DYNAMIC SIMULATION OF SPLIT HOPKINSON PRESSURE BAR (SHPB) FOR COMPOSITE MATERIALS USING LS-DYNA

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Energy Methods II

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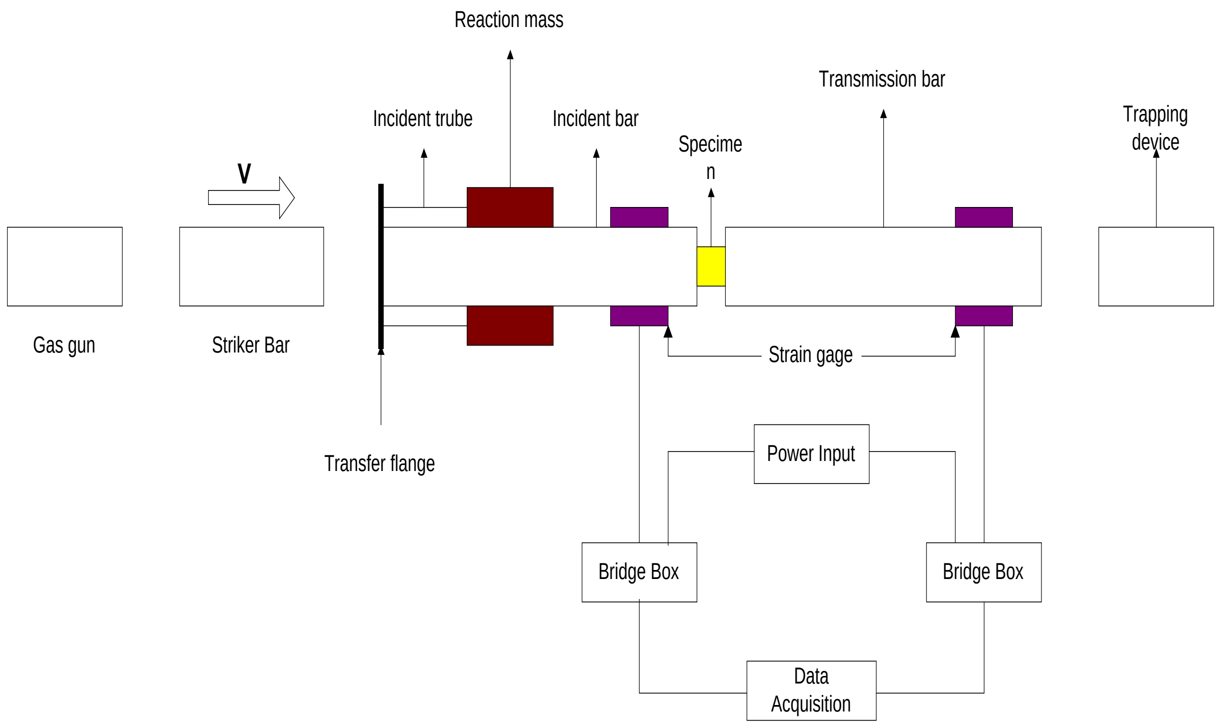
INTRODUCTION

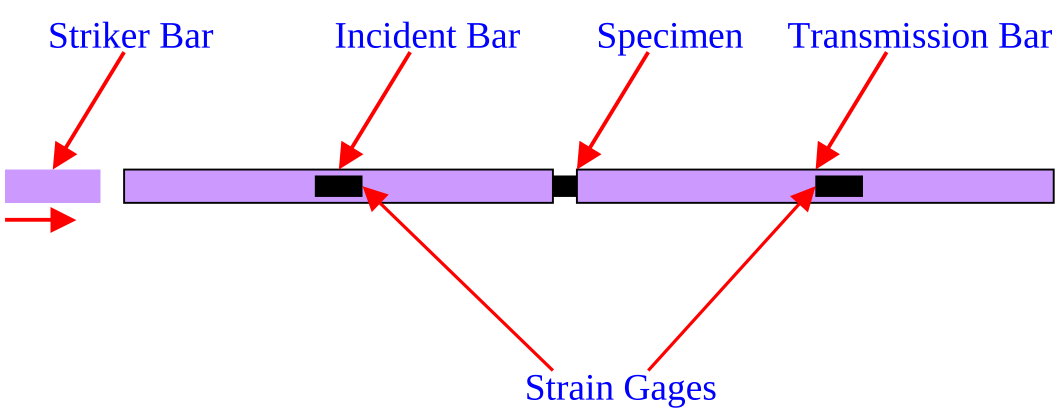
- The composite structures that undergo dynamic loading can produce excessive design weight or cause unexplained and untimely failure.
- Designers therefore require an in-depth understanding of dynamic responses of composites for reliable design of its components.
- Lot of modeling has been done for the static loading conditions but not much is known of composite's response to dynamic loading at various environmental conditions.
- The wide range of attractive properties and increasing use of composite in important areas of industries and the insufficient data in the relevant field lead to the selection of this project.

