PHD THESIS SUMMARY

"CONTRIBUTIONS REGARDING THE ANALYSIS OF A QUADCOPTER-TYPE DRONE STRUCTURE IN ORDER TO INCREASE THE TECHNICAL-TACTICAL PERFORMANCES"

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The doctoral thesis presents the current state of knowledge regarding the classification, design, construction and use of drones, which is the result of a bibliographic documentation. Classifications of drones are made, design stages, manufacturing methods, their limitations, solutions proposed in development for future generations and construction processes adopted are detailed, including the types of specific materials used in the structural development of drones. Drone applications, the categorizations used by NATO and the EU in dividing military UAVs (unmanned aerial vehicles) into classes, and a statistic using data on all confirmed drone strikes against targets in Afghanistan, Somalia, Yemen and Pakistan are exemplified. Issues related to the development, proliferation and use of armed military drones and their impact are discussed, as well as issues related to the regulations brought about their weaponization. Following the analysis carried out on the current state of knowledge on drones, the drone configuration was chosen for the study in the thesis, namely that of the Tarot Iron Man 650 quadcopter rotary wing MAV, in order to improve the technical-tactical performances.

In the thesis, general aspects about advanced fibre reinforced composite materials are presented and two techniques for making composite materials are analysed with the carbon fibre biaxial fabric (woven) reinforcement of twill type and polymer matrix of epoxy thermoset resin type used in the work to make composite laminates. The laminates made with the manual technique assumed stacking of the laminates with different orientations in the laminate, respectively 0°/90°, -45°/45°, -60°/30°, from which the specimens subjected to the tensile test for drawing characteristic diagrams were made. Laminates made with the VARTM (vacuum bag resin transfer molding) technique were used to evaluate the processed surfaces by varying the machining parameters and cutting tools. Findings from the microscopic analysis of the cutting surface and the analysis of the vibration regime produced by each setting of the cutting parameters led to the determination of the optimal cutting tools and machining parameters. This research concludes by performing a static MEF analysis of the quadcopter arm made of the composite materials analysed to obtain the longitudinal stresses on each carbon fibre lamina and the maximum deformations of the composite tube due to a force applied in the free end area, force equivalent to a thrust required to achieve hovering flight.

The paper describes three theoretical modal analysis models for undamped linear transverse vibrations of a beam on the Euler – Bernoulli model, for which the expressions for undamped natural frequencies and mode shapes are obtained. The numerical and experimental analysis are carried out on the determination of the transverse vibration eigenmodes and the corresponding frequencies for the beam represented by the composite tube of the quadcopter arm.

Three theoretical approaches to the dynamic response of the drone arm are analysed in the thesis. In the first theoretical approach, the dynamic response of the quadcopter arm structure to the forced undamped bending vibrations in the xOz plane due to a harmonic perturbation was studied, which led to a function form determined to be used in the research where the influence of the force of pressure exerted by the air jet (produced by the propeller blades during engine operation) on the dynamic response of the quadcopter arm. In the second theoretical approach, the response of the structure to undamped forced bending vibrations in the xOz plane due to a harmonic perturbation of the boundary condition was studied. Thus, for the case of static imbalance of the rotor-propeller assembly (which represents one of the three cases of possible excitation produced by the engine on the structure) the influence of the inertia force of the eccentric mass of the rotor-propeller assembly, which produces the excitation of the structure, was analysed, obtaining a form of the displacement function. In the third theoretical approach, that through the finite difference method, the following were discretized: the differential equation of the forced transverse vibrations, the bending moment equation from the free end of the arm and the shear force equation from the free end of the arm with finite differences, resulting in the new forms corresponding to the equations. The numerical approach was carried out with the aim of comparing the results obtained with those from the theoretical approach through the finite difference method.

The experimental analyses involved tests to determine the engine rotational speed, tests to obtain the traction force generated by the engine-propeller assembly for the engine operating regimes, tests to determine the velocity fields measured at different points of the air entrained in motion by the engine-propeller assembly propellers, tests to obtain the frequency of forced vibrations generated by the engine-propeller assembly during operation.

The results of the numerical analysis carried out in order to determine the air flow domain properties around the quadcopter arm according to the one obtained from the experimental analysis are presented in the paper. The influence of the air jet, produced by the propeller, on the quadcopter arm was analysed, and the numerical simulations consisting in determining the time variation of the pressure force distribution on the quadcopter arm were carried out.

A comparative analysis of the results of the experimental measurements sets on the average velocities determined with the hot wire anemometer and those determined numerically from the flow simulations for the 4 operating regimes of the engine, also performing an analysis of the average absolute percentage errors are presented in the thesis.

In order to improve the performance of the drone, section aerofoil adapters were designed for the quadcopter arm. Nine adapter models were analysed by numerical simulations in order to determine the dynamic response of the quadcopter arm in the operating regimes of the electric motor. The first set of simulations involved studying the arm dynamic response considering only the pressure forces developed by the propellers as loads. The arm-mounted adapter that provided the lowest vibration amplitudes for all engine operating modes was analysed in the second set of simulations, along with the arm without the adapter. These simulations involved the introduction into the numerical analysis of both the pressure forces and the inertia force due to the static imbalance of the rotor-propeller assembly. This inertia force represents the force generated by the static imbalance of the rotor-propeller assembly during engine operation. The realization of the physical model of the NACA0024 adapter was presented through the 3D printing technique, and both the arm without the adapter and the one with the adapter were tested in the experiment bench.