Exploring the Response of Jointed Structures to Blast Waves using a Shock Tube

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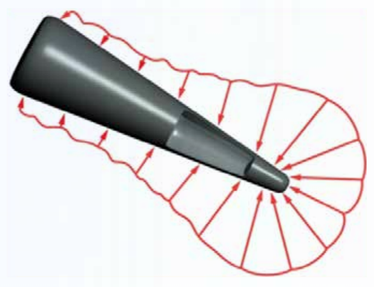
Motivation

Weapons Response in Blast Structure and Fluid Structure interactions (BSI and FSI)?

Weapons Bays



Hypersonic Reentry

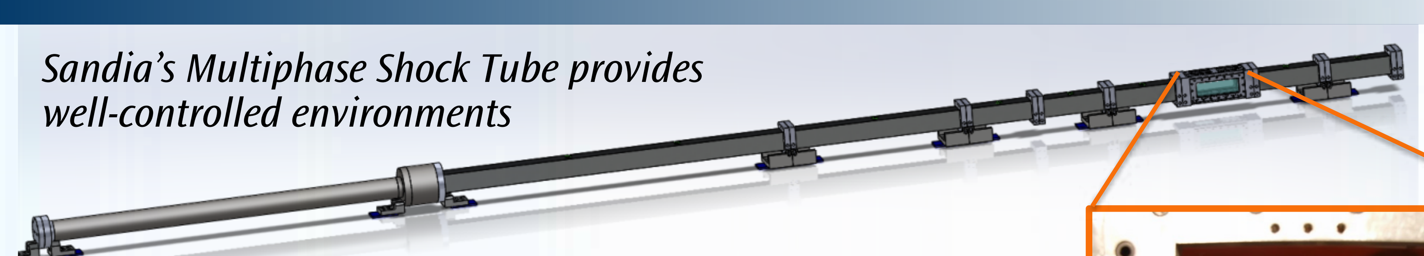
- Prediction of momentum transfer from the flow through the vehicle remains quite challenging.
- One of the biggest gaps is our ability to model nonlinear structural response in complex fluid dynamic environments.
- Jointed-structures have been called the "turbulence" of the structural dynamics community

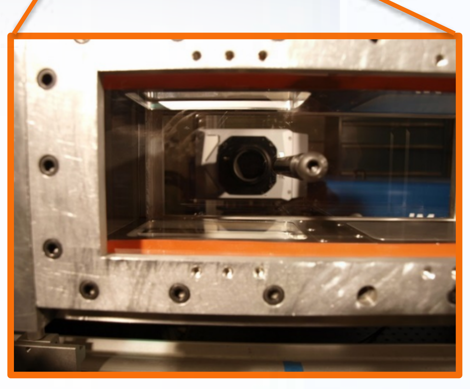
Hypothesis: Well-controlled experiments with diagnostics that spatially and temporally capture the underlying fluid dynamic and structural physical phenomena will reduce model form error.

Overarching Project Goal of this Exploratory LDRD: Explore the possibility of performing well-controlled FSI experiments in a shock tube and characterize experimental challenges

Fluid Dynamic Approach

Sandia's Multiphase Shock Tube provides well-controlled environments

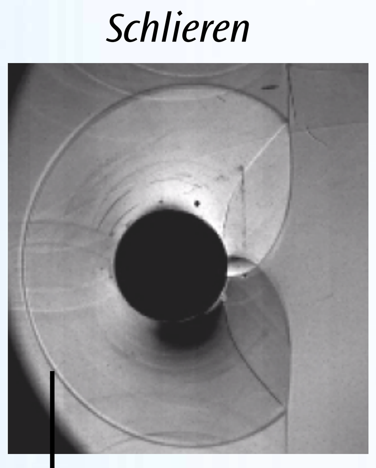




- Lab-scale size allows experimental flexibility and optical access for diagnostics development

