EVALUATION OF SPLIT HOPKINSON PRESSURE BAR METHODOLOGIES

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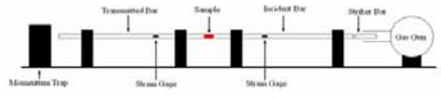
MOTIVATION

Motivation: Frequently high strain rate properties (i.e. modulus) obtained from Split Hopkinson Pressure Bar experiments do not match published values for materials

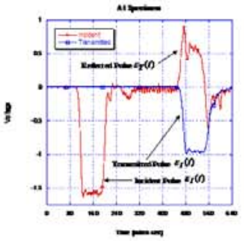
Objective: Accurately determine high strain rate dynamic compressive properties of a material using the Split Hopkinson Pressure Bar

- Minimizing errors inherent to the testing process
  - Wave dispersion
  - Variable strain-rate
  - Specimen surface finish
- Minimizing errors in the analysis
  - Time shift
  - Dispersion correction
  - Correct strain calculation

SPLIT HOPKINSON PRESSURE BAR CLASSIC METHODOLOGY



Schematic of the Split Hopkinson Pressure Bar



Classic 1-Wave Analysis

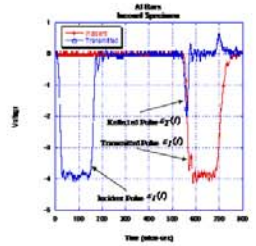
$$\varepsilon_{s,cl}(t) = -\frac{2c}{H}\int_0^t \varepsilon_R(t)\,dt$$

$$\sigma_{s,cl}(t) = E_{Bar}\frac{A_{Bar}}{A_s}\varepsilon_T(t)$$

Velocity of sound in the bar must be less than the velocity of sound in the specimen, $C_b < C_s$

SPLIT HOPKINSON PRESSURE BAR NEW METHODOLOGY

What if the velocity of sound in the bar is greater than the velocity of sound in the specimen? $C_b > C_s$



$$r = \frac{\rho_S c_S - \rho_B c_B}{\rho_S c_S + \rho_B c_B}$$

$$K_S = -\frac{(1-r)^2}{4r}$$

$$K_S^{dyn} = \frac{(1+5r)\cdot(1-r)^3}{4r(1+r)^2}$$

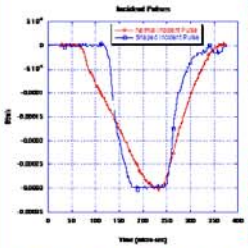
$$\left\langle \bar{\varepsilon}_S(n\bar{T})\right\rangle_{n=1}^N = K_S\cdot\left\langle \bar{\varepsilon}_S^{cl}(n\bar{T})\right\rangle_{n=1}^N + K_S^{dyn}\cdot\frac{\rho_S}{\rho}\cdot\left\langle \varepsilon_R(n\bar{T},0)\right\rangle_{n=1}^N$$

$$\left\langle \Sigma_S(n\bar{T})\right\rangle_{n=1}^N = E\left\langle \varepsilon_T(n\bar{T},H)\right\rangle_{n=1}^N + E\frac{\rho_S}{2\rho}\cdot\tau\cdot\left\langle \frac{d}{d(n\bar{T})}\varepsilon_T(n\bar{T},H)\right\rangle_{n=1}^N$$

TESTING PARAMETERS

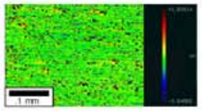
- Wave dispersion correction
  - All bars are dispersive in nature
  - Dispersion correction predicts the waves at the bar-specimen interfaces
- Pulse shaping
  - Creates a slowly rising incident pulse
    - Constant deformation over duration of pulse
    - Eliminates premature failure in brittle materials
  - Able to tailor stress level in specimen
  - Constant strain rate
  - Reduces high frequency oscillations, minimizing dispersion effects
- Time shift
  - Shifts all data to the same time domain
- Similar bar-specimen diameter ratio
- Specimen surface finish

TESTING PARAMETERS

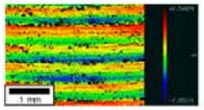


Examples of shaped and non-shaped incident pulses

Note the constant strain rate in the shaped pulse



Polished Al specimen, rms roughness = .327 µm

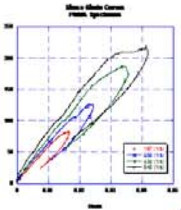


As machined Al specimen, rms roughness = .766 µm

EXPERIMENTAL RESULTS

Al Specimens, E=69 GPa	
1-Wave Classic Analysis	
Specimen-Bar Diameter Ratio	Modulus (GPa)
0.6	58.9
0.7	61.2
0.8	65.5
0.9	66.9
1	68.7
UD-CCM Analysis	
Specimen-Bar Diameter Ratio	Modulus (GPa)
0.6	58.4
0.7	59.2
0.8	64.0
0.9	63.1
1	66.4

Results show how specimen-bar diameter ratio affects modulus



PMMA specimens tested at different strain rates

Future Work: Develop a technique for accurately determining the high rate properties of a visco-elastic material (PMMA)

CONCLUSIONS

Criteria for correct measurement of modulus

- The specimen-bar diameter ratio must be close to 1
- Specimens must be polished
- Pulse shaping should be used to create a constant strain rate in the specimen
- Dispersion correction and time shifting of the data should be performed
- 1-wave classical analysis seems to yield correct result when the above parameters are present

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