MASTER OF SCIENCE
IN
APPLIED PHYSICS

DEVELOPMENT OF SHROUDED TURBOJET TO FORM A TURBORAMJET FOR FUTURE MISSILE APPLICATIONS

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Development of a shroud to form part of an afterburner for a turbo-ramjet engine which has a possible application for high speed long range missile applications. Research has been conducted on scram-jet engines with little or no emphasis on turbojet/ramjet combined cycle engines. With the possibility of the turbojet providing the thrust at subsonic conditions and the ramjet providing the thrust at supersonic conditions. A small turbojet engine, the Sophia J450, was evaluated experimentally and the results were compared to the prediction using an industry standard program with a perfect comparison over a wide operating range. In order to study possible turbo-ramjet configurations, a Sophia J450 turbojet engine was used with various shroud configurations, to compare static thrust and specific fuel consumption measured in a test rig. Shroud pressures were also recorded to determine the entrainment rate of the ducts. The short shroud results were found to produce the best performance of the three configurations tested. The performance improvements were more significant at lower engine spool speeds that produced a sharp increase in secondary entrainment pressure.

A conical supersonic intake was designed for combined cycle engine at a Mach 2 flight condition resulting in a near optimum cone angle of 15 (deg) to be tested in the new free jet facility. The flight envelope of the baseline engine was also determined over a wide range of flight speeds and operating altitudes.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Micro-Turbojet, GASTURB, Engine Shroud, Turboramjet, Sophia J450, Microturbine Performance

AMPLITUDE AND TEMPORAL JITTER ASSOCIATED WITH THE NPS ACTIVE MODE-LOCKED SIGMA LASER

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Electro-optic techniques for analog-to-digital conversion (ADC) are being developed for wideband signal collection and analysis. They have the capability of being used for direct signal reception and ADC at an antenna. A fundamental requirement for these designs is a high-frequency optical pulse train with uniform amplitude and pulse spacing. A mode-locked fiber laser can provide pulse rates and pulsewidths suitable for these high bandwidth applications. In this thesis an accurate method for calculating and characterizing both the amplitude and timing jitters of the NPS active mode-locked sigma laser was designed and demonstrated. The method utilizes a wide bandwidth photodetector and a microwave spectrum analyzer to

obtain data for analysis. Labview 4.0 software was used to extract and store the data displayed on the spectrum analyzer. Matlab 5.1 software was then used to analyze the Labview data and to perform calculations for the amplitude and temporal jitter. Measurements were made for a microwave sweep oscillator and a cw generator, then again with the fiber laser operating with each signal source. Final measurements were taken with variable laser diode pump powers by varying the controller currents. Results show that the calculation of the laser jitter is not dependent on the upper limit of the noise power integral calculation above 10 kHz; however, the jitter is highly dependent on the value of the lower frequency limit and decreases dramatically as the lower limit is increased. Laser amplitude jitter was found to decrease by 30% and timing jitter by 0.85 ps when the laser was operated with the cw generator instead of the sweep oscillator. Also, it was found that as pump power was increased, laser timing jitter decreased.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Mode-Locked Laser, Sigma Laser, Amplitude Jitter, Temporal Jitter

EFFECTS OF SHIPBOARD COMPARTMENT FUEL FIRE AND FIRE EXTINGUISHING ON RF SIGNAL PROPAGATION IN THE 2.4 GHz ISM BAND

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The objective of this research was to quantify the effects of fuel fire and the follow-on fire extinguishing actions on wireless shipboard communications in the 2.4 GHz ISM band. Directional and non-directional antennas with horizontal and vertical polarization, and a PC-controlled scalar network analyzer, were used onboard ex-USS SHADWELL to measure the attenuation of 2.4 - 2.485 GHz signals transmitted through diesel and heptane fire, water mist created by the fire extinguishing system, and subsequently developed steam. A MATLAB code has been used to analyze the data statistically.

The attenuation for directional antennas exhibits relatively small variations with time and frequency, but fire and the follow-on fire-extinguishing phases create severe non-stationary frequency selective fading for non-directional antennas. Therefore standard communication techniques effective against frequency selective fading (non-stationary but slowly varying with time) are recommended for use with communication systems intended for shipboard indoors use. Even in normal conditions, without fire, water mist, or steam, it was determined that frequency selective fading would be a problem for non-directional antennas used in shipboard compartments and thus a system with anti-fading capability should be considered for shipboard use.

DoD KEY TECHNOLOGY AREA: Other (Shipboard Wireless Communications)

KEYWORDS: Instrumentation Scientific Medical (ISM) Band, Radio Frequency (RF) Propagation, Attenuation, Fire Extinguishing System, Plasma, MATLAB

DESIGN, CONSTRUCTION, AND OPERATION OF AN ELECTROMAGNETIC RAIL GUN TEST BENCH

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For over two decades, the United States Army has conducted research in the field of electromagnetic launch railguns. With the advent of electric propulsion ships, the Navy is now considering the use of electric power to launch projectiles in support of maritime land attack. Bore wear is the most significant challenge for a naval railgun program. The interface between the armature and rails is the most stressed point of a railgun because it transitions to liquid under high current densities. This liquid interface causes rail and projectile material to redistribute unevenly and produces rail degradation. The focus of this thesis is to test different interface materials to minimize damage to the rail and armature during firing. A railgun test bench with a 4-inch long rail was designed, constructed, and operated to investigate rail wear and rail-armature interface dynamics. Various combinations of tungsten, copper, and silver alloys were tested for rail and armature materials. The least degradation of rail and projectile was observed with a silver-tungsten projectile and copper-tungsten rails: 10% loss in projectile mass for a current density of approximately 200 kA/cm^2. Indium at the interface protected the rails and projectile from damage at current densities under 45 kA/cm^2.