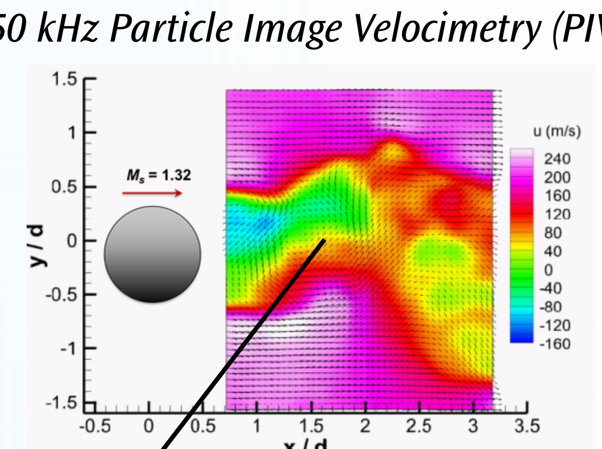
Example: Cylinder in Cross-Flow

Schlieren



Transient Shocks

50 kHz Particle Image Velocimetry (PIV)



Periodic shedding and turbulent wake

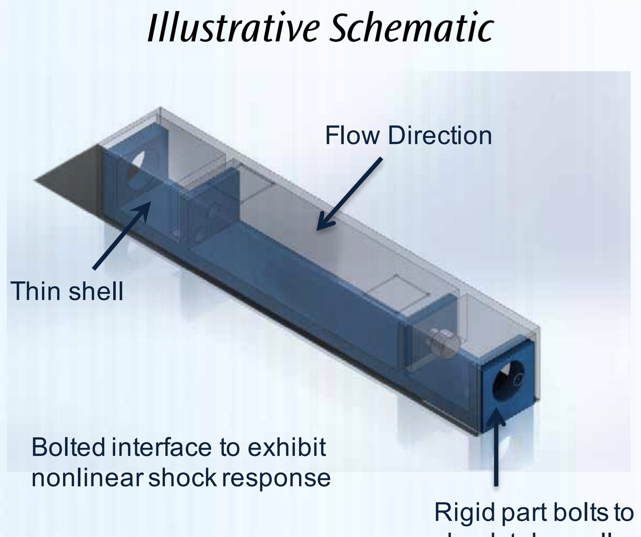
Physically rich loading

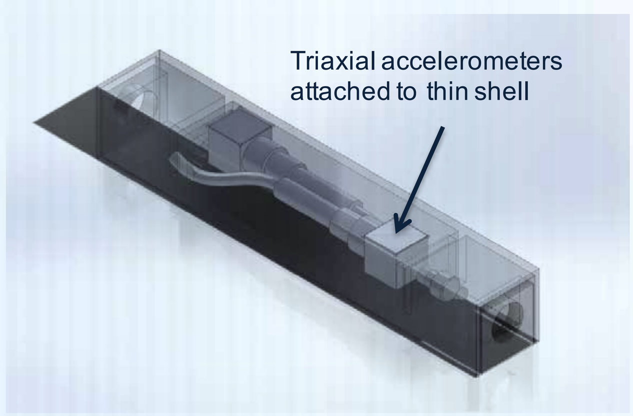
- Shock wave creates longitudinal forcing
- Vortex shedding forces the structure in the transverse and longitudinal directions.
- Stochastic, turbulent loading in wake

Fundamental environment to enable physical discovery.

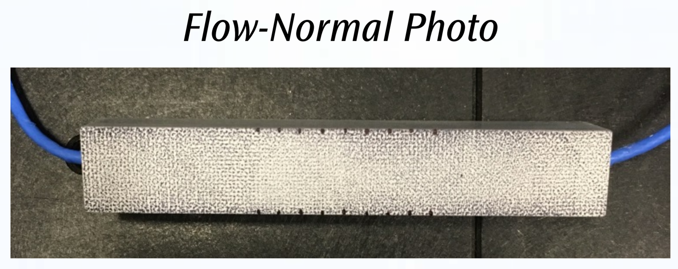
Structural Dynamic Approach

Illustrative Schematic





Flow-Normal Photo



Side View

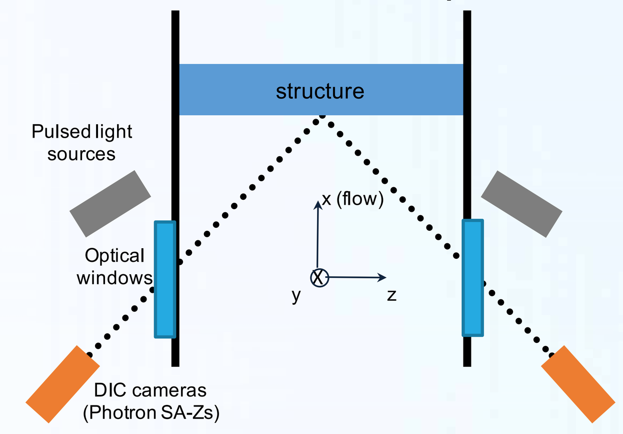
- Five identical structures made since shock loading alters properties of the bolted interface
- Experiments also with a solid beam to serve as a baseline and quantify flow-induced optical distortions

