DATA REDUCTION IN SPLIT HOPKINSON PRESSURE BAR (SHPB): A NEW APPROACH

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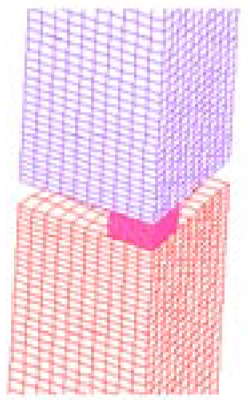
BACKGROUND

Split Hopkinson Pressure Bar (SHPB)

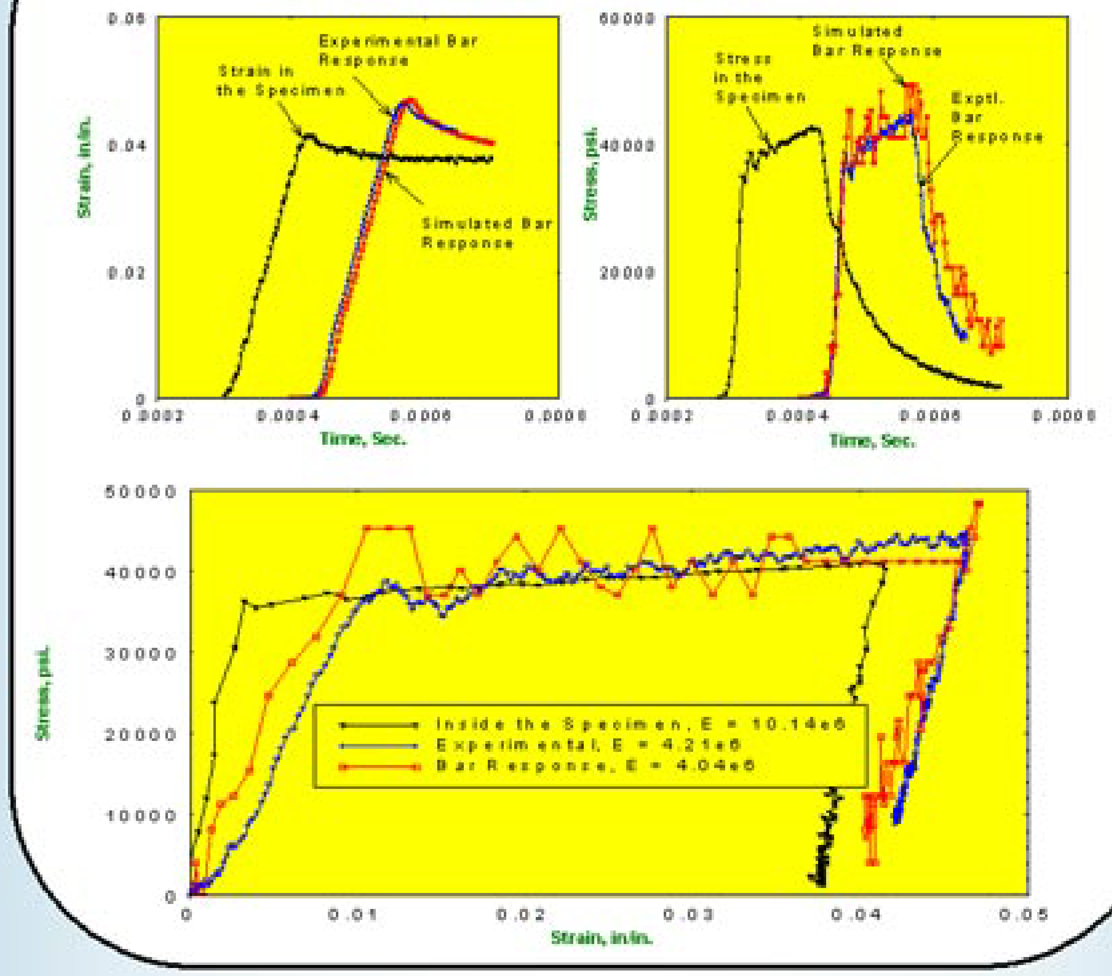


Finite Element Model of SHPB

- The High Strain Rate Stress-Strain Response Using Classical SHPB Data Reduction Shows that the Measured Modulus is Less than its Quasi-Static Value
- THIS LED US TO DO SOME BASELINE SHPB EXPERIMENT AND NUMERICAL SIMULATION
- The Strain Measured from Experimental and Incident Bar Response Correlates Well with the Numerical Simulation
- However, the Strain in the Specimen as Obtained from Numerical Simulation is Much Different than that Calculated Using Classical SHPB Data Reduction Scheme
- The Specimen Effective Stress Measured from Transmitted Bar, However, Correlates Well with the Numerical Simulation

THE CLASSICAL SHPB DATA REDUCTION SCHEME IS REVISITED AND A NEW DATA REDUCTION APPROACH IS PRESENTED

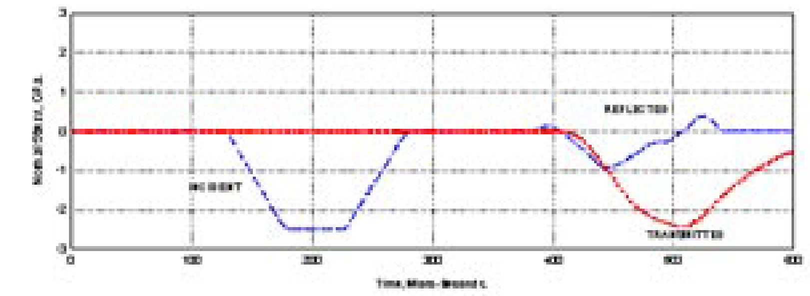
SHPB EXPERIMENT AND LS-DYNA SIMULATION OF ELASTIC-PLASTIC ALUMINUM



