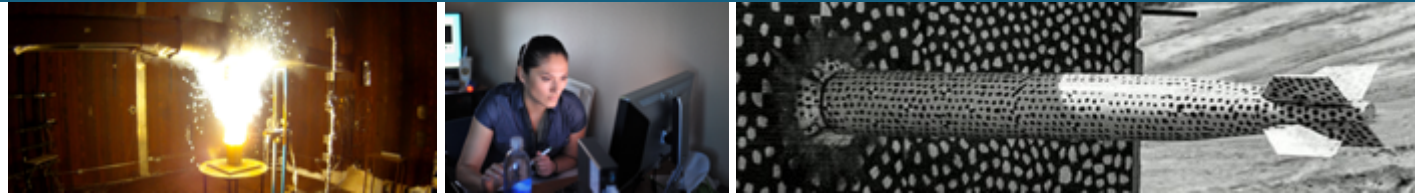# X-ray image acquisition of a device undergoing pyroshock

Robert Waymel, Enrico C. Quintana, Phillip L. Reu, Kyle R. Thompson, Andrew Lentfer, Gabriella Dalton, and Thomas L. Martinez
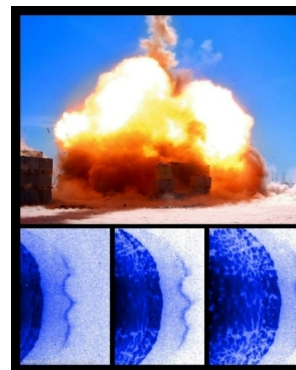