OBJECTIVES

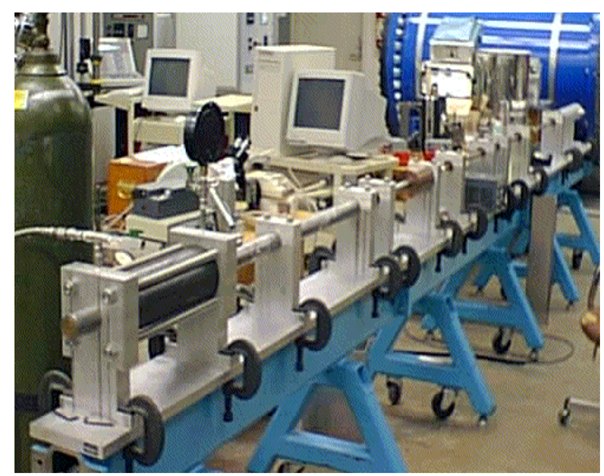
- **Develop a computational model to simulate the SHPB using LS-DYNA.**
- **Evaluate the dynamic behavior of composite materials using the model.**
- **Compare the simulated data with the experimental results.**
- **Investigate the temperature effect with high strain rate effect and compare the simulated results with the experimental results in the future.**

EXPERIMETAL SETUP OF SHPB





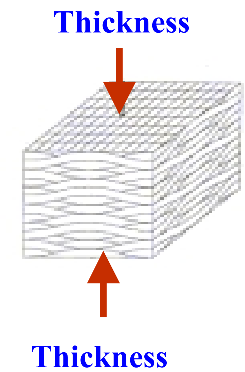
Compression Split Hopkinson Pressure Bar bar/specimen interface



MATERIALS, ASSUMPTIONS AND FORMULATION

Materials

- Specimen: S2-Glass/Vinyl Ester Composite (0.5 inch cube).
- SHPB: High Strength Maraging Steel (0.75 inch diameter).



Assumptions

- The incident (60 inch long), transmission (60 inch long), and the striker bar (6 inch long) bar remain elastic during the testing.
- Wave propagation within the pressure bar is one-dimensional
- Specimen undergoes homogeneous deformation.

Formulation

From the momentum conservation,

$\acute{\varepsilon} \leq V_0/L$

Where, $\acute{\varepsilon}$ = Strain Rate, 500 s^{-1} and 1000 s^{-1}

V_0 = Velocity of the Striker Bar, 250 in/sec and 500 in/sec

L = Length of the Specimen, o.5 inch

MODELING PROCEDURE

- Altair Hyper Mesh was used to draw the geometry of the model.
- Altair Hyper Mesh was used to generate the LS-DYNA keywords files.
- LS-DYNA was used to postprocess the results.

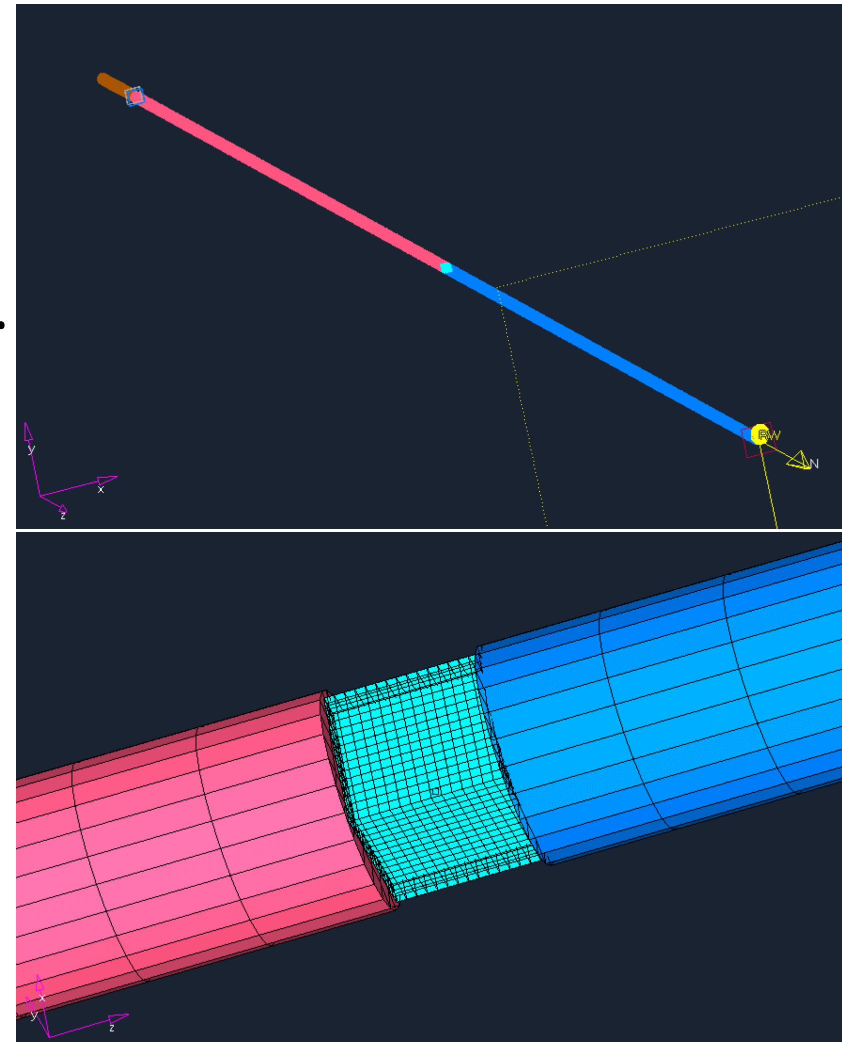
Steps of the Modeling

- Geometry and Discretization
- Boundary and Initial Conditions
- Material Model
- Material Properties
- Elements

MODELING PROCEDURE (Continued)

Geometry and Discretization

- The geometric model was created creating the material collector, property collector and component collector by Hyper Mesh.
- The model was meshed by the Hyper Mesh as shell elements and finally as solid elements keeping the aspect ratio less than five.
- The shell elements were deleted and solid elements were used for the modeling.
- The specimen mesh-density was higher than bars mesh-density.



