Engineering Failure Analysis 32 (2013) 1–15

Contents lists available at SciVerse ScienceDirect

Engineering Failure Analysis

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

Failure analysis of an aircraft engine cylinder head

Branimir Krstic [a,*], Bosko Rasuo [b], Dragan Trifkovic [a], Igor Radisavljevic [c], Zoran Rajic [c], Mirko Dinulovic [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*
[c] *Military Technical Institute, Ratka Resanovica 1, 11000 Belgrade, Serbia*

ARTICLE INFO

Article history:
Received 3 March 2013
Accepted 6 March 2013
Available online 15 March 2013

Keywords:
Aircraft
Cylinder head
Failure analysis
Fatigue failure
Finite element analysis

ABSTRACT

The piston engine of the training aircraft malfunctioned during the flight due to the cracking of its cylinder head (CH), which is manufactured from an aluminum casting alloy. Based on the fractographic examination of the mating fracture surfaces, the characteristic ratchet and beach marks were observed indicating the occurrence of fatigue failure. The crack was initiated from multiple origins located on the inner flange fillet on the exhaust side of the CH. The metallography examination has shown that the fatigue was promoted from pre-existing material defect due to an elevated presence of shrinkage pores at the crack initiation zone and was most likely associated with the manufacturing process of casting. The finite element (FE) method, utilized to determine the stress state of the CH subjected to gas pressure, also confirmed that the crack origin was located at the most stress area.

1. Introduction

Apart from pilot errors, the majority of aviation accidents have been caused by failures of aircraft structure or failures of some technical systems. In recent years, an increasing attention has been given to the investigation of different aircraft technical systems' contribution to the aircraft losses and their potential for failure that lead to repeating incidents and accidents. One of the most important technical systems in aircraft is an engine, nevertheless if the aircraft is propelled by a jet or a piston engine. The extremely changeable operating conditions for components in aircraft engine together with their age and maintenance procedure can influence failures.

Bhaumik et al. [1] have investigated the reason of crankshaft fracture in the transport aircraft piston engine. They have concluded that the shaft had been subjected to high contact pressure and cyclic loading leading to pitting and spalling at the region of the journals where the fatigue cracks appeared. Also, fatigue was found as a major cause of failure of many aircraft piston engine components like connecting rods [2]. In this concrete case, it has been reported that enormous friction between the bearing and the crank pin had contributed to fatigue crack initiation.

In addition to fatigue, some material discontinuities caused by a casting process can attribute to failure appearance in engine parts. The case study of cracking in a gray-iron cylinder head has revealed that high operational stresses of the engine acting on a material microporosity can produce cracking in the area adjacent to the vent plug [3]. There are a few of reasons for porosity in casting material among them inadequate pouring temperature is predominant.

The training aircraft Utva-75 (Fig. 1), with two pilots on board, was on a training flight when pilots reported an engine problem. Shortly after takeoff, pilots heard a very loud "bang" and the engine began to run rough and vibrate. The engine

* Corresponding author. Address: University of Defence in Belgrade, Military Academy, Belgrade, Department of Military Aviation, Generala Pavla Jurisica Sturma 33, 11000 Belgrade, Serbia. Tel.: +381 11 3603 365; fax: +381 11 3005 190.
E-mail address: branimir.krstic@va.mod.gov.rs (B. Krstic).

1350-6307/$ - see front matter
http://dx.doi.org/10.1016/j.engfailanal.2013.03.004

Fig. 1. Utva-75 training aircraft.

working parameters degraded and pilots decided to return at the airport. After successful forced landing at the airport, the engine was removed from the aircraft and significant damage to the engine was observed. However, no damage to the aircraft structure has been found. An examination of the aircraft engine revealed a crack in cylinder head (CH), between the fifth and the sixth cooling fins (counting from the barrel). The damaged cylinder was sent to the Military Technical Institute, Structural and Technical Materials Laboratory to determine the cause of the failure.

Similar two cases happened in Canada. First one, in June 2009 the airplane Glastar struck trees and the engine was found with one cylinder head separated from the barrel. The engine was an Aero Sport Power which is identical to the Lycoming O-360-A2A model. It has been reported by Transportation Safety Board of Canada – Operational Services Branch that the separation of the cylinder head occurred due to fatigue cracks developed at the thread. Stress concentration formed by the sharp corners of the barrel threads led to initiation of metal fatigue [4]. The next year, in May 2010, Cirrus Design SR20 aircraft crashed onto the roof of a building due to the same problem, i.e. cylinder head separation from the cylinder head barrel. The aircraft engine was Teledyne Continental Motors model IO-360-ES. Engineering examination suggested that the cylinder head separated as a result of the instantaneous overstress extension of a pre-existing high-cycle fatigue crack. Combination of corrosion damage and a sharp corner on the aluminum casting thread contributed to the fatigue initiation [5].

Damaged cylinder from Utva-75 had been installed on the engine in the number one position (Fig. 2). By the time of the occurrence flight, it had accumulated 1560 flight hours since new and 360 h since overhaul. The recommended time between overhauls for this type of engine is 2000 h. The last periodic (50 h) compression test was conducted at 1545 h of total flight time or 15 h before accident. The result of differential pressure test is presented in Table 1.

The Utva-75 training aircraft is propelled by four cylinder, direct drive, horizontally opposed, air cooled engine. The cylinders are of conventional air cooled construction with the two major parts, head and barrel, screwed and shrunk together. The heads are made from an aluminum casting alloy with a fully machined combustion chamber. The cylinder barrels are machined from chrome nickel molybdenum steel forging with deep integral cooling fins. The interior of the barrels are ground and honed to a specified finish. The engine specifications [6] are presented in Table 2.

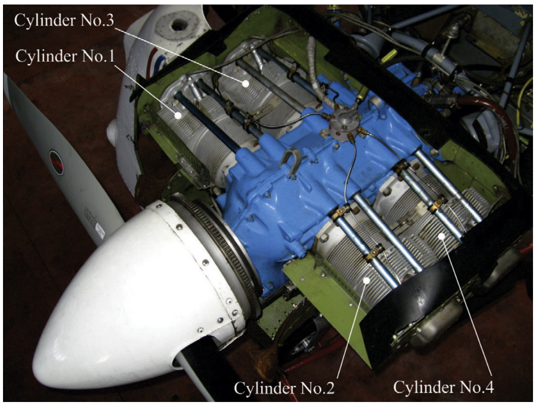

Fig. 2. Utva-75 engine.