ASSUMPTIONS IN CLASSICAL SHPB DATA REDUCTION SCHEME

- Requires 3-4 Reflections in the Specimen to Reach Force Equilibrium
- Force Equilibrium can be Expressed as THUS $\varepsilon_I(t) + \varepsilon_R(t) = \varepsilon_T(t)$
- Average Specimen Strain $\bar{\varepsilon}_{Classic}(t) = -\dfrac{2C_B}{H_S}\int_0^t \varepsilon_R(t)dt$
- Average Specimen Stress $\bar{\sigma}_{Classic}(t) = \dfrac{E_B A_B}{A_S}\varepsilon_T(t)$

EXAMPLE: Lets Suggest that $\rho_S C_S > \rho_B C_B$



Simulated Aluminum Bars with Steel Specimen

- Classical Data Reduction Scheme will Predict Average Expansion of Specimen, Because Measured Strain is Positive in terms of Reflected Strain Pulse, thus Calculated Specimen Modulus will be Negative

AN EXACT THEORY FOR ONE-DIMENSIONAL LINEAR SYSTEM

- Dynamic Force Equilibrium

$$\varepsilon_I(t) + \varepsilon_R(t) - \varepsilon_T(t) = K(r)\varepsilon_R(t)$$

$$K(r) = \frac{1}{2}\frac{(1+r)^2}{r} \qquad r = \frac{\rho_S C_S - \rho_B C_B}{\rho_S C_S + \rho_B C_B}$$

- Average Specimen Strain

$$\bar{\varepsilon}(t) = \frac{(1-r)^2}{4r}\frac{2C_B}{H_S}\int_0^t \varepsilon_R(t)dt$$

