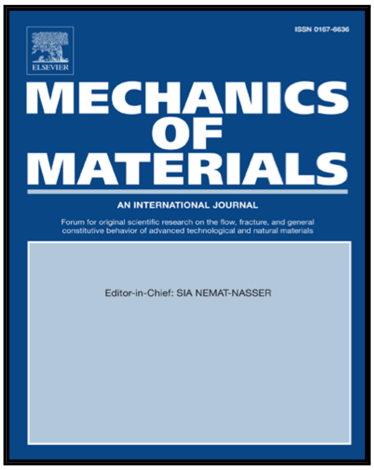
Accepted Manuscript



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PII: S0167-6636(16)30415-X
DOI: 10.1016/j.mechmat.2016.12.004
Reference: MECMAT 2682

To appear in: *Mechanics of Materials*

Received date: 21 October 2016
Revised date: 1 December 2016
Accepted date: 16 December 2016

Please cite this article as: Helio Matos , Sachin Gupta , Arun Shukla , Structural Instability and Water Hammer Signatures from Shock-Initiated Implosions in Confining Environments, *Mechanics of Materials* (2017), doi: 10.1016/j.mechmat.2016.12.004

Structural Instability and Water Hammer Signatures from Shock-Initiated Implosions in Confining Environments

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ABSTRACT

An experimental study is conducted to investigate the dynamic response and instability of cylindrical structures subjected to hydrostatic pressure in conjunction with explosive loading. Full-field displacements/velocities, and localized pressures, of imploding aluminum structures within a confining environment are captured during the experiments. Also, polyurea coatings of 1:1 volume ratios are evaluated as a possible energy mitigation technique. Two high-speed cameras are used to capture the imploding structures while various dynamic pressure transducers measure the emitted pressure pulses. The specimens are confined inside a thick-walled cylindrical structure that had one end open to the hydrostatic pressure inside the pressure vessel and the other end closed. This confinement configuration generates a water hammer at the closed end of the confinement. The results of these experiments indicate that after the collapse, pressure profiles of hydrostatic and explosive initiated implosions are about the same. Moreover, the energy from the implosion's high-pressure pulses, present at the confinement's closed end, was greater than the energy of the explosive itself due to the water hammer effect. The polyurea coatings used in this study caused a sufficient phase shift in the implosion pressures such that the hammer and implosion high-pressure pulses were not superimposed; thus, the maximum pressures and energy after the implosion was reduced. However, the polyurea coatings did not significantly mitigate neither the hammer nor the implosion pressures individually. Finally, a non-linear Riks model from ABAQUS was used to show that the energy input requirement for dynamic-initiated implosions decreases rapidly as initial hydrostatic pressure increases.
KEYWORDS: Implosion, water hammer, instability, shock, digital image correlation, polyurea coating

1. Introduction

In this study, an experimental investigation is conducted to evaluate the implosion pressure pulses, water hammer waves, and their mitigation in a confined environment while subjected to shock loadings. This research arises from the concern of damage to naval and marine structures such as underwater pipelines, submarines, and autonomous underwater vehicles (AUVs). When these structures are submerged deep underwater and experience high hydrostatic pressures, they can instantaneously collapse inward and release strong propagating shockwaves in a process known as implosion [1-5]. In a confining environment, the implosion's pressure waves and any induced particle velocity can interact with its surroundings leading to a water hammer wave that is even stronger and more destructive than the implosion's pressure waves. Previous work shows the water hammer pressures reaching values of 150-200% the implosion's peak pressures [6-8].

Implosion has been of interest to the marine community since the mid-1900s [3-5]. However, one key accident that renewed the interest in this topic was the 2001 Super-Kamiokande laboratory accident in Japan where one photomultiplier tube imploded, and the pressure pulses from this implosion caused adjacent tubes to implode; leading to a chain reaction that destroyed