MODELING PROCEDURE (Continued)

Boundary and Initial Conditions

- Two blocks were created: one at the end of the striker bar and the other at the starting end of the incident bar.
- Three surface to surface contact surfaces were created:

  1. Surface to surface contact in between the striker bar and the incident bar.

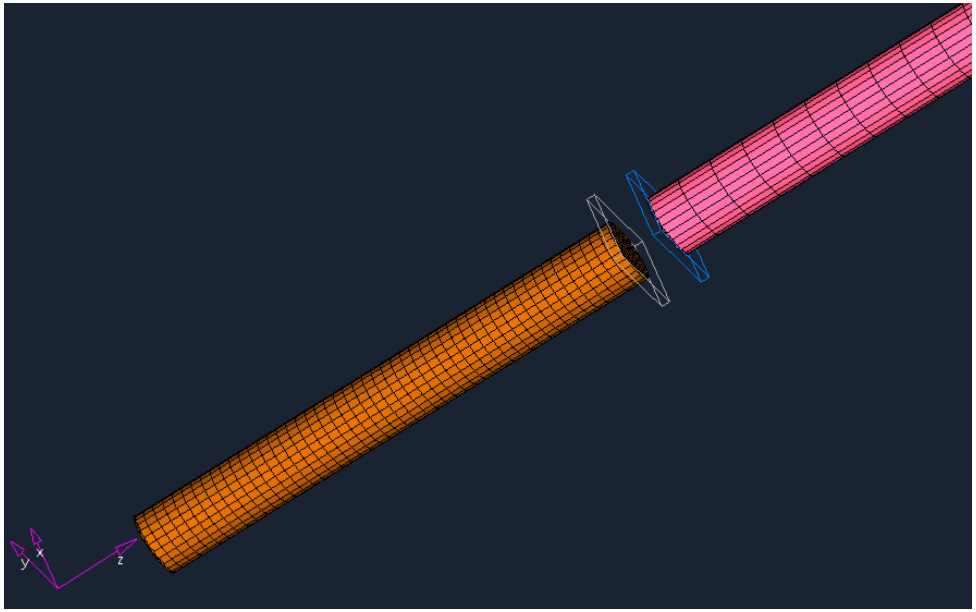
  2. Surface to surface contact in between the incident bar and the specimen.

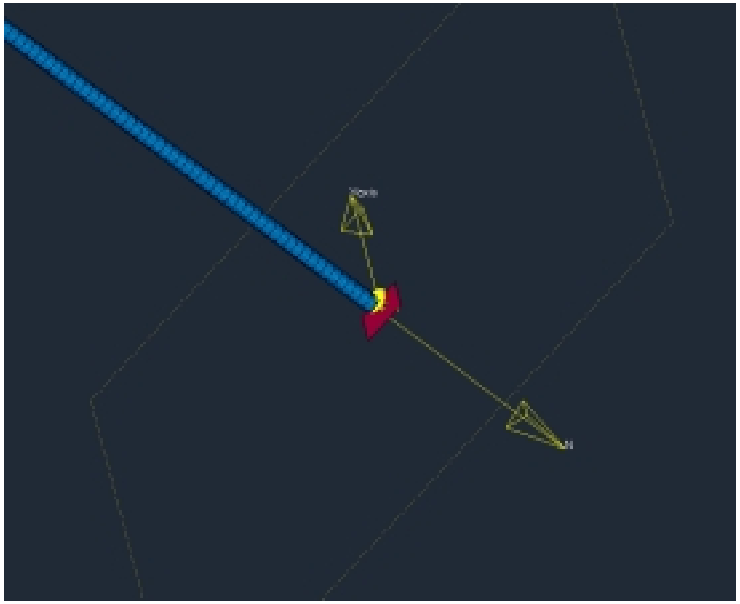
  3. Surface to surface contact in between the specimen and the transmission bar.

- A rigid wall was created at the end of the transmission bar.
- Velocities of 250 in/sec and 500 in/sec were applied at the striker bar creating an entity set for all the nodes of the striker bar for the strain rates of 500 s^{-1} and 1000 s^{-1}, respectively.

