Measurement of normal modes of the main rotor blade of an unmanned helicopter using contact and non-contact methods

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Abstract. This article describes the use of two different vibration measurement methods to identify natural vibrations of the main rotor blade of a miniature unmanned helicopter. The goal of this type of testing is to determine resonant modes and frequencies within the required range [2,5]. Studying the natural vibrations of rotor blades is a critical element of helicopter design and operation [8]. Understanding the natural frequencies affects not only operating conditions but also the critical strength of the structure [2,5,8]. Structural resonance, including ground resonance, can lead to catastrophic failure [8,11]. Vibrations also affect material fatigue through permanent cyclic loading [2,5].

Advanced measurement equipment is used, including techniques based on piezoelectric accelerometers or laser beams [9,12]. The measurement systems are operated at the Institute of Aeronautical Technology (IAT – a unit of the Faculty of Mechatronics, Armament and Aerospace of the Military University of Technology, FMAA MUT) to conduct measurements and provide data collected from tests on real objects, with the possibility of their integration into the simulation process [1,4]. In the classic vibration measurement method, sensors are attached to the surface of the component. All sensors are connected to a multi-channel analyzer [5]. During the measurement they stay active, which allows detection of all response signals simultaneously [5]. The mass of the sensors and cables is negligible; however, in lightweight structures this additional mass can cause differences (mass-loading effect) [5,9]. For measurements, the blade is attached as it would be to a real helicopter rotor. This means it is mounted as a slender cantilever beam [2,5,8].

The aim of this article is to present a methodology for testing vibrations in lightweight structures using two different vibration measurement methods: contact and non-contact. Specialized measurement equipment was used to conduct this type of testing. The contact system consists of a multi-channel LMS SCADAS analyzer, a set of piezoelectric accelerometers, an electrodynamic exciter with an amplifier, an impedance head, and a computer station with Simcenter Testlab software [6,7,9]. The non-contact method is performed using a Polytec PSV-400 laser scanning vibrometer. This advanced instrument is used for non-contact measurement of structural vibrations based on laser Doppler vibrometry principles [12]. The operating principle is based on splitting a laser beam within the measuring head: one part acts as a reference beam, while the other is directed towards the vibrating object; the returned beam is compared with the reference signal to determine the vibration response [12]. Dedicated software analyzes the collected measurement data and uses it to create animations illustrating the vibration patterns of a given object across a wide frequency range [12]. The equipment scans oscillations in all measurement grid points sequentially. The results collected from all scanning points are then processed [12]. Practical LDV performance and robustness can be influenced by measurement conditions and optical/signal effects, which motivates performance and evaluation studies [13,14].

The paper describes two measurement methods and presents sample results. The aim of the study was to collect and compare experimental data from both measurement methods. The summary describes the effect of placing sensors on a very lightweight structure (mass-loading) and the differences in the natural frequencies of the blade obtained from two different measurement systems [5,9,12].