Goals: Design and fabricate an experimental structure to exhibit nonlinear response when subjected to shock waves

Use the structure to obtain a preliminary dataset and evaluate capabilities of existing optical diagnostics such as digital image correlation (DIC)

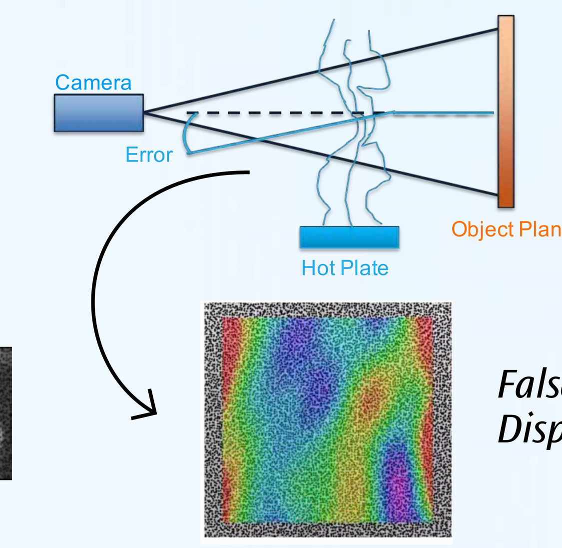
Structural Dynamic Approach

Shock Tube Setup



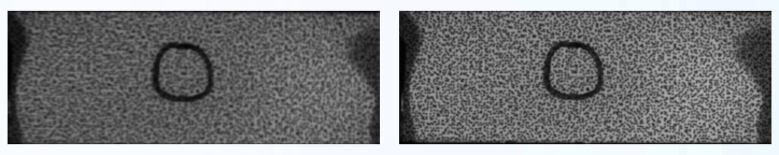
Density Gradients = Optical Distortion

- Density gradients that allow for optical visualization of shocks corrupt DIC.



