Engineering Failure Analysis 18 (2011) 97–109

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Failure analysis of a composite main rotor helicopter hub

F. Viganò [a], A. Manes [a,*], M. Giglio [a], U. Mariani [b]

[a] Politecnico di Milano, Department of Mechanical Engineering, Via la Masa 1, Milano 20156, Italy
[b] AgustaWestland, Via Giovanni Agusta 520, Cascina Costa di Samarate, VA, Italy

ARTICLE INFO

Article history:
Received 19 April 2010
Accepted 15 August 2010
Available online 26 August 2010

Keywords:
Composite rotor hub
Fatigue
Experimental
Numerical model

ABSTRACT

A full scale fatigue test of a helicopter main rotor hub MR/H has been performed by spectrum loading. The test has been supported by a detailed finite element model of the component providing relevant information about its behaviour under loading. The MR/H has been made of Ti–6Al–4V wrapped up by a circular carbon band. Stress and strain from FE model have been validated by strain survey addressing the most critical locations. Fatigue life evaluation has been carried out by analysis in good agreement with the test results. The combined approach by test and validated numerical models has proved to be a reliable tool for fatigue substantiation of critical parts.

1. Introduction

The structural integrity of the main rotor hub (MR/H) during service is a crucial task in helicopter design and maintenance strategy. A failure of this component may lead to a catastrophic effect on the whole machine. At present, fatigue evaluation of MR/H is carried out in agreement with the civil rule CS 29.571 [1], which requires that catastrophic failure due to fatigue must be avoided taking into account also the additional impact of the environment, intrinsic or discrete flaws and accidental damages. This is obtained by a combination of safe life, fail-safe, and flaw tolerant evaluations.

Nowadays deep structural analyses are conducted on helicopter hubs, and more in general on helicopter components, in order to analyze their behaviour during the application of contingent loads and to obtain the certification of the machine. In [2,3] the authors have illustrated the application of flaw tolerance methodologies dedicated on rotorcraft components. Particular attention has been addressed to the typical problem of the fatigue load scenario in helicopter structural assessment, i.e. the high frequency load cycles induced by the aerodynamic interaction of the rotor blades. The very high number of cycles per flight coupled with the presence of defects is a real big issue in the design and maintenance of modern helicopter structures. Moreover, for what concerns the rotor components the presence of interspersed high amplitude spectra like start-stop condition can influence the integrity of the structure. Thus in the last few years a very specific design methodology and approach, called "enhanced safe life", has been developed. Particular attention has been dedicated to the near threshold fatigue crack growth, very short crack that can nucleate naturally at notches and can propagate at lower stress intensity range than the long crack threshold and at higher growth rate [2–4]. The presence of start-stop cycles, inside the high frequency flight cycles, can in fact be very dangerous and lead to a fast nucleation that can became progressively significant during the flight. This is especially important for materials like titanium alloys, whose fatigue properties are extremely sensitive to the presence of notches, heat treatment and surface condition. Of course a low stress design and frequent inspections can reduce the risk of failure, but there are some economic limits that push toward a more refined and accurate design approach. As shown in [5], a failure that occurs within a main rotor grip device is examined. From the picture of the failure section,

* Corresponding author. Tel.: +39 02 2399 8630; fax: +39 02 2399 8282.
E-mail address: andrea.manes@polimi.it (A. Manes).

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doi:10.1016/j.engfailanal.2010.08.009