STUDY OF THE BEHAVIOUR OF MULTI-METALLIC SYSTEMS UNDER HIGH-VELOCITY IMPACT LOADS

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Degree of Master of Science

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October 2023

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Declaration of the Candidate and Supervisor

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The above candidate has carried out research for the Master's thesis under my supervision.

Name of the supervisor: Dr. Lakshitha Fernando

Signature of the supervisor: Date: 26/01/2024

Acknowledgments

First and foremost, I would like to express my sincere gratitude to my research supervisor, Dr. Lakshitha Fernando, for providing me the opportunity to do research under his invaluable guidance throughout. Without his support, this would have not been possible.

I would like to say my special thanks to Dr. Hasitha Damruwan for the valuable comments during the progress reviews which inspired me to think out of the box.

In addition, I would like to acknowledge all academic staff members of the Department of Civil Engineering, for their constant support throughout.

I would like to show my gratitude for the financial assistance provided by the Structural Engineering Division, University of Moratuwa.

Finally, and most importantly, I am thankful to my family and friends for their constant source of inspiration and moral support.

Abstract

The behavior of multi-material layered systems under high-velocity impact loads, such as impact and blast scenarios, has gained significant attention from researchers over the past years due to its extensive applications in the automobile and aerospace industries, and ballistic armor and blast resilient structures. The focus is being shifted to multi-material systems over monolithic systems due to their superior characteristics in stress attenuation and energy absorption, and high preference for lightweight structures.

In this research, an attempt has been made to investigate the impact-induced stress wave propagation through a multi-metallic layered system that is subjected to high-velocity impact loads. This study consists of two major components. 1) Elastic wave propagation and 2) Shock wave propagation. For the elastic wave propagation, four different test cases including a steel monolithic target, steel-titanium and steel-aluminium bi-metallic targets, and a steel-titanium-aluminium tri-metallic target, were considered. They were subjected to a low-velocity (180 ms^{-1}) impact where only elastic waves are anticipated to be generated in the target. For shock wave propagation, only a steel monolithic target was considered which was subjected to an impact velocity of 350 ms^{-1}. For both cases, numerical and analytical frameworks were developed to simulate the material response. The LS-DYNA finite element package was used to develop two-dimensional axisymmetric numerical models, and it was validated against the existing experimental results obtained from a single-stage gas gun test which were in good agreement.

The analytical models which were the main focus of the present research were implemented in MATLAB which monitors and resolves the interaction of each propagation wave and then provides the overall response of the flyer-target system. The analytical model was validated against the results obtained from the validated numerical models considering stress-time histories.

The outputs acquired from the analytical model for elastic wave propagation agree with that of the numerical model with reasonable accuracy. However, the developed analytical model for shock wave propagation gives reasonable results only up to the separation of the flyer and multi-material target where a significant variation can be identified between results after the separation. The developed models can be used to

find the most optimum configuration in terms of stress attenuation for a given set of metallic materials which reduces the time and cost associated with high-velocity impact tests. Also, they can be used to find the required bonding strength to avoid debonding at material interfaces that cannot be obtained from experiments.

Keywords: elastic waves, shock waves, multi-metallic, numerical modeling, wave interaction, analytical modeling

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List of Abbreviations

Abbreviation	**Description**
EOS	Equation Of State
HEL	Hugoniot Elastic Limit
FEM	Finite Element Modeling
SPH	Smooth Particle Hydrodynamics
PDV	Photonic Doppler Velocimetry
CFRP	Carbon Fibre Reinforced Polymer

List of Symbols

Symbol	Description
σ_H	Hydrostatic stress
$\sigma_{11}, \sigma_{22}, \sigma_{33}$	Principal stresses
$\sigma_{12}, \sigma_{21}, \sigma_{13}, \sigma_{31}, \sigma_{23}, \sigma_{32}$	Inplane shear stresses
A	Yield stress
B	Strain hardening constant
n	Strain hardening coefficient
C*	Strengthening coefficient of strain rate
m	Thermal softening coefficient
T	Temperature in Kelvin degrees
σ	Stress
ε	Strain
C_B	Bulk sound speed
S1	Hugoniot slope coefficient
S2, S3	Higher order Hugoniot slope coefficients
υ	Poisson's ratio
Y_d	Dynamic yield strength
ρ	Mass density
V	Particle velocity
U	Shock velocity
e	Specific internal energy
E	Young's modulus
C	Elastic wave velocity