False DIC Displacements

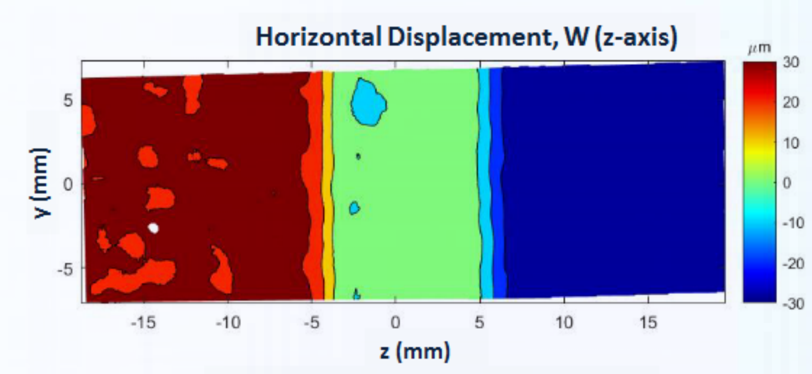
DIC Speckle View Through Windows

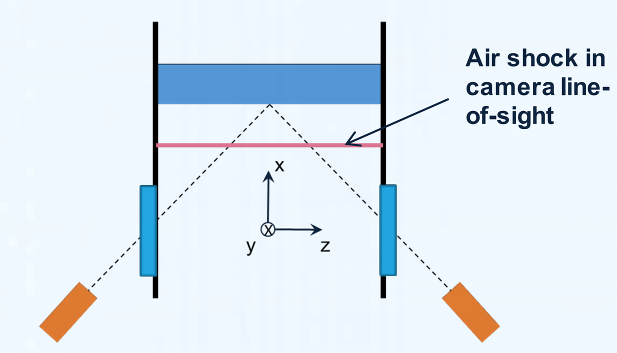


f/# = 2.8 *f/# = 22*

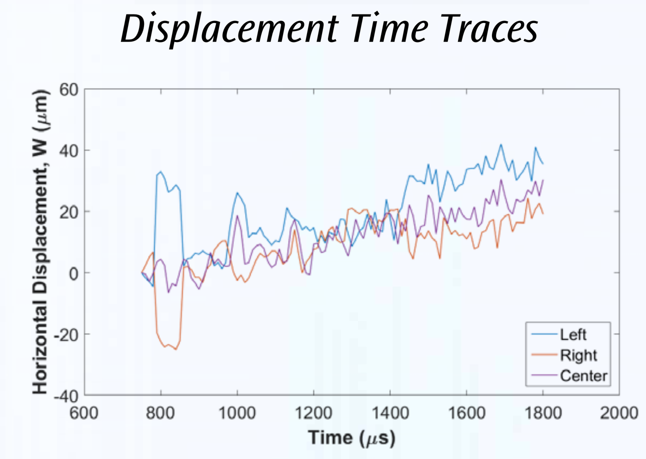
Shock Tube DIC on Solid Beam (Baseline)

Shock Passage Effects





Displacement Time Traces

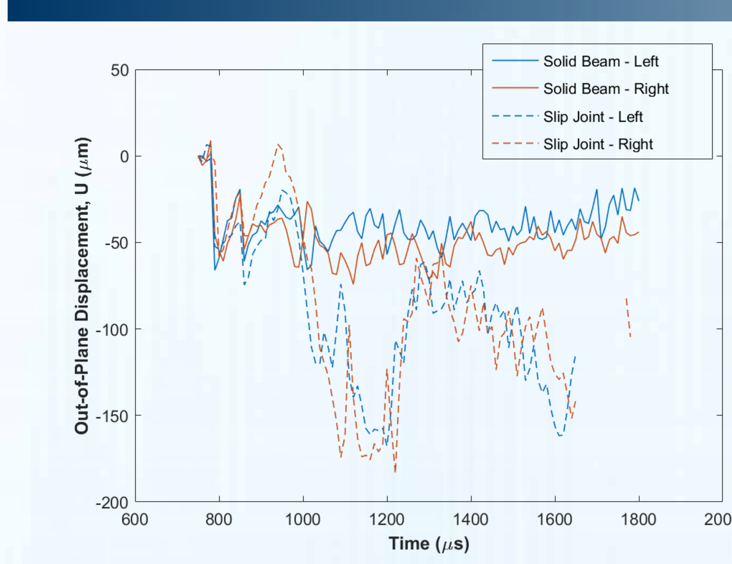


Baseline Summary

- Ideally we would see zero displacement for the rigid beam.
- Instead we obtain false displacements caused by the shock wave and noisy results following.

Still, can we measure a difference in the case with nonlinear slip joint?

Shock Tube DIC on Solid Beam (Baseline)



Despite the noise floor, we are able to clearly measure the response of the jointed-structure to the shock wave.

This exploratory LDRD demonstrated feasibility for FSI and BSI experiments in a shock tube while identifying remaining experimental challenges.

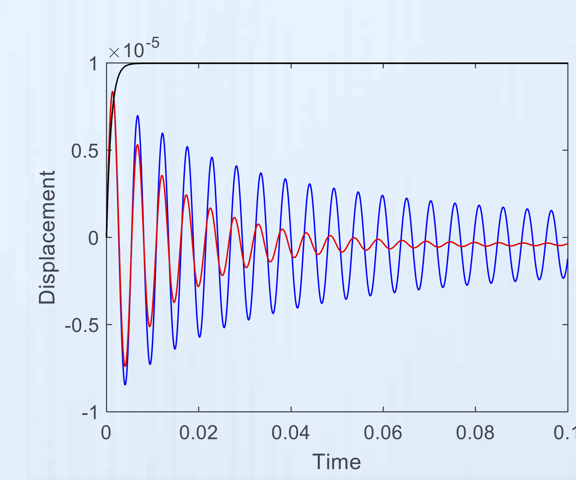
What's Next?

The exploratory project has led to a full experimental / computational LDRD project involving a team of fluid and structural dynamicists.

Project Goals

1. Time and spatially resolved measurements of the flowfield and the structural response
   - Flowfield with tomographic, time-resolved PIV
   - Pressure field (forcing function) using fast-response pressure sensitive paint (PSP)
   - Structural response using a new variant of DIC not susceptible to optical refraction effects
2. High-fidelity dataset will allow for *direct performance evaluation of existing structural dynamics models under FSI and BSI loading environments*

Preliminary Calculation of Response to Air-Shock Loading with Three Existing SD Models



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