Engineering Failure Analysis 63 (2016) 121–130

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Investigation into recurring military helicopter landing gear failure

Branimir Krstic [a], Lamine Rebhi [a], Dragan Trifkovic [a,*], Nabil Khettou [a], Marjan Dodic [a], Sreten Peric [a], Milorad Milovancevic [b]

[a] University of Defence in Belgrade, Military Academy, Generala Pavla Jurisica Sturma 33, 11000 Belgrade, Serbia
[b] University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, Serbia

ARTICLE INFO

Article history:
Received 5 November 2015
Received in revised form 3 January 2016
Accepted 15 February 2016
Available online 19 February 2016

Keywords:
Helicopter landing gear
Failure analysis
Fracture
Stress corrosion cracking
Finite element analysis

ABSTRACT

The skid landing gear of a military helicopter failed while the helicopter was moored on the ground at the airport. The rear cross tube of the landing gear assembly was found fractured into two separated pieces. The fracture occurred in the right flange of the rear cross tube, where a connection with the spring tube is established using a clamp. The initial visual inspection of the fracture zone revealed a presence of heavy corrosion and significant damage of the anti-corrosion protective layer on the outer surface of the flange of the rear cross tube. Fractographic analysis highlighted corrosion as the main cause of the failure. Evidence was found to show that the fracture was initiated from corrosion pits located on the exterior, underside of the cylindrical part of the flange. Metallographic examination discovered corrosion pits with micro cracks and multiple branched secondary cracks in the crack origin area, indicating the occurrence of stress corrosion cracking. Chemical analysis of the corrosion deposits showed the presence of sodium, chlorine, calcium and sulfur. The stress analysis of the helicopter landing gear assembly, carried out by means of finite element method, confirmed that the crack origin was located at the area with the maximum tensile stress in the flange.

1. Introduction

Landing gears are responsible for providing aircraft support when on the ground and absorbing the loads during landing and take-off. Although they are not used in flight, they represent an extremely important aircraft system and have to be designed, manufactured and maintained in a proper way to secure a high reliability in service. To carry out their functions with minimum weight and use of space, they are made of materials with high specific strengths [1]. Failure of any structural component of landing gear assembly can lead to serious accident or incident.

Among the huge number of aircraft mechanical components that belong to different assemblies or technical systems, elements of landing gear are widely presented in scientific papers in terms of frequent failures. They are usually subjected both to severe operational and environmental conditions in their long service life.

Azevedo et al. investigated two failures of outer cylinders of aircraft landing gear shock strut assemblies. In the first case of failure [2], the landing gear failed due to the fracture of its outer cylinder attachment lug. Presented results showed that corrosion cavities, located in a critical area, were the main cause of the failure. In the second case of the failure [3], the outer cylinder was fractured into several fragments during landing. The crack propagation map indicated that the most of cracking was originated at

* Corresponding author at: University of Defence in Belgrade, Military Academy, Belgrade, Department of Military Mechanical Engineering, Generala Pavla Jurisica Sturma 33, 11000 Belgrade, Serbia.

E-mail address: dragan.trifkovic@va.mod.gov.rs (D. Trifkovic).

http://dx.doi.org/10.1016/j.engfailanal.2016.02.018
1350-6307/

pre-existing fatigue cracks. However, in the both cases of the failures, fracture path was microstructure sensitive and both stable and unstable cracks propagated primarily along the orientation of microstructure.

Bagnoli et al. presented fatigue failures of the wheel and swinging lever of an aircraft main landing gear. The failure of the right wheel of the main landing gear of Piaggio Avant 180 aircraft [4] that occurred during taxing on the runaway originated from corrosion pitting. The pitting was caused from damage to the protective coating by fretting from the tire bead and the tube well. These pits were followed by fatigue. The investigation of the failure of a left-hand main landing gear of a civil aircraft evidenced a fatigue failure of its swinging lever, which was promoted by a pre-existing material defect and identified as a high silicon concentration in the most stressed area of the external surface [5].

Paper [6] shows failure analyses of the nose landing gear of a military transport aircraft EMB 121 – Xingu which collapsed during take-off. The initial crack growth in the landing gear was due to fatigue, originated from corrosion pits. To identify further failures, the authors recommended the high quality dye penetrant inspection to detect cracks.

Failures of aircraft landing gear components may also occur as a result of human's error, not only material defects. Ossa in reference [7] described in detail the failure of the main landing gear of the Cessna 402B civil aircraft due to a pilot's error. Although the landing was performed under normal wind and visibility conditions, the failure was caused by a heavy landing, leading to shear failure of the clevis bolts of the locking linkages. There were no indications that failure was initiated by pre-existing material defect. Therefore, it was concluded that the failure was a consequence of the pilot's error. It can be concluded, from the refs [2–7], that harsh environments can often lead to corrosion in landing gear elements while large (sometimes unexpected) cyclic loads contribute to fatigue occurrence.

Generally, aircraft landing gears are being made of high strength steel alloys which are commonly sensitive to environments, and their environmentally induced degradation includes stress corrosion cracking (SCC) and hydrogen embrittlement [8,9].

Two case studies of aircraft landing gear structural component failures due to SCC are presented in detail in [1]. In the first failure case, a main landing gear truck beam, made from AISI 4340 high strength steel, fractured while aircraft was on the ground. The crack was located next to the oleo attachment point. Visual and microscopic examinations highlighted SCC as a main cause of failure. The stress corrosion crack initiated from a corrosion pit that was quite broad but shallow. In addition, numerous corrosion pits were also observed in the vicinity of the fracture. The second case of failure involves an investigation into a main landing gear axle assembly of a fighter aircraft, made from 300 M high strength steel, which failed during landing. The fracture occurred on the hub while it was locating the axle in the hydraulic tube. Through different examinations, it was established that SCC was the mechanism of fracture. The crack originated from one of corrosion pits, caused by flaking and cracking damage to the electroless nickel by the crank lever.

A left main landing gear of Boeing 737-400 was detached from the airplane during landing [10]. Examinations of remains of the left main landing gear revealed a fracture on the inner cylinder of the MLG, which is made from 4340 M high strength steel. Furthermore, the chromium coating of the inner cylinder has been found to be damaged, inducing corrosion. The fracture surface exhibited three distinguished areas, corresponding to SCC, fatigue and ductile. It was concluded that the main cause of failure was SCC compounded by fatigue.

This paper highlights the metallurgical and numerical approaches to failure analysis of the skid landing gear of the military multi-role, lightweight, single-engine, helicopter Aerospatiale Gazelle SA 341H, Fig. 1. The helicopter skid landing gear (HSLG) consists of two skid tubes and two cross tubes as is shown in Fig. 2. Skid and cross tubes are connected by four vertical spring

Fig. 1. Military helicopter Aerospatiale Gazelle SA 341H.