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Designing and Simulation of the Rotor and Hub of the Unmanned Helicopter

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Abstract : Today's progress in the rotorcraft is mostly associated with an optimization of aircraft performance achieved by active and passive modifications of main rotor assemblies and a tail propeller. The key task is to improve their performance, improve the hover quality factor for rotors but not change in specific fuel consumption. One of the tasks to improve the helicopter is an active optimization of the main rotor providing for flight stages, i.e., an ascend, flight, a descend. An active interference with the airflow around the rotor blade section can significantly change characteristics of the aerodynamic airfoil. The efficiency of actuator systems modifying aerodynamic coefficients in the current solutions is relatively high and significantly affects the increase in strength. The solution to actively change aerodynamic characteristics assumes a periodic change of geometric features of blades depending on flight stages. Changing geometric parameters of blade warping enables an optimization of main rotor performance depending on helicopter flight stages. Structurally, an adaptation of shape memory alloys does not significantly affect rotor blade fatigue strength, which contributes to reduce costs associated with an adaptation of the system to the existing blades, and gains from a better performance can easily amortize such a modification and improve profitability of such a structure. In order to obtain quantitative and qualitative data to solve this research problem, a number of numerical analyses have been necessary. The main problem is a selection of design parameters of the main rotor and a preliminary optimization of its performance to improve the hover quality factor for rotors. This design concept assumes a three-bladed main rotor with a chord of 0.07 m and radius R = 1 m. The value of rotor speed is a calculated parameter of an optimization function. To specify the initial distribution of geometric warping, a special software has been created that uses a numerical method of a blade element which respects dynamic design features such as fluctuations of a blade in its joints. A number of performance analyses as a function of rotor speed, forward speed, and altitude have been performed. The calculations were carried out for the full model assembly. This approach makes it possible to observe the behavior of components and their mutual interaction resulting from the forces. The key element of each rotor is the shaft, hub and pins holding the joints and blade yokes. These components are exposed to the highest loads. As a result of the analysis, the safety factor was determined at the level of k > 1.5, which gives grounds to obtain certification for the strength of the structure. The construction of the joint rotor has numerous moving elements in its structure. Despite the high safety factor, the places with the highest stresses, where the signs of wear and tear may appear, have been indicated. The numerical analysis carried out showed that the most loaded element is the pin connecting the modular bearing of the blade yoke with the element of the horizontal oscillation joint. The stresses in this element result in a safety factor of k=1.7. The other analysed rotor components have a safety factor of more than 2 and in the case of the shaft, this factor is more than 3. However, it must be remembered that the structure is as strong as the weakest cell is. Designed rotor for unmanned aerial vehicles adapted to work with blades with intelligent materials in its structure meets the requirements for certification testing. Acknowledgement: This work has been financed by the Polish National Centre for Research and Development under the LIDER program, Grant Agreement No. LIDER/45/0177/L-9/17/NCBR/2018.

Keywords : main rotor, rotorcraft aerodynamics, shape memory alloy, materials, unmanned helicopter

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