fig. 4c. This failure location is predictable, as the highest stress concentration and most severe loading are located in this area The bolt holes are designated as ‘A’, ‘B’, and ‘C’ in clockwise direction. There are two alignment holes between bolt holes designated ‘C1’ and ‘A1’ (identified in Fig. 4(c)).

Fig. 5 shows the backside view of the remaining bolts in holes, ‘A’ and ‘B’. It was observed that the protruding length of the bolt