MODELING PROCEDURE (Continued)

Boundary and Initial Conditions





MODELING PROCEDURE (Continued)

Material Model

- The Material Type 3 was used for the SHPB as an isotropic solid element
- The Material Type 2 was used for the sample as an elastic-orthotropic solid element

Material Properties

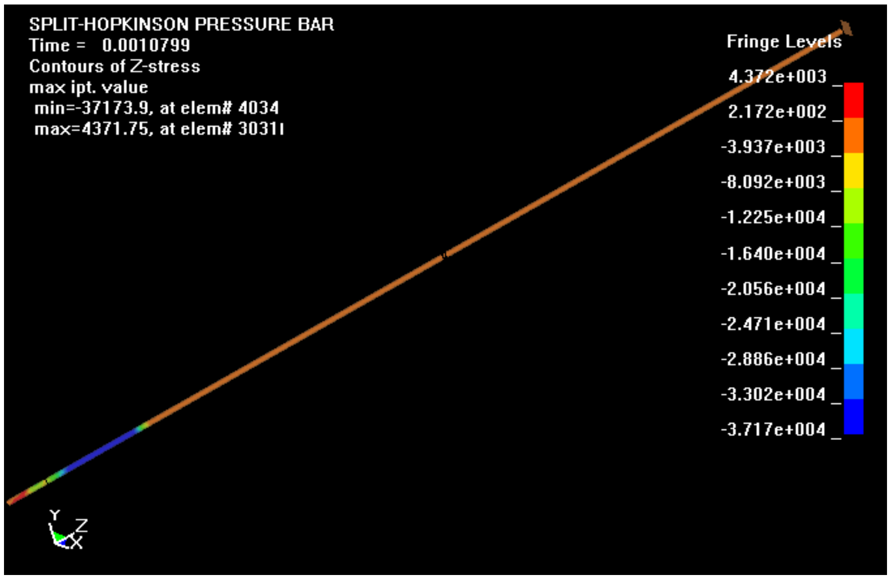
Materials	Density, ρ ($lb\text{-}s^2/in^4$)	Modulus, E (psi)			Modulus, G (psi)			Poisson's Ratio, v		
		E_x	E_y	E_z	G_x	G_y	G_z	v_x	v_y	v_z
Steel	7.4881E-04	27.5E+06	-	-	-	-	-	0.30	-	-
Composite	1.7222E-04	1.75E+06	1.75E+06	0.94E+06	0.68E+06	0.36E+06	0.36E+06	0.27	0.30	0.30

RESULTS

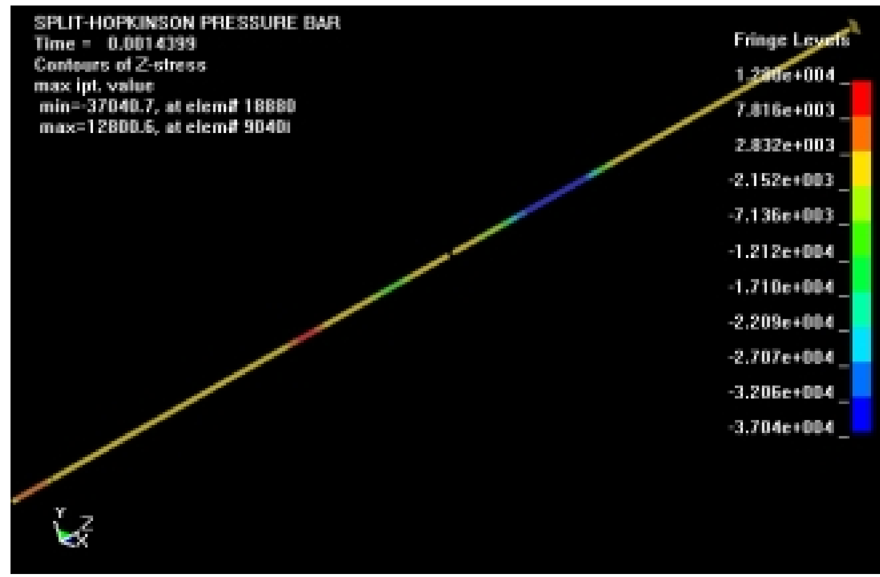
- **Striker bar strikes the incident bar with predetermined velocity for the certain strain rate.**
- **The compressive wave pulse produced in the incident bar.**
- **The compressive pulse travels toward the sample.**
- **Some of them passes through the specimen to the transmission bar and some of them reflected back to the incident bar due to the impedance mismatch between the sample and bar.**
- **The specimen is sandwiched in between the incident bar and the transmission bar.**
- **The stress-strain plot is obtained and peak/failure stress and peak/failure strain are obtained.**

RESULTS

Deformed Geometry



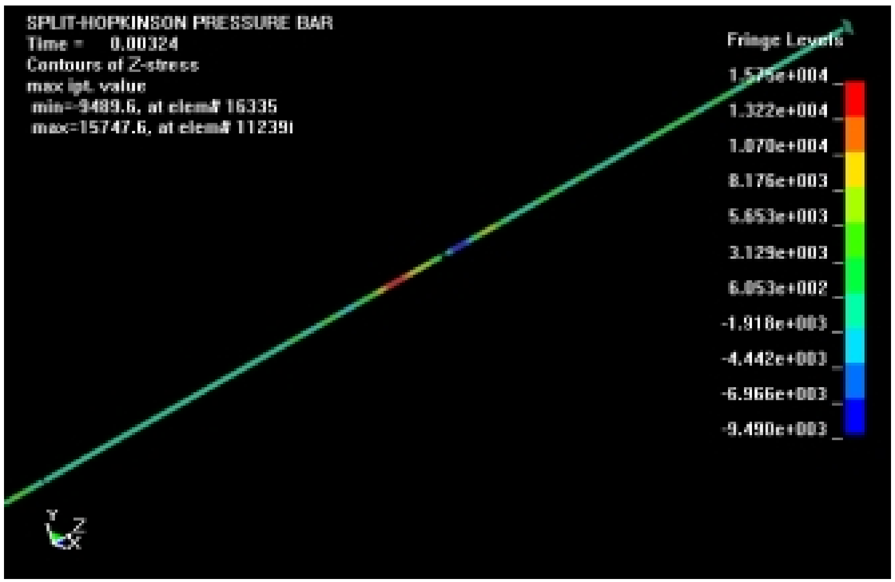
Wave in the Incident Bar for Strain Rate of 1000 s^{-1}



