MASTER OF SCIENCE
IN
MECHANICAL ENGINEERING

ANALYSIS OF THE SENSITIVITY OF MULTI-STAGE AXIAL COMPRESSORS TO FOULING AT VARIOUS STAGES

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This thesis presents a simple, meanline analysis of the impact of blade roughness on the mass flow, work coefficient, and efficiency of a three-stage axial compressor as a function of the location of fouling. First, an extensive review is presented on the state-of-the-art of measuring compressor degradation and on the impact of roughness on loss and deviation in a compressor cascade. The performance of a baseline, three-stage compressor, which has hydrodynamically smooth blades, is predicted. Using this baseline geometry, the influence of roughness in the front, middle and rear stages is calculated using empirical data for the enhanced losses and increased deviation, with a stage stacking technique. Influence coefficients that relate percentage changes in one parameter to percentage changes in other parameters are calculated. This analysis predicts that the most sensitive parameter for predicting fouling in the front stages is the percentage change in mass flow and the most sensitive parameter for predicting fouling in the rear stages is the efficiency.

KEYWORDS: Gas Turbine, Compressor, Roughness, Fouling, Detection, Localization, Condition-Based-Maintenance

EXPERIMENTAL STUDIES OF WELDING EFFECTS ON DAMPING FOR UNDERSEA WARFARE APPLICATIONS

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Damping in structures has historically been of great importance in nearly all branches of engineering endeavors, and it also happens to be one of the most difficult parameters to predict. The purpose of this research is to study the effects that welding has on damping. Measurements and comparisons of the damping ratios of two welded stiffened plates, two flat plates and one machined stiffened plate are undertaken. The frequency response and natural frequencies of five steel structures are determined experimentally. A finite element model is created for three of the structures to determine the natural frequencies and associated mode shapes. The damping ratios are then determined using the half-power point method.

The results show that at frequencies less than 500 Hz, welding tends to cause the damping ratio to increase. The experimental and numerical results show that the mode shapes that experience the highest degree of stress at a weld are associated with the natural frequencies with the highest damping ratio. These results may lend to better understanding of the effects of welding on damping and assist in obtaining better empirical approximations of damping for use in ship shock computer simulations.

KEYWORDS: Vibrations, Welding, Damping

MICROSTRUCTURE CHARACTERIZATION OF FRICTION-STIR PROCESSED NICKEL-ALUMINUM BRONZE THROUGH ORIENTATION IMAGING MICROSCOPY

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The effect of friction-stir processing (FSP) on the microstructure of a cast nickel-aluminum bronze (NAB) material has been characterized by various micro-analytical methods including orientation imaging microscopy (OIM). Cast NAB is widely utilized in the production of propellers for the surface ships and submarines of the U.S. Navy due to excellent corrosion-resistance. New applications require improved mechanical properties that may be attainable using FSP to achieve localized microstructure modification. Friction between a rotating tool and the surface of the material results in a "stirring" action that, in turn, produces adiabatic heating and local softening of the material. The tool rotation results in very large shear deformations in the softened regions and thus microstructure refinement and homogenization; in effect FSP may convert an as-cast microstructure to a wrought condition in the absence of macroscopic shape change. In as-cast material, results of optical and scanning electron microscopy (using energy dispersive analysis) show an a (FCC) matrix containing globular and particulate dispersions that correspond to the $?_I$, $?_{II}$ and $?_{IV}$ second phases; these represent various morphologies of the Fe_3Al intermetallic compound, which has a $D0_3$ structure. Also present are lamellar particles of $?_{III}$, which is NiAl and has a B2 structure. The grain size in the a matrix is ~ 1 mm. In OIM, the microtexture and microstructure in the a (FCC) matrix may be readily obtained and analyzed. However, interatom distances in the Fe_3Al and NiAl phases differ by only about one percent and so these phases are not distinguishable from one another during OIM. Altogether, microstructure and microtexture analysis showed that there are several regions in the thermomechanically-affected zone (TMAZ) of a material subjected to FSP. From base material inward toward the TMAZ, these include: annealing effects in undeformed base material; a region just inside the TMAZ in which grain deformation and C-type shear deformation textures are observed; regions of highly refined and recrystallized grains further inside the TMAZ, wherein the grain size is < 5μm; and, finally, regions of elongated, banded and twinned grain structures that suggest grain growth following recrystallization.

