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Failure investigation of fuel tubes of a jet engine augmenter assembly

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ABSTRACT

Failure of the fuel tube in a jet engine augmenter assembly has been investigated. A routine inspection detected that the fuel tube connected to the fuel augmenter was completely fractured into two pieces in two separate jet engines. Both fractures of the tubes occurred adjacent to a mounting area in the engine augmenter assembly. Fractographic observation revealed that fatigue cracking was initiated from multiple origins on the outer surface of the tube and progressed over 95% due to fatigue along the circumference, ultimately resulting in fracture. Features of the fractured surfaces in both failed tubes showed almost identical morphologies. X-ray observations showed no evidence of defects in the joint area. 3D scanning technology was employed to precisely measure the tubes, which revealed that both failed tubes had significant dimensional mismatches with the design drawings. Stress analysis including both finite element analysis and X-ray diffraction was used to identify the stress concentration level of the failed tube. Through detailed investigation, it was revealed that the primary reason for premature fatigue cracking of the fuel tube was unintended assembly stress due to the force of mounting the tube during installation.

1. Introduction

Failure in tubes used in aircraft systems such as fuel, hydraulic, and environmental control systems can occur for a variety of reasons [1]. Failed tubes in fuel systems are of special importance as they may often result in catastrophic failure. The Republic of Korea Air Force (ROKAF) experienced several critical failures of the fuel tubes in the jet engine augmenter assembly. Routine inspection detected fuel leaking from the connecting tube between the augmenter fuel control and augmenter fuel pump controller in the jet engine augmenter assembly. At the moment of the failure, the jet engine had been in service for 1650 h since its manufacture. The leakage of fuel from the augmenter fuel tube was cited as a potential cause of a fire incident in similar jet engines, therefore a special investigation on the augmenter tubes was conducted over the entire fleet. It was discovered that the fuel tube was completely fractured into two pieces in two separate jet fighters. The axis of the failed tube was slightly misaligned toward the 4 o'clock direction from the remaining tube which was attached to fuel pump controller (Fig. 1). Generally, failures of the tubes used in aircraft systems are associated with various causes such as fatigue, corrosion, wear, creep, and overload fracture. The most common failure mechanism of the tubes in engine components is usually due to fatigue cracking induced by thermo-mechanical cyclic loading [2]. If there is a corrosive environment, this fatigue cracking can be accelerated. Fatigue problems in tubes can also be promoted by various other sources, including deficiencies in the manufacturing, design, and severe operational conditions during service of the tubes. A similar failure of the afterburner fuel line was presented by B. Panda et al. [3] and M. Mansoor et al. [4]. According to the investigation [3], the jet fighter experienced an incident of fire in the jet engine due to fatigue

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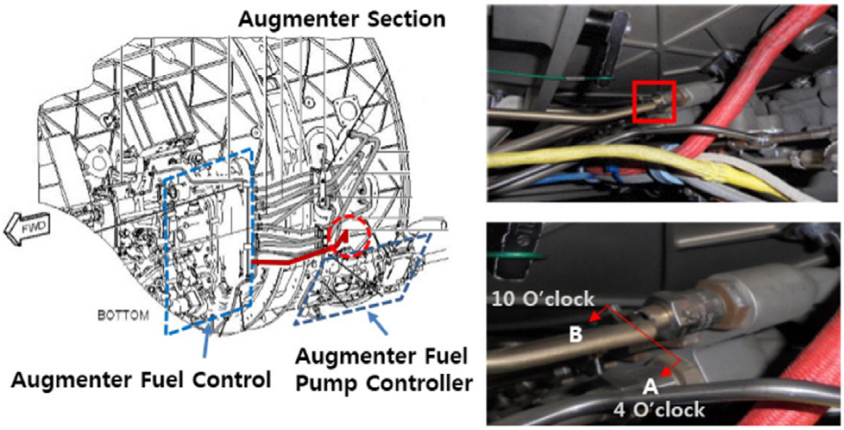

Fig. 1. Attachment location of the failed fuel tube of the augmenter control system.

failure at the afterburner fuel manifold. The primary factor for fatigue cracking was assembly stress that generated the stress concentration in the weld joint where they are susceptible to fatigue failure.

This paper describes an investigation of premature fatigue cracking at the connecting tube between the augmenter fuel control and augmenter fuel pump controller. It was conclusively established through various methods of failure analysis that premature fatigue failure at the tube was caused by excessive assembly stresses during installation. In order to investigate the cause of failure, experimental procedures included optical microscope and fractographic, i.e. field emission scanning electron microscope examination, metallography and X-ray energy dispersive spectroscopy. In addition, 3D scanning technology was used to precisely measure the dimensions of the tube. Stress analysis techniques, i.e. finite element analysis and X-ray diffraction were employed to estimate the stresses present in the failed tubes.

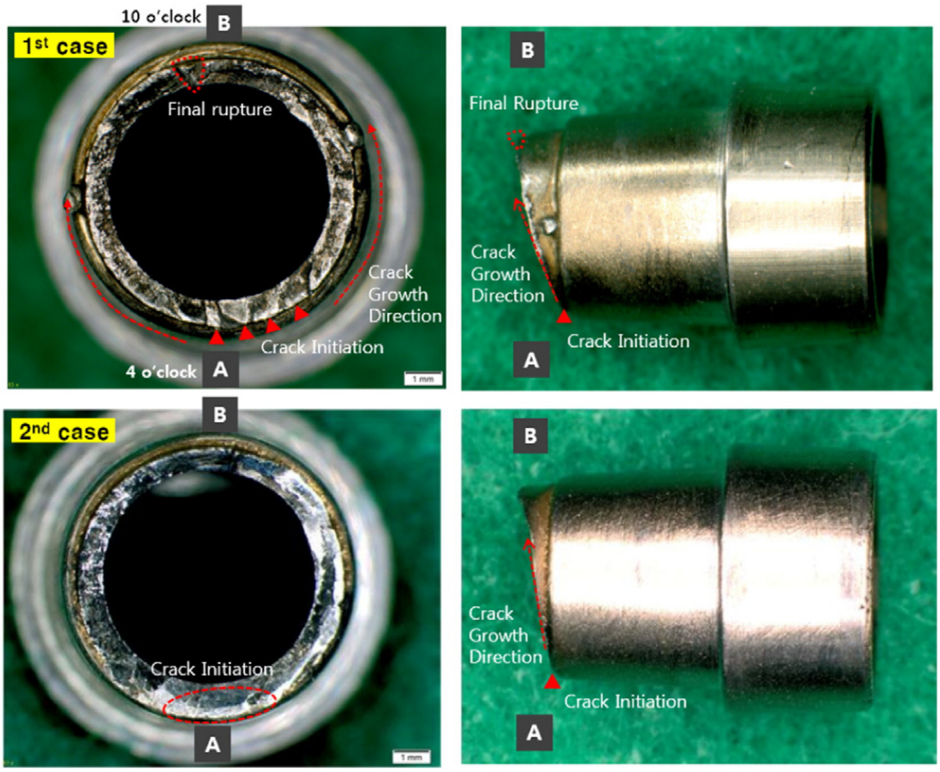

Fig. 2. Fracture surfaces of the failed tubes.