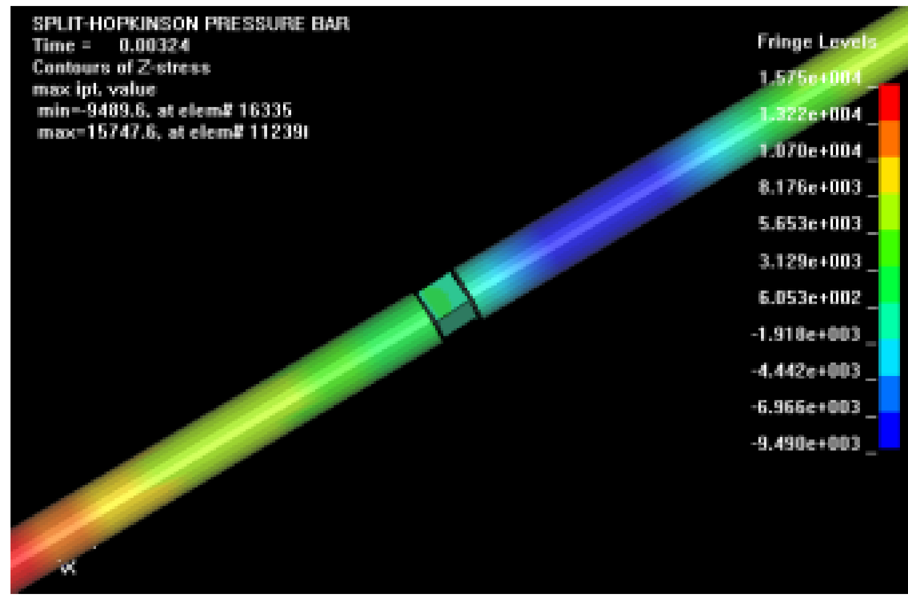
Transmission of Wave from the Incident to the Transmission Bar for Strain Rate of 1000 s^{-1}

