Engineering Failure Analysis 70 (2016) 351–363

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Failure of mounting bolt of helicopter main gearbox support strut

Branimir Krstic [a,*], Lamine Rebhi [a], Nada Ilic [b], Marjan Dodic [a], Mirko Dinulovic [c], Predrag Andric [d], Dragan Trifkovic [a]

[a] University of Defence in Belgrade, Military Academy, Generala Pavla Jurisica Sturma 33, 11000 Belgrade, Republic of Serbia
[b] Military Technical Institute, Ratka Resanovica 1, 11000 Belgrade, Republic of Serbia
[c] University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, Republic of Serbia
[d] École Polytechnique Fédérale de Lausanne, Institute of Mechanical Engineering, EPFL STI IGM LAMMM ME D3 1126 Station 9, CH-1015 Lausanne, Switzerland

ARTICLE INFO

Article history:
Received 8 July 2016
Received in revised form 20 September 2016
Accepted 24 September 2016
Available online 28 September 2016

Keywords:
Helicopter
Bolt failures
Finite element analysis
Hydrogen-induced stress corrosion cracking

ABSTRACT

The mounting bolt of helicopter main gearbox support strut was fractured into two pieces during the flight mission. The fracture occurred at the root of the first engaged thread of the bolt-nut assembly. Visual inspection of the fracture zone revealed cracks, formed by interlinking of corrosion pits, at the almost all thread roots of the bolt. Energy dispersive spectroscopy disclosed significant damage of the cadmium plating as well as the presence of large amounts of corrosion products at the bolt threads. Through the fractography and metallography analysis, it was found that the mounting bolt failed due to hydrogen-induced intergranular stress corrosion cracking (HI-IGSCC). The finite element (FE) analysis confirmed that the crack origin was located at the area with the maximum tensile stress in the bolt.

1. Introduction

The Permskie motory VR-8A main helicopter gearbox along with two Klimov TV2-117A turboshaft engines is a component of the power plant of the Mi-8 multipurpose medium-load helicopter. The primary purpose of the VR-8A two stage planetary main reduction gearbox is to take power from the engines output, torque at angular velocity of 12,000 rpm, and to transfer it to the main rotor at optimum angular velocity of 192 rpm. In the case of the helicopter Mi-8, one more function of the main rotor transmission is to change the axis of rotation from horizontal axis of the engines to the vertical axis of the rotor shaft. The main gearbox is mounted on the top of the center fuselage deck (Fig. 1) and connected to the helicopter airframe using a set of eight long support struts, Fig. 2. These struts are the structural components designed to carry the in-flight quasi-static loads i.e. to take large compressive and tensile mechanical loads [1]. They also act as vibration transmission paths, connecting the major noise and vibration generators of the main rotor and gearbox to the helicopter airframe [2]. The support struts are attached to the fuselage, to reinforced frames no. 7 and no. 10, using four vertically positioned bolt-nut connections, Fig. 2. These bolts are defined as a flight safety parts, since they effectively carry almost the entire helicopter weight during flight. Given their role in structural integrity of the helicopter, failures of mounting bolts of the main gearbox support strut may have serious or fatal consequences to the safety of the crew/passengers and the aircraft itself. Therefore, the accurate determination of the root causes of failures is of the highest importance.

* Corresponding author at: University of Defence in Belgrade, Military Academy, Department of Military Mechanical Engineering, Generala Pavla Jurisica Sturma 33, 11000 Belgrade, Republic of Serbia.
E-mail address: branimir.krstic@va.mod.gov.rs (B. Krstic).

http://dx.doi.org/10.1016/j.engfailanal.2016.09.012
1350-6307/

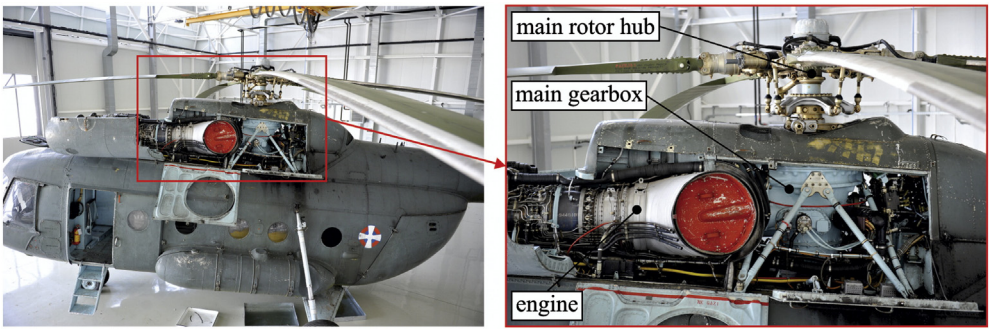

Fig. 1. Main rotor gearbox of helicopter Mi-8.