KEYWORDS: Nickel Aluminum Bronze, Friction Stir Processing, Orientation Imaging Microscopy, Electron Backscatter Diffraction, Energy Dispersive Spectroscopy, Optical Microscopy, Thermomechanically-Affected Zone, Shear Deformation

CLOSE-PROXIMITY VESSEL TOWING IN SIX DEGREE-OF-FREEDOM MOTIONS IN SHORT CRESTED SEAS

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The scope of this thesis is to investigate the vertical and horizontal plane motions of surface ships in close proximity towing in irregular waves. Strip theory calculations have been utilized in order to predict the hydrodynamic coefficients and wave exciting forces and moments in sway and yaw, heave and pitch. The appropriate matching conditions between the two ships are provided in terms of the resistance-speed characteristics of the leading ship. The two-parameter Bretschneider spectrum with a cosine-squared spreading function is used to model the sea state environment. An extensive set of parametric studies is presented in a wide variety of developing and decaying sea states.

KEYWORDS: Close-Proximity Towing, Ocean Waves, Hydrostatics, Hydrodynamics, Ship Response, Wave Spectra, Slice, Kaimalino, SWATH, Bretschneider

NANOMECHANICS MODEL FOR STATIC EQUILIBRIUM

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This study presented a computational technique to model and simulate atomistic behavior of materials under static loads. Interatomic potential energy was used to maintain equilibrium among atoms under static loads and constraints. In addition, the atomistic model was coupled with the finite element analysis model so that more flexible loads and constraints could be applied to the atomis tic model. A multi-scale technique was also presented for some single wall nanotubes of both zigzag and armchair and then their effective stiffness were estimated. Those designed nanotubes are woven into fabric composites, which can be used in various military applications including body armors, armored vehicles, and infantry transportation vehicles because advanced nano-composites could be much lighter and stronger than current ones. Some example problems were presented to illustrate the developed technique for the nano-composites and SWNTs. The proposed technique for nanomechanics can be used for design and analysis of materials at the atomic or molecular level.

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KEYWORDS: Nanomechanics, Nanocomposite, Atomistic Model, Molecular Dynamics, Finite Element Analysis, Static Equilibrium, Multi-Scale Technique

STUDY OF PROCESSING AND MICROSTRUCTURE OF A SUPERPLASTIC 5083 ALUMINUM ALLOY

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Orientation Imaging Microscopy (OIM) methods were applied to the analysis of the microstructure and microtexture as well as the deformation and failure modes of superplastic AA5083 aluminum alloys. Annealing of a cold-rolled AA5083 material at 450ºC resulted in the formation of equiaxed grains approximately 7µm – 8µm in size. Random grain-to-grain misorientations were consistent with particle-stimulated nucleation of recrystallization during processing for superplasticity. Such a microstructure is necessary for superplasticity but mechanical property data indicated only moderate ductility and failure by cavity formation and linkage. This investigation then employed OIM methods to identify the misorientations of boundaries prone to cavitation and determine the role of such boundaries in failure of these materials during elevated temperature deformation.

KEYWORDS: Orientation Imaging Microscopy, Superplasticity, Recrystallization, Deformation Mechanisms, Grain Boundary Sliding, Dislocation Creep, Cavitation

PARAMETER OPTIMIZATION OF SEISMIC ISOLATOR MODELS USING RECURSIVE BLOCK-BY-BLOCK NONLINEAR TRANSIENT STRUCTURAL SYNTHESIS

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In order to increase building safety under earthquake motions, there has been increasing interest in base isolation with passive isolators. Computer modeling is an important aspect of the building design and evaluation process, but solving for the transient response of large structural systems with localized nonlinearities is computationally demanding. Current finite element programs can rapidly determine normalized mode shapes and natural frequencies of several thousand degree of freedom structures for use

in determining the transient response. However, actual computation of the transient response can be very time-consuming and expensive for such large structures. A recently developed convolution algorithm utilizes the Volterra integral in a recursive block-by-block integral equation formulation to efficiently compute the transient response of multi-story, nonlinear, base isolated buildings. This algorithm was utilized in a versatile optimization scheme which determines parameters for both linear and nonlinear mathematical model isolators coupled to a multi-degree of freedom structure. To optimize the isolator parameters, the procedure incorporates modal properties computed from a finite element model of the structure, the earthquake accelogram of interest, and user-defined objective and constraint functions. An example is given of a 4-story, single bay structure subjected to the 1940 El Centro NS excitation.

KEYWORDS: Nonlinear Transient, Structural Synthesis, Seismic Isolator Models, Base Isolation