RESULTS

Deformed Geometry

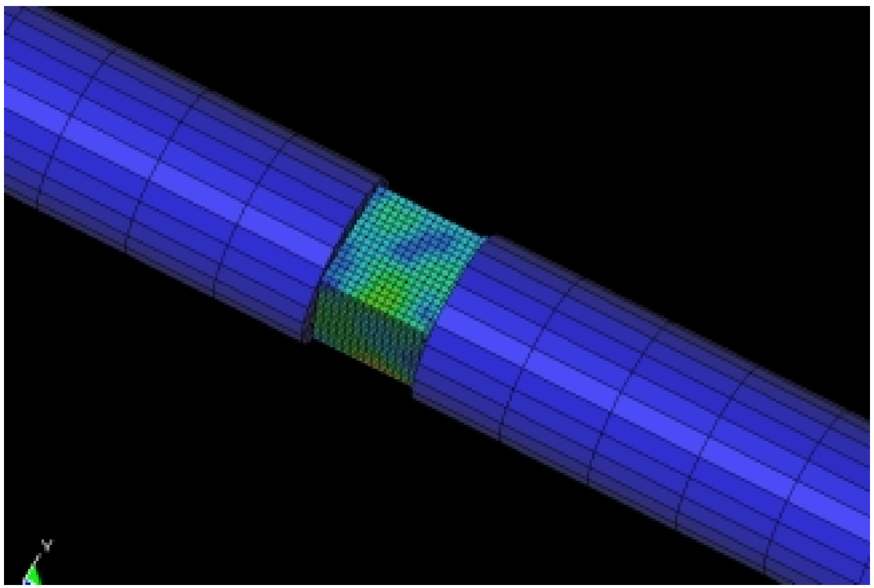


Reflected Wave in the Incident Bar for Strain Rate of 1000 s^{-1}

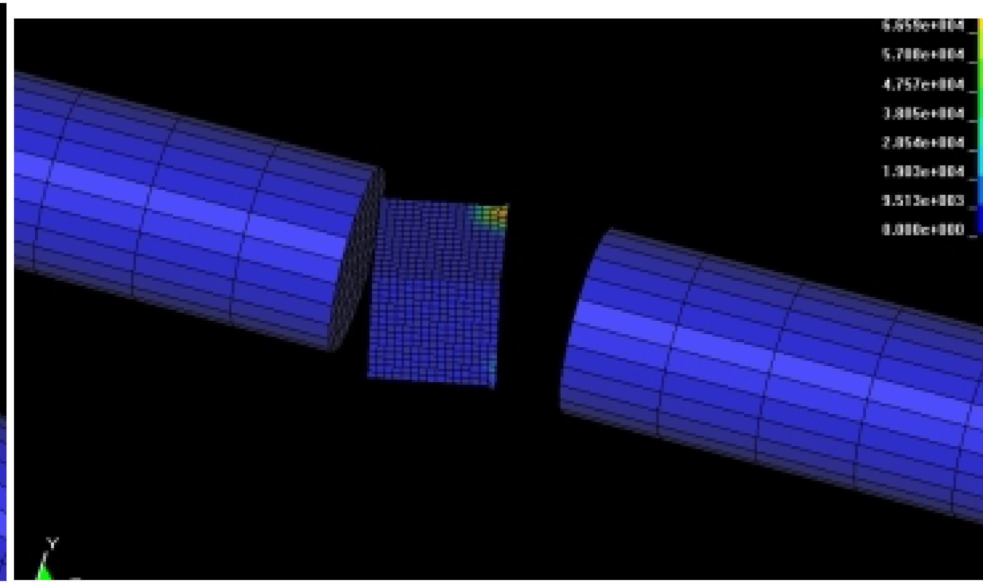


Sandwiched-Specimen in between the incident bar and the transmission bar

Deformed Geometry



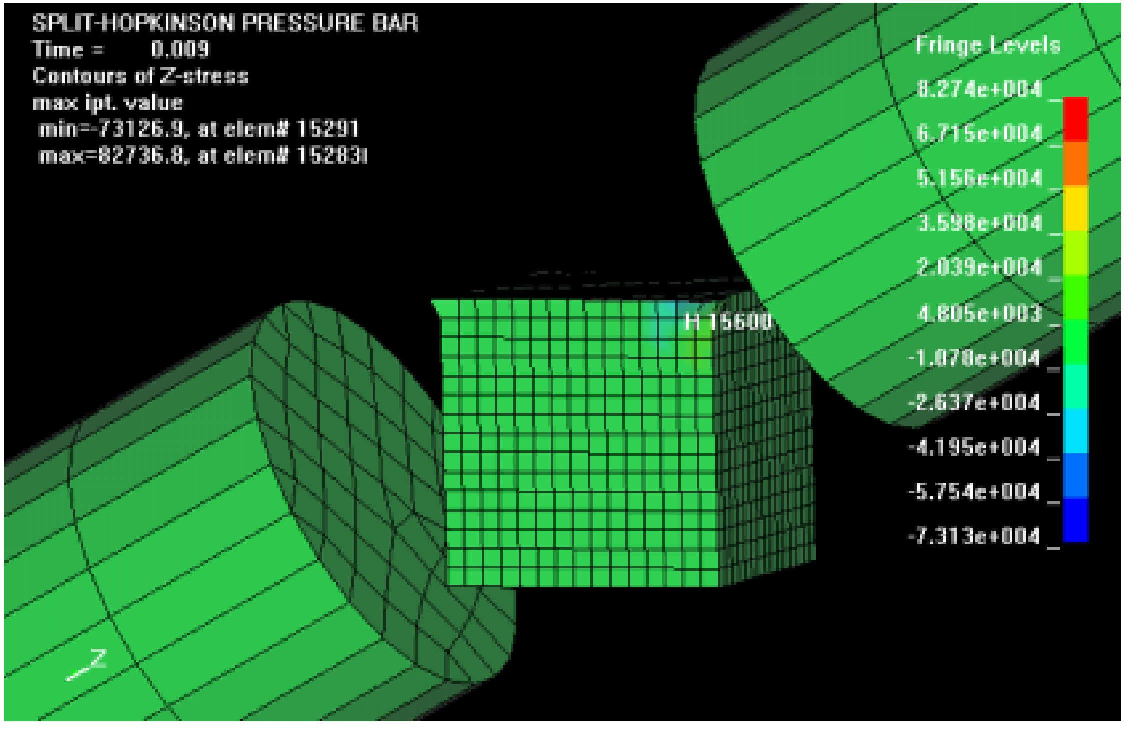
Specimen geometry at the time of impact



Specimen geometry after the impact