This study presents a metallurgical and numerical failure analysis of mounting bolt of the main gearbox support strut of the military helicopter Mi-8. The failure occurred in 2013 during the flight mission and the postflight inspection revealed that the mounting bolt of the aft left support strut of the main gearbox was fractured. The considered bolt was original equipment on the 33-year-old helicopter. By the time of the occurrence flight, helicopter had accumulated 3090 flight hours since new and 1097 h since overhaul.

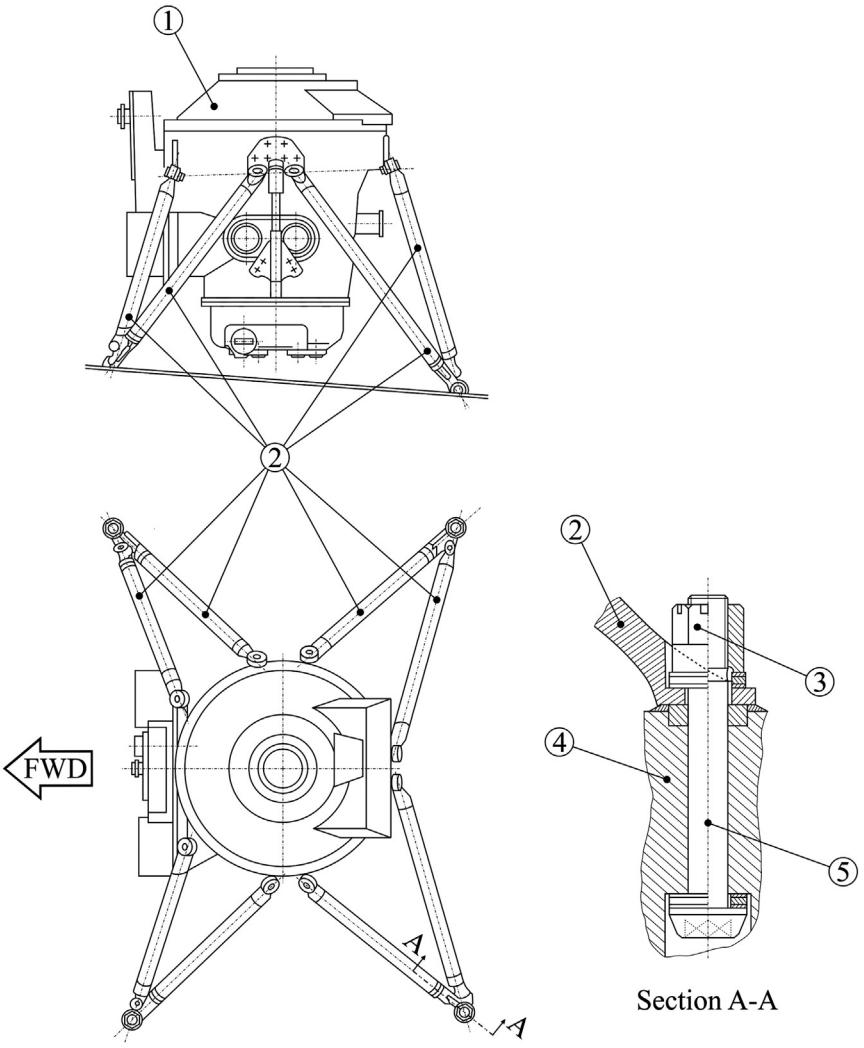

Fig. 2. Schematic drawing of the main gearbox support assembly and longitudinal section through the bolt of the aft left support strut: 1 - helicopter main rotor gearbox; 2 - support strut; 3 - castle nut; 4 - reinforced airframe no.10; 5 - bolt.