DOCTOR OF PHILOSOPHY

A THREE-DIMENSIONAL FLUTTER THEORY FOR ROTOR BLADES WITH TRAILING-EDGE FLAPS

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This dissertation develops the equations of motion for the structural and aerodynamic forces and moments of a rotor blade with a trailing-edge flap using eight degrees of freedom. Lagrange's equation is applied using normal modes to find the flutter frequency and speed similar to the classic fixed-wing method developed by Smilg and Wasserman. However, rotary-wing concerns are addressed, including different freestream velocities along the blade (variation of reduced frequency along the span of the rotor blade) and the influence of previously shed vortices on the aerodynamic forces and moments (Loewy's returning wake). While Loewy did not explicitly state that his 2-D theory would apply to rotor blades with trailing-edge flaps, the manner in which the theory was developed allows it to be applied in this manner. Comparisons to classic 1DOF, 2DOF and 3DOF flutter theories are made to validate this theory in the limiting cases. Flutter analyses, including g-Ω plots, of an example rotor blade with five degrees of freedom are performed for various rigid body flap frequencies.

Classic methods of rotor blade design of ensuring freedom from flutter are to collocate the center of gravity (c.g.), elastic axis (e.a.), and aerodynamic center (a.c) at the 25% chord. With the development of rotor blades with trailing-edge flaps, it is shown that this current design practice is not valid when a trailing-edge flap is incorporated.

KEYWORDS: Flutter, Rotary Wing, Aeroelasticity, Trailing-edge Flaps, Unsteady Aerodynamics, Structural Dynamics, Holzer Method, Myklestad-Prohl Method, Rotor Blades, Vibrations

NUMERICAL AND EXPERIMENTAL ANALYSIS OF THE PERFORMANCE OF STAGGERED SHORT PIN-FIN HEAT EXCHANGERS

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A three-dimensional finite element based numerical model was used to analyze the heat transfer characteristics of various staggered short pin-fin array heat exchangers. The simulation was validated against data from an experimental rig as well as historical data, and then used to estimate the heat transfer coefficient and pressure drop for a wide range of Reynolds numbers for circular and airfoil-shaped pin fins. Circular pin configuration variations included changes in pin spacing, axial pitch and pin height ratio. Airfoil pin variations also included changes in length and aspect ratio. Correlations for Nusselt number and friction factor were developed. Using established performance metrics, optimum configurations for bothpin shapes were determined. The optimum airfoil pin array was shown to match the heat transfer rates obtained by the optimum circular pin configuration while incurring less than one third the specific fluid friction power loss. The results from this study would be of direct value in the design of a shroud enclosed heat exchanger concept being proposed for turbine blade cooling, or for cooling of high power electronic components, or in other high heat flux dissipation applications requiring a low-profile, high area-density based micro-heat exchanger design.

KEYWORDS: Numerical Analysis, Heat Transfer, Pin-Fin Heat Exchanger, Turbine Blade Cooling, Electronic Component Cooling

ACOUSTIC BASED TACTICAL CONTROL OF UNDERWATER VEHICLES

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Advances in command and control of Autonomous Underwater Vehicles (AUVs) using acoustic communications are crucial to future Fleet objectives, particularly in Very Shallow Water Mine Countermeasures (VSW MCM). Understanding of the capability to redirect missions, provide relatively high rate downloads of mission information, and perform cooperative tracking for multi-vehicle systems is currently limited to some bounding data based on fixed node experiments, while the impact of working in the environment presented by a moving vehicle is not understood.

The main objectives of this dissertation were to investigate and demonstrate the capabilities of tactical acoustic control of a dynamic, operational underwater vehicle in the Very Shallow Water (VSW) ocean environment. This necessarily required studies on the limitations of Acoustic Control and relatively High Data Rate Transfer when using commercial acoustic modems in underwater vehicles, and an investigation of their acoustic transmission characteristics. Comprehensive empirical evidence through field validation with the *ARIES* vehicle indicated that reduced ranges were required for successful acoustic communications in a realistic very shallow water environment. Background noise, multipath reflections, and vehicle induced Doppler shifts all limit the communication link. Occasionally, configurations may be found where vehicle body shielding against multipath destructive interference can be used to advantage. A simulation was developed to demonstrate a solution for reducing the range and conducting multi-vehicle behaviors for cooperative tracking and acoustic communications data transfer.

KEYWORDS: Autonomous Underwater Vehicles, Acoustics, Acoustic Control, Acoustic Data Transfer, Modems