RESULTS

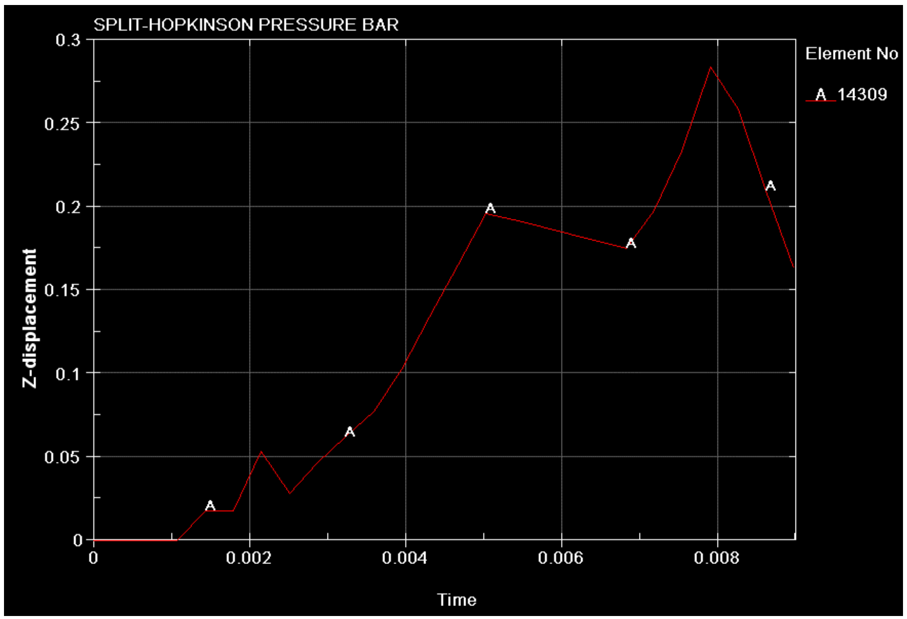
Deformed Geometry



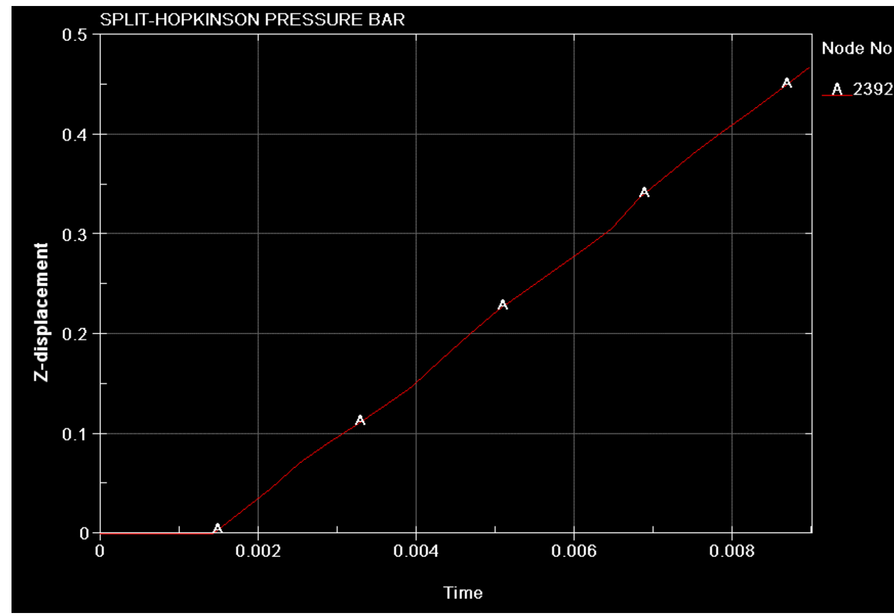
Maximum Stress in the Sample for Strain Rate of 1000 s^{-1}

RESULTS

Simulated Plots



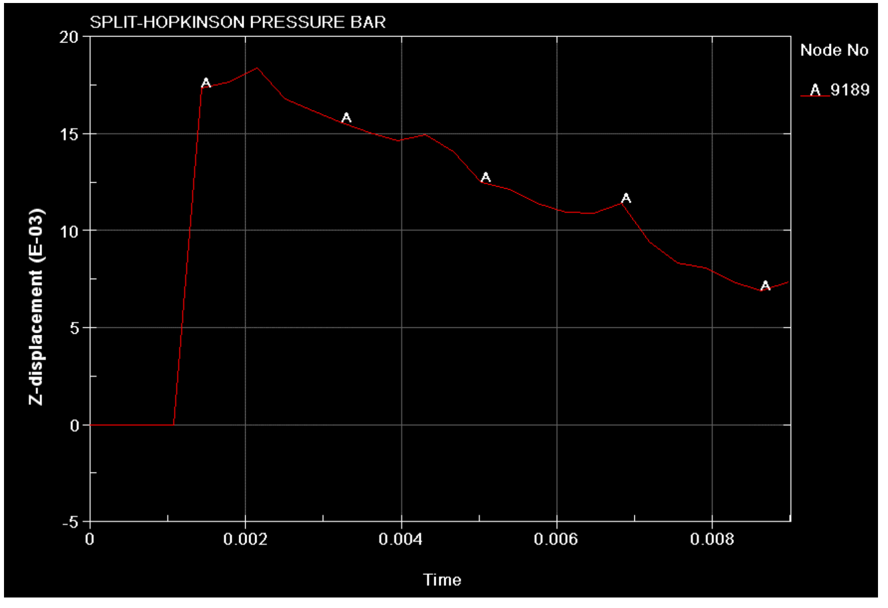
Displacement vs. Time Plot in the Incident Bar



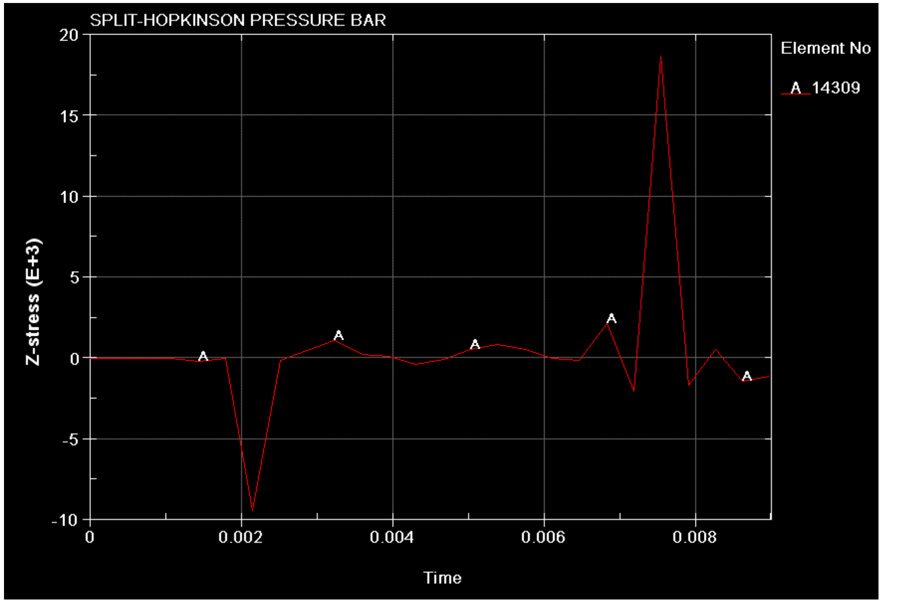
Displacement vs. Time Plot in the Transmission Bar