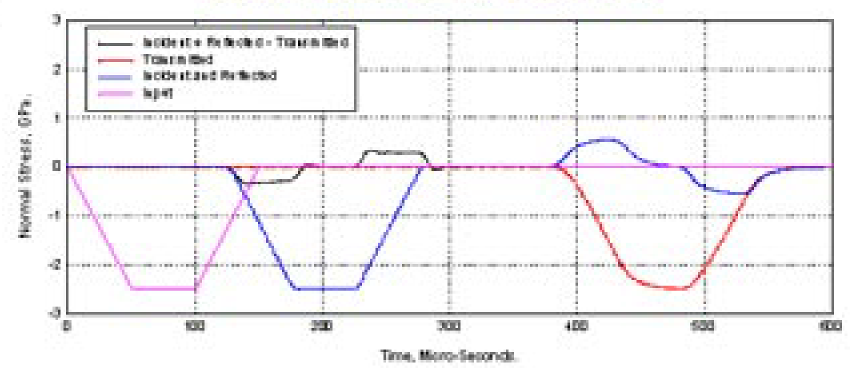
- Average Specimen Stress

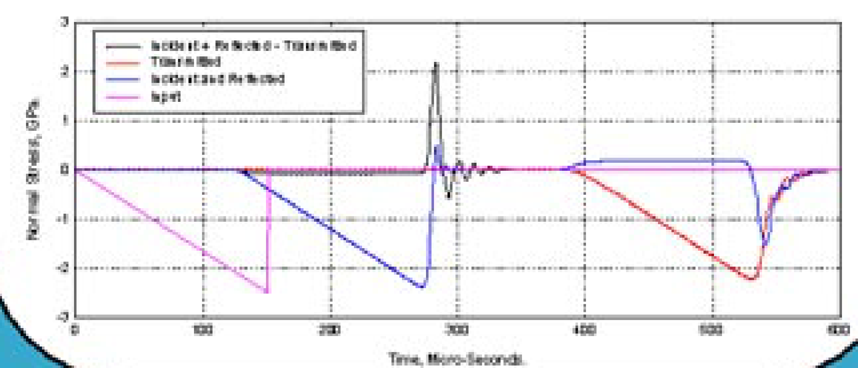
$$\bar{\sigma}(t) = E_B\left[\varepsilon_T(t) + \frac{r}{1-r}\frac{H_S}{C_S}\frac{d\varepsilon_T(t)}{dt}\right]$$

$$\bar{\sigma}(t) = \bar{\sigma}_{Classic}(t) + \text{Dynamic Adjustment}$$

- Dynamic Adjustment is Significant if Stress Rate is High

DEVIATION FROM EQUILIBRIUM: NUMERICAL EXAMPLES





SPECIAL CASES

- Impedance of the Specimen is not Known A Priori, One must Solve the Following Equation for LINEAR ELASTIC Case

$$E_S = \rho_S C_S^2 = \frac{2r}{(1-r)^2}E_B\frac{\varepsilon_T(t)}{\dfrac{C_B}{H_S}\int_0^t \varepsilon_R(t)dt}$$

- For NON-LINEAR ELASTIC Case, with Some Approximation, the Following Equation Needs to be Solved

$$E_S = \rho_S C_S^2 = \frac{2r}{(1-r)^2}E_B\frac{\dfrac{d\varepsilon_T(t)}{dt}}{\dfrac{C_B}{H_S}\varepsilon_R(t)}$$

Which is Very Sensitive to Noise and Special Procedures to Eliminate Noise should be Incorporated

- FOR FINITE DIAMETER SPECIMEN AND BARS – the Reflected Pulse can be Approximated as Follows

$$\varepsilon_{R_{Corrected}}(t) = \frac{A_B}{A_S}\left[\varepsilon_R(t) + \left(1 - \frac{A_S}{A_B}\right)\varepsilon_I(t)\right]$$

CONCLUSIONS

- The Strain Axis of Classical SHPB Stress-Strain Diagram is Distorted and can be Corrected Using the Present Approach
- Relations between Specimen Thickness and Material Non-Linearity has been Developed
- Different Data Reduction Schemes are Necessary for Different Material Behavior

FUTURE WORK

- Stress Wave Propagation in Finite Size Bars and Specimen will be Considered
- Data Reduction Schemes for Elastic-Plastic and Visco-Elastic Materials will be Developed
- The Developed Methods will be Verified with SHPB Experiments and Numerical Simulations