College of Engineering

TENNESSEE TECH

The Department of

Mechanical Engineering

Announces the Thesis Defense

of

Drew Winder

In Partial Fulfillment of the Requirements

For the degree of

Doctor of Philosophy in Engineering

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Tennessee Tech University

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FIELD OF STUDY

Mechanical Engineering

Dissertation Topic

Modeling Improvements of a Liquid Metal and Gas Filled Container Struck by a Sudden Pressure

EXAMINING COMMITTEE

Dr. Sally Pardue (Chairperson)
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ABSTRACT

Scientific research often requires facilities and apparatuses which push the boundaries of engineering capabilities. The Spallation Neutron Source's target system at the Oak Ridge National Laboratory receives short, intense bursts of protons into mercury target material to produce neutrons. The pulses arrive multiple times each second. The energy deposited leads to cyclic loads on the target module structure, which has led to premature failure and interruptions to scientific productivity. Mixing helium gas with the mercury has been shown to reduce the loads on the structure. However, this also increased the difficulty in predicting the loads imparted on the structure. Knowledge of the structural loading is critical to predicting and improving target module lifetime and reliability.

A material model was developed to address this challenge, which improved over the current modeling approaches by incorporating volume and pressure coupling between liquid and gas bubbles through known bubble equations. The model was implemented into a user-defined material subroutine suitable for dynamic simulations of the fluid-structure interactions. The subroutine was verified at the lowest level of complexity by comparing results from the subroutine to commercial differential equation solvers. Higher levels of complexity were first approached by examining the sensitivity of the predicted strain of the structure to the model and simulation parameters.

An initial validation effort was performed using experimental data from proton pulse experiments on flowing mercury and helium mixtures made by various bubble generating devices. Experimental conditions were replicated numerically, including measured bubble size distributions. Improvements were made to the model to increase its utility and reduce its computational costs. The computational costs ranged from equivalent to the previous modeling approach to twelve times higher depending on the bubble size distribution. The model improved over current modeling approaches by improving the fit between the measured strains on the structure containing the fluid.

BIOGRAPHICAL SKETCH

Drew E. Winder was born and raised in the eastern valley of Tennessee. He attended the University of Tennessee-Knoxville and received a Bachelor of Science in Mechanical Engineering in 2004. While working at the Bettis Atomic Power Laboratory and then the Y-12 National Security Complex, he attended the Georgia Institute of Technology and received a Master of Science in Mechanical Engineering in 2011. He became a registered Professional Engineer in 2012. In 2014, he joined the Oak Ridge National Laboratory.

EDUCATION

Ph. D. Engineering
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M.S. Mechanical Engineering
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