UNIVERSITY OF DELAWARE

STRESS WAVE PROPAGATION IN MULTILAYER MATERIALS

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OBJECTIVES

- To develop understanding of stress wave effects in multi-layer materials and develop predictive capability
- To investigate how useful the SHPB, and possible experiments derivative from it
- To provide experimental data to validate finite element models

SHPB is a convenient tool for high strain rate testing

Direct interpretation of SHPB data is not possible for materials which are non-linear, or of very low or very high impedance relative to the bars, or anisotropic, or composed of several layers of distinctly different materials. An example of such materials is composite integrated armor.

Development of such multi-layer materials must be guided by synergistic modeling and experimental efforts since simple analytical descriptions such as 'conventional stress vs. strain curves' are meaningless in these cases, particularly at high strain rate.

ACKNOWLEDGEMENTS

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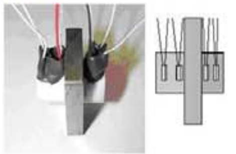
MATERIALS

- ceramic only
- composite only
- ceramic/composite
- ceramic/rubber/composite

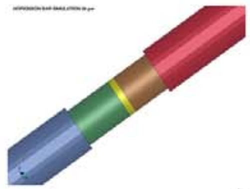


13.96 mm thick alumina ceramic
1.5 mm thick layer of EPDM rubber
11.3 mm thick S2 glass fiber woven fabric composite plates

Lateral confinement of the rubber interlayer was obtained by placing a 6 mm wide steel retaining ring around the junction of the sample

Samples were fitted with strain gages so as to monitor real-time strains (and stresses) during the course of the tests, most importantly the high strain rate tests where wave propagation effects were to be investigated.

NUMERICAL MODEL

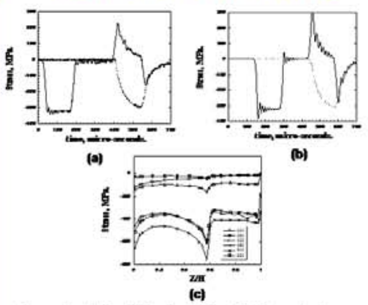


LS-DYNA 960
Surface to Surface Contact
Mat_Elastic for Bars
Mesh Biasing

Bar Length – 152.4 cm
Length – 400 elements
Initial Velocity BC for Striker Bar
Two axes of symmetry

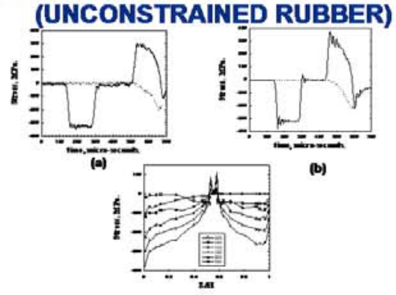
Material	Modulus of Elasticity (GPa)	Poisson's Ratio	Density (kg/m3)	Other
Ceramic	370	0.22	3900	-
Mooney-Rivlin Rubber	-	0.495	1200	A: =0.2, B: =0.8 (MPa)
Blatz-Ko Rubber	-	0.493	1200	G: 20 MPa
Composite	E1: 40 E2: 40 E3: 15	ν_{21} : 0.12 ν_{31} : 0.173 ν_{32} : 0.173	1668	G1: 8 (GPa) G2: 8 (GPa) G3: 8 (GPa)
Inconel	207	0.3	7850	

CERAMIC/COMPOSITE



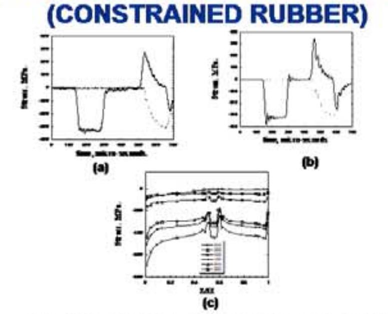
a) experimental and b) calculated output from strain gages on the incident and transmitter bars
c) stress-distance-time plot

CERAMIC/RUBBER/COMPOSITE (UNCONSTRAINED RUBBER)



a) experimental and b) calculated output from strain gages on the incident and transmitter bars
c) stress-distance-time plot
(unconstrained rubber interlayer)

CERAMIC/RUBBER/COMPOSITE (CONSTRAINED RUBBER)



a) experimental and b) calculated output from strain gages on the incident and transmitter bars
c) stress-distance-time plot
(constrained rubber interlayer)

CONCLUSIONS

1. The present work has demonstrated the feasibility of modeling stress wave propagation in complex multi-layer materials.
2. It has been shown that the effects of confinement of normally low modulus materials can significantly affect their response to wave propagation.
3. Severe stress inhomogeneities and discontinuities may exist in multi-layer materials and these may have serious consequences for the mechanical and other properties.
4. Numerical modeling clearly shows that during Hopkinson bar testing of multilayer materials, stress is not distributed uniformly inside the specimen. Even for the single layer material, simulations show the non-uniform stress distribution along both axial and radial directions.
5. The one dimensional stress state usually assumed for conventional SHPB testing is questionable and for a complete understanding of the wave propagation both numerical and experimental results have to be coupled.
6. In this study, both methods were used and the stress state inside the components were presented. Accuracy can be increased, especially for the high pressure levels, by implementing damage parameters in material models.