MASTER OF SCIENCE
IN
MECHANICAL ENGINEERING

A COMPARISON OF SHIP MANEUVERING CHARACTERISTICS FOR RUDDERS AND PODDED PROPULSORS

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A comparison of a high speed container ship using a rudder versus a podded propulsor is made to study replacing a rudder with a pod. A mathematical model is altered to simulate a ship operating with a rudder and with a pod to maneuver. The model incorporates the nonlinear maneuvering equations and couples the surge and sway forces, yaw and roll moment, and the roll angle induced during a steady turn with varying rudder and pod angles. The model uses the hydrodynamic derivatives and coefficients for a high speed container ship. The equations are numerically integrated in order to predict the roll angle, sway and surge velocities, and the ship's position in the xy-plane. Both transient and steady state results are utilized to quantify the relative efficiency of each system. The results are used as a preliminary study into replacing a rudder on a ship with a podded propulsor. The results indicate that the ship responds faster and has a shorter turning radius with the pod at lower initial speeds and pod angles, while the rudder responds better at high speeds regardless of angle. Further research is necessary to study the effects of changing the pod's position and increasing the number of pods used.

KEYWORDS: Surface Ship, Podded Propulsors, Rudders

NUMERICAL AND EXPERIMENTAL STUDY OF THE PERFORMANCE OF A DROP-SHAPED PIN FIN HEAT EXCHANGER

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This research presents the results of a combined numerical and experimental study of heat transfer and pressure drop behavior in a compact heat exchanger (CHE) designed with drop-shaped pin fins. A numerical study using ANSYS was first conducted to select the optimum pin shape and configuration for the CHE. This was followed by an experimental study to validate the numerical model.

The results indicate that the drop shaped pin fins yield a considerable improvement in heat transfer compared to circular pin fins for the same pressure drop characteristics. This improvement is mainly due to the increased wetted surface area of the drop pins, and the delay in the flow separation as it passes the more streamlined drop shaped pin fins. The data and conclusions of this study can be used in heat exchanger design for large heat flux cooling applications such as in gas turbine blades, and high-power electronics

KEYWORDS: Pin-fin Array, Compact Heat Exchanger, Drop-shaped Pin Fins, Heat Transfer, Pressure Drop, Micro Heat Exchanger, Turbine Blade Cooling, High Power Electronics Cooling

AN EXPERIMENTAL STUDY OF HIGH HEAT FLUX REMOVAL USING MICRO-DROPLET SPRAY COOLING

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Recent studies have shown that thermophotovoltaic (TPV) technology is a promising source of high power density generation. Enhanced TPV systems can theoretically provide power densities of up to 100 W/cm2. The inherent inefficiencies in the system dictate that up to 90% of that energy is not converted to electrical power, and must be removed as waste heat to ensure that the components are maintained at a reasonable operating temperature. The present study addresses this issue by investigating the suitability of using spray cooling techniques to remove heat generated by power densities of up to 100 W/cm2. A simple, scaleable experiment was designed using low-cost commercially available components to study the effects that spray mass flux and droplet size have on the heat removal capacity of the system. A series of nozzles were used so that mass flux and droplet size could be studied independently, giving high resolution to the data so that predictive correlations could be developed over the range of parameters varied in the study.

KEYWORDS: High Heat Flux, Spray Cooling, Nucleate Boiling, Critical Heat Flux

DAMPING IN STIFFENER WELDED STRUCTURES

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Damping of welded structures is a subject of great interest and application for the Navy as relates to ship shock survivability and acoustic transmission of ship noise. The purpose of this research is to study the effects of welding on damping. A generic model of a warship's hull structure was used to study damping effects. The model's natural frequencies and mode shapes were calculated using a finite element model prior to model testing. The frequency response and natural frequencies of the model were determined experimentally by exciting the model and measuring the response throughout the structure using Frequency Response Functions (FRF's). The results were compared with the finite element modeling. The damping ratio of the model in relation to position from excitation was calculated using the half-power point method and then a more detailed analysis of frequency dependent damping versus position was made using modal parameter extraction using the Complex Exponential Method.

