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The Role of Advanced Technologies of Vibration Diagnostics to Provide Efficiency of Helicopter Life Cycle

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Abstract

Vibration diagnostic techniques (VDT) application to helicopters is growing gradually both in production stage and in technical operation and maintenance. The development of appropriate technologies requires considerable investment and is often hampered by the lack of a clear perspective, understanding of the possibilities and areas of application. The article presents new opportunities for the use of VDT for helicopter diagnostics at different stages of its life cycle, providing increased efficiency of production and operation. In paper, the taxonomy of VDT applicable to most of critical machines, mechanisms and structures of a helicopter is presented and discussed. The paper illustrates effective diagnostic techniques applications on helicopter engines exceeded vibration limits in delivery trials. In the paper, the capabilities of advanced VDT are considered using samples of experimental operating systems application. Advanced VDT is possible platform for design of Health and Usage Monitoring Systems (HUMS). In article the general approach for development of HUMS using the VDT and application of HUMS to provide condition-based maintenance for more efficiency of helicopter life cycle on criteria reliability/cost are discussed.

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Keywords: condition monitoring, vibration diagnostics, Health and Usage Monitoring Systems

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1. Introduction

The helicopter design is a challenging experience for fatigue concern as it is subjected to a wide range of low- and high-frequency load cycles per flight, much more than a fixed wing aircraft. Condition monitoring systems appear in recent years to increase flight safety and mission reliability, to extend duration of life-limited components and to reduce inspection and maintenance activities. In particular, Structural Health Monitoring (SHM) seems capable to help in reducing the maintenance and operational costs, which is about 25 per cent of the direct operating cost of the helicopter (Sbarufatti *et al.*, 2010). Thanks to the continuous engines monitoring and the helicopter SHM, it could be possible to set a Condition Based Maintenance (CBM) providing technical maintenance according to its current structural condition instead of relying just on the statistical data and assumptions.

The term of condition monitoring relates on vibration diagnostic techniques (VDT) applied widely for rotating machines (Mironov *et al.*, 2009) while SHM unites data acquisition and analysis in order to control the technical condition of structures throughout their life cycle (Hall, 1999). Typical health and Usage Monitoring system (HUMS) covers mainly drive train aggregates and main gearbox applying traditional VDT. Only last decade the actual condition monitoring of an engine becomes available based on advanced VDT (Mironov *et al.*, 2009). SHM defines the approach that provides the possibility to reveal dangerous changes of a construction resulting from caused damage or due to functionality failure (Kessler, 2002). Aviation has the highest potential return from prevention of the damages with the assistance of SHM or VDT, as regular technical maintenance of the airplanes is results in as much as 27% of the cost of the aircraft life cycle (Hall and Conquest, 1999).

Changes of dynamic behavior of the structure, represented in the form of modal parameters, are the basis of defect location strategy (Magpantay 2003, Mironov *et al.*, 2015). For rotating blades of a helicopter loaded both statically and dynamically Operational Modal Analysis (OMA) that uses only the response of the stressed structure excited by the surrounding environment for evaluation of modal features.

Kiddy (Kiddy and Pines, 2001) came the closest to solving the problem of the on-line monitoring of a rotating blade. of the Hughes TH-55A helicopter. The method proved capable of bringing out the defects with the high modal power. Luczak *et al.*, (2010) run static and dynamic testing of the full scale helicopter rotor blades using optical Fiber Bragg Grating and classical strain sensors as well as noncontact measurement techniques. The accuracy of the results appears frequency dependent and the discrepancy between models grows in frequency.

Helicopter life cycle includes two main stages: manufacture (production and overhaul) and operation (up to utilization). Nowadays at manufacture stage only few vibration parameters are measured on a testing rig during operation test that are rotor harmonics. If these vibration parameters exceed thresholds the engine to be returned for reprocessing works which list is determined based on the technical routines and stuff's experience but not on the technical condition of this specific engine. Advanced VDT, briefly considered in the paper, allow faults identification in both: the testing process and the operating helicopter within HUMS. The paper purpose is to present practical verification of VDT in application on helicopter engines, main gearbox and rotor in industrial conditions.

2. Abilities of advanced technologies of vibration diagnostics

For a helicopter the VDT must treat both rotating (machines and aggregates) and structural units. Such wide scope requires methodical consideration of both aspects of dynamic processes: actuation from rotating parts and response of structural elements. Vibration passport (VP) (Mironov *et al.*, 2010) is one of advanced tools that provides such complex consideration. As actuators VP considers rotating units of machines and aggregates, including engines, main gearbox, aggregates of electro-, hydro-, fuel and lubricating systems. As structural units VP considers helicopter static parts (like tail beam, fuselage parts and landing gear) and rotating ones, like main rotor shaft, blades and its components. Models of physical interactions used by VP consider machine vibration as the response to the set of the correlated and uncorrelated quasi-periodical and random pulsate sources of actuation that are spatially distributed. These models capable to describe both deterministic and random vibration components (Mironov *et al.*, 2010a) are used for development of the object-oriented data development techniques. These techniques become the part of VP and treat dynamic signals in time, phase and frequency domains (Mironov *et al.*, 2010b) providing computation of the VP diagnostic parameters. Diagnostic parameters of VP characterize any