DoD KEY TECHNOLOGY AREAS: Conventional Weapons, Directed Energy Weapons

KEYWORDS: Electromagnetic Railgun, Electromagnetic Launch, EML Rail/Armature Interface

EXPERIMENTAL INVESTIGATION OF SINKING A BUOYANT BODY IN WATER WITH BUBBLES

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The introduction of gas bubbles into a liquid decreases the average density, and thus decreases the buoyant force on a floating body. This thesis investigates the critical average density required to sink a buoyant body in water with rising bubbles. A volume of bubbly water is created in a clear acrylic tube of inner diameter 30 cm and height 60 cm, that is closed at the bottom and open at the top. An array of diffusers at the bottom produces 2 mm diameter bubbles that are uniform over the cross section of the tube. A 10-cm diameter hollow steel ball whose average density is varied from 0.70 to 0.99 g/cm^3 is employed as the buoyant body. A theory of the critical density for sinking is developed, and predicts that the average fluid density is greater than the ball density for sinking. The experimental data, which include a quantitative error analysis, agree well with the theory for average ball densities from 0.94 to 0.99 g/cm^3, but show a definite trend of fluid densities that are smaller than those predicted for ball densities varying from 0.70 to 0.94 g/cm^3.

DoD KEY TECHNOLOGY AREA: Other (Fluid Dynamics)

KEYWORDS: Water, Density, Specific Gravity, Volume Fraction, Bubbles, Buoyancy, Nonnewtonian Fluid

INFLUENCE OF IGNITION ENERGY, IGNITION LOCATION, AND STOICHIOMETRY ON THE DEFLAGRATION-TO-DETONATION DISTANCE IN A PULSE DETONATION ENGINE

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The feasibility of utilizing detonations for air-breathing propulsion is the subject of a significant research effort headed by the Office of Naval Research. Pulse Detonation Engines (PDE) have a theoretically greater efficiency than current combustion cycles. However, pulse detonation technology must mature beginning with research in the fundamental process of developing a detonation wave. This thesis explores various ignition conditions which minimize the deflagration-to-detonation transition distance (X_{DDT}) of a single detonation wave in a gaseous mixture.

Specifically, the minimum X_{DDT} was determined for different Ethylene and Oxygen/Nitrogen gaseous mixtures under varying ignition energy (0.33-8.31 Joules), mixture equivalence ratios (0.6-2.0), and ignitor locations. To conduct the experiments a 6 feet long, 3 inch diameter tube combustor, support equipment, and operating software was built. Four independent test scenarios were investigated and trends developed to determine the minimum X_{DDT} while reducing oxidizer blend ratios.

Results show that X_{DDT} significantly depends on mixture equivalence ratio (φ) and was minimized at φ ● 1.1. No dependence on ignition energies greater than 0.5 Joules was observed. A further reduction in X_{DDT} was observed with the ignitor located one combustor diameter from the head wall. These results will be useful in future designs of pre-detonators for larger PDEs.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Detonation, Pulse Detonation Engine, Deflagration-to-Detonation Transition, DDT

MEASUREMENT OF FUEL ADDITIVE EFFECTS ON THE SOOT MASS LOADING IN OXYGEN/KEROSENE EXHAUST PLUMES

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Measurements of the soot mass loading in the exhaust of a small liquid rocket engine burning gaseous oxygen with kerosene and kerosene with additive mixtures have been made. The rocket engine was operated over a high soot-producing regime, to simulate the film-cooling region of an actual system, which covered an oxygen-to-fuel ratio (O/F) range of 0.6 to 1.3 and produced a nearly uniform plume distribution. Using a dual fuel tank system, the fuel source was switched during the runs to allow both kerosene and kerosene with additive measurements to be conducted during the same run to ensure nearly identical engine operating conditions. A multi-wavelength optical transmission technique was used to determine the amount of soot present and utilized the transmission ratio of six wavelengths from the near UV to the visible through the plume of the engine. The experimental technique was analyzed to determine the potential error introduced when the transmission values were extremely low (<5%) and what potential effect any organic absorbers (PAHs) may have had on the transmission ratios for the near UV wavelengths. Experimental results show that the addition of as little as 1% by mass of an additive can significantly reduce the amount of soot present in the engine exhaust, and therefore alter the associated IR radiation from the plume.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Soot Measurement, Kerosene/Oxygen Liquid Rocket Engines, Additive Effects

MAGNETIC FIELD-INDUCED ABSORPTION OF SHORT ULTRA-INTENSE LASER PULSES

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Self-generated magnetic fields up to 10^9 Gauss have been predicted in overdense plasmas irradiated with ultra-intense laser light pulses. It was found that the laser absorption can be significantly enhanced by the oscillation of electrons across these fields. There is then a very large Lorentz force, which can strongly accelerate electrons into the plasma and can lead to generation of harmonics in the reflected light. It was shown that large magnetic fields can be significantly amplified to even larger values by the pressure of the light pulse. Potential applications are discussed. All data used in the simulations was unclassified.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Lasers)

KEYWORDS: Laser, Plasma, Ultra-Short Ultra-Intense Laser Pulses, Magnetic Fields