KEYWORDS: Damping, Vibration, Welding

EFFECTS OF WELDING ON ENERGY DISSIPATION IN A WATERTIGHT BULKHEAD

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Surface combatants face a wide range of threats and perhaps the most destructive of these is the underwater explosion generated by a mine or a torpedo. The shock wave generated by an underwater explosion can cause severe damage or even a catastrophic failure. As the shock wave hits the ship, its energy is transmitted through the structural members of the ship. The purpose of this thesis is to examine how this energy is transmitted through the watertight bulkhead of a DDG and how the welded stiffeners affect the bulkhead's energy damping properties. To investigate the effects of the welding, the bulkhead was modeled both as a finite element model and as a scaled physical model. The modes and natural frequencies

of the bulkhead were first calculated using PATRAN and NASTRAN. Using a one half scale model, the bulkhead was excited using random noise over a 250 Hz frequency span, while measuring the accelerations at 60 points along the panel. These measured accelerations were then used to calculate the frequency response of the bulkhead and the damping ratios as a function of frequency. By plotting the damping ratios versus frequency for each measurement point on the bulkhead, there can be a better understanding of how energy waves propagate through a welded structure.

KEYWORDS: Damping, Rayleigh Damping, Weldment Effects, Modal Analysis, Complex Exponential Method

AN EXPERIMENTAL STUDY OF A PIN-FIN HEAT EXCHANGER

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A detailed experimental study has been carried out on the heat transfer and pressure drop characteristics of a compact heat exchanger with pin fins. A modular wind-tunnel with a rectangular cross-section duct-flow area was constructed that would accommodate the heat exchanger test section with varying pin designs. The flow in the tunnel was achieved through a suction-type blower, and a leading entrance length section was added to achieve predictable flow conditions into the heat exchanger test section. The rig was comprehensively instrumented to provide all desired thermal and flow data. The results from this study provide useful empirical data to validate ongoing numerical studies of such heat exchanger designs.

KEYWORDS: Compact Heat Exchanger, Experimental Study, Pin-fin Array

AUTOPILOT USING DIFFERENTIAL THRUST FOR *ARIES* AUTONOMOUS UNDERWATER VEHICLE

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Future underwater missions will require data transmission via satellite. In particular, the Office of Naval Research (ONR) is interested in experimenting with communications using the GOES satellite system, which is government owned. Unfortunately, communication antennas must point to specific satellites in this system, and thus underwater vehicles must steer a specific course on the surface during the communication process. While surfaced, underwater vehicles are subject to wind and wave disturbances and it has been suggested that control using differential thrust from propellers may provide advantages. This thesis covers efforts to create and test such a steering autopilot based on the use of the *ARIES* AUV and differing the voltage supplied to each propeller. It is planned to use the *ARIES* in an ocean experiment to test this satellite communication capability. This control is embedded in the control of *ARIES* during extended pop up maneuvers for GPS navigational fixes. When surfaced, not only are navigational fixes obtained, but also data packets are communicated to a command center.

KEYWORDS: Differential Thrust, AUV, Autonomous Underwater Vehicle, Autopilot

PREDICTION OF SURFACE SHIP RESPONSE TO SEVERE UNDERWATER EXPLOSIONS USING A VIRTUAL UNDERWATER SHOCK ENVIRONMENT

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During World War II, many surface combatants were severely crippled by close-proximity underwater explosions from ordnance that had actually missed their target. Since that time, in order to test the survivability of mission essential equipment in a severe shock environment, all new classes of combatants have been required to have shock trial tests conducted on the lead ship of the class. While these tests are extremely important in determining the vulnerabilities of a surface ship, they require an extensive amount of preparation, manhours, and money. Furthermore, these tests present an obvious danger to the crew onboard, the ship itself, and any marine life in the vicinity.

Creating a virtual shock environment by use of a computer to model the ship structure and the surrounding fluid presents a valuable design tool and an attractive alternative to these tests. This thesis examines the accuracy of shock simulation using the shock trials conducted on *USS WINSTON S. CHURCHILL* (DDG 81) in 2001. Specifically, all three explosions the DDG 81 was subjected to are simulated and the resulting predictions compared with actual shock trial data. The effects of the fluid volume size, mesh density, mesh quality, and shot location are investigated.

KEYWORDS: Underwater Explosion, Modeling and Simulation, Shock and Vibration, Ship Shock, Virtual Environment, UNDEX, Shock Measurement