RESULTS

Simulated Plots



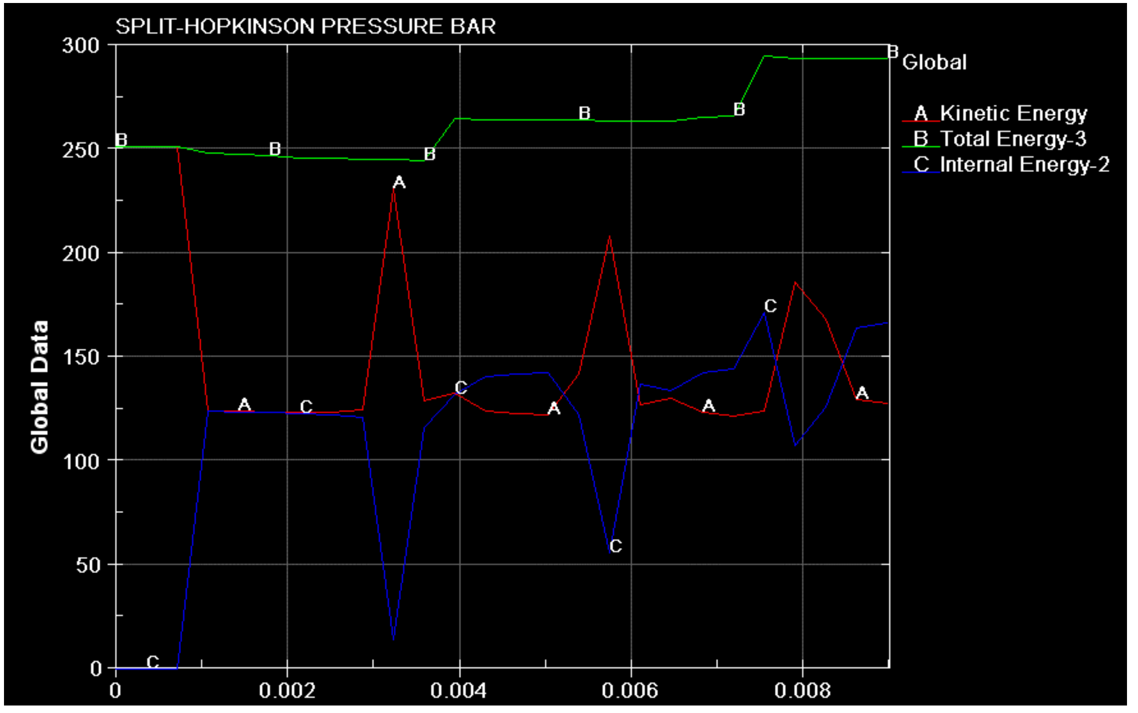
Displacement vs. Time Plot in the Specimen



Stress vs Time plot in the Specimen

RESULTS

Simulated Plots



Energy vs. Time Plot in the Specimen

RESULTS (Continued)

- The peak stresses were obtained from the LS-DYNA analysis for different strain rates.
- Comparison was made between the experimental and the simulated results.

Strain Rate (s^{-1})	Pick Stress (psi)		%Error
	Experimental	Simulated	
500	69890	20716	70
1000	81668	73127	10

CONCLUSIONS

- LS-DYNA is a good tool for dynamic/transient analysis to predict the high strain rate effects of the composite materials.
- The simulated stresses are within 70% and 10% of the experimental results for the strain rates of 500 s^{-1} and 1000 s^{-1} respectively.
- The discrepancy between the experimental and simulation may be due to the the improper selection of the materials or due to the ununiformed mesh between the samples and the bar.
- The accuracy of the simulated result may be improved by using accurate contact surface control cards for the composite sample and the steel bars.
- The proper selection of materials and fined mesh between the sample and bar can also provide better result.

REFERENCES

1. Meyers, M. A. And Ravichandran, G., “Short Course in Dynamic Behavior of Materials,” Center of Excellence for Advanced Materials, University of California, San Diego, pp. 1- 7, 1989.

2. Hossain, M. and Haque, A., “Effects of Moisture and Temperature on High Strain Rate Behavior of S2-Glass/Vinyl Ester Composites,” Master’s Thesis, Department of Mechanical Engineering, Tuskegee University, May 2002.

3. Nasser, S. N., Isaacs, J. B. and Starrett, J. E., “Hopkinson Techniques for Dynamic Recovery Experiments,” Proc. R. Soc. London, Vol. 435A, pp. 371-387, 1991.

4. “Special Metals” Company Website