BladeSense – A novel approach for measuring dynamic helicopter rotor blade deformation

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The emphasis on safety in the rotorcraft community has led to today's operational practices to actively adopt state-of-the-art technology but also maintain highly conservative practices, especially in the operation, maintenance and servicing of rotor blades. The inability to directly monitor the rotor blades' operational loading and resulting structural deformations has led to pragmatic solutions that rely on human qualitative judgement that may not be economical from a customer perspective. The technology to monitor the health of the rotor blades in-flight will overcome those limitations. This can be achieved through instrumentation systems using fibre Bragg grating surface strain sensors or a method using a direct shape deformation measurement approach. These technologies bring benefits to operator and maintainer through continuous in-flight monitoring which results in enhanced flight safety, simpler operations and timely maintenance. The measured data can also be processed and exploited in the overall aircraft design, especially blade aeroelastic design. A collaborative project between Airbus Helicopters, Cranfield University, BHR Group and Helitune, the BladeSense project aims to develop a high performance, robust instrumentation system capable of operating in the challenging and harsh environment of a helicopter rotor hub. The activities within the BladeSense project focus on (1) the development of mathematical baseline models, (2) the development of a fibre-optic instrumentation for direct shape measurement, (3) transfer of data between the rotating rotor hub and the airframe and, (4) incorporation within a health monitoring unit.

The paper will be structured such that the mathematical baseline models suitable for real-time analyses are presented first. The baseline models consist of computational fluid dynamics (CFD) coupled with finite element analysis (FEA) to provide steady state structural deformations along the rotor blade for different azimuth and pitch angles. Based on this output a stochastic model is developed to surrogate the computationally expensive fluid-structural interaction (FSI) simulation. Then a methodology of how these models are validated and improved through finite element model updating techniques is presented. This is followed by an overview of the two fibre optic instrumentation systems: (1) fibre Bragg gratings acting as strain gauges and, (2) a novel method that allows direct shape sensing. The main benefits of this novel approach are that no perfect strain transfer is required from the structure to the sensor, and the deformations do not need to be inferred from the measured strain data.

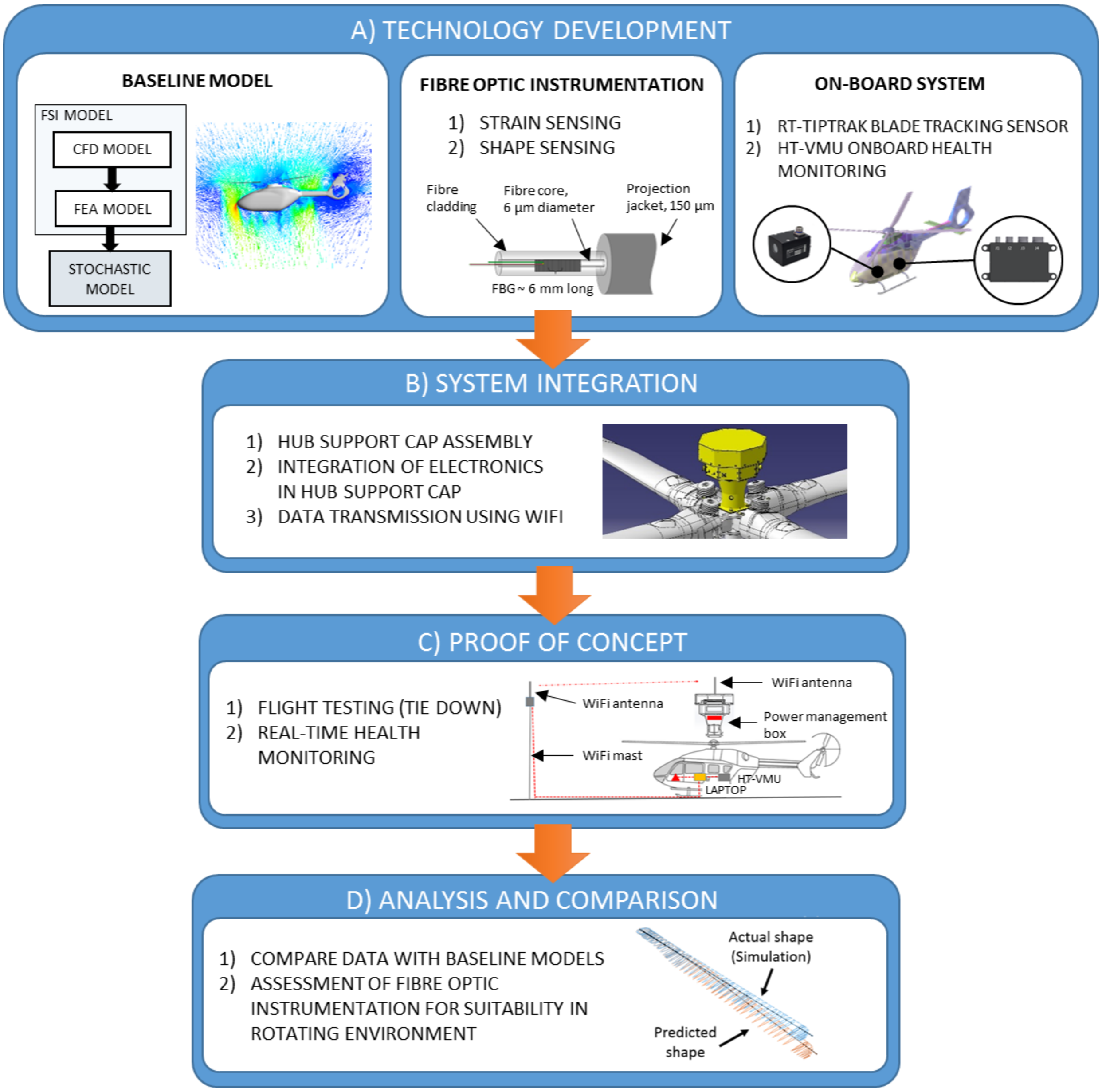

Figure 1: Overview of the BladeSense project

The associated tasks of integrating the required electronic equipment, such as interrogator, mini-PC, or power supply into the airframe will also be discussed, followed by a description of the data transfer from the rotating to the non-rotating frame. Real-time health monitoring of the rotor blades is done by integrating the Vehicle Health Monitoring (HT-VMU) vibration monitoring unit on the H135 to capture data not only from the fibre optic sensors, but also from other sensors and on-board avionics. The paper concludes by summarising the key challenges of systems integration, such as the integration of the HT-VMU with the fibre-optic system, synchronisation of the data streams and the data transmission using WiFi to stream strain and blade shape during operation for health monitoring, balancing the hub support cap assembly, and the attachment of the fibre optic sensors to the surface of the rotor blade.