Optimal Active Twist Comparative Design and Testing of Helicopter Rotor Blades with C and D-Spars

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ABSTRACT

In time of helicopter flight, rotor blades produce significant vibration and noise as a result of variations in rotor blade aerodynamic loads with blade azimuth angle. Likely, significant vibration and noise reduction can be achieved without the need for complex mechanisms in the rotating system using active twist control of helicopter rotor blades by an application of the macro-fibre composite (MFC) actuators. In this case MFC actuators are implemented in the form of active plies within the composite skin of the rotor blade with orientation at 45° to the blade axis to maximize the shear deformations in the laminated skin producing a distributed twisting moment along the blade.

A number of theoretical and experimental studies were performed to estimate an active twist of helicopter rotor blades required for the reduction of noise and vibration and improvement of the overall performance of helicopters. The early studies were mostly experimental in nature and were undertaken to prove the concept of an active twist control using piezoceramic materials. Most present numerical investigations are based on simple box–beam blade models or combination of 2D cross–section analysis and 1D beam analysis. Recently, using these approaches, optimisation methodologies were developed to maximise an active twist response for some rotor blade models. The present investigations demonstrate the optimal design of an active twist of helicopter rotor blades with C and D-spar developed by using new 3D finite element (FE) model and verified by the testing of demonstrator blade. Two design solutions for an application of active materials were studied to estimate their effectiveness.

An investigated helicopter rotor blade (model scale) is equipped with NACA23012 aerofoil and has a rectangular shape with the active part radius 1.56 m and chord length 0.121 m. This rotor blade consists of C or D-spar made of unidirectional GFRP, skin made of +45°/-45° GFRP, foam core, MFC actuators embedded into the skin and balance weight. To investigate an active twist of the helicopter rotor blade, the steady-state thermal analysis was developed. In this case thermal strain analogy between piezoelectric strains and thermally induced strains is used to model piezoelectric effects. New 3D FE model of the rotor blade was built by ANSYS, where the rotor blade skin, spar “moustaches” and rib in D-spar are modelled by the linear layered structural shell elements SHELL99, and the spar and foam - by 3D 20-node structural solid elements SOLID186.

Due to a large dimension of the numerical problem to be solved, an optimisation methodology is developed employing the method of experimental design and response surface technique. Two optimal problems were solved with the purpose to obtain maximal torsion angle and minimal distance between location of the centre of gravity and elastic axis taking into account the designers’ requirements. The comparative analysis allows for designers to choose an appropriate optimal solution between rotor blades with C and D-spar in the desired design space. The experimental measurements of the torsion angle made on demonstrator blade confirm high accuracy of the developed 3D FE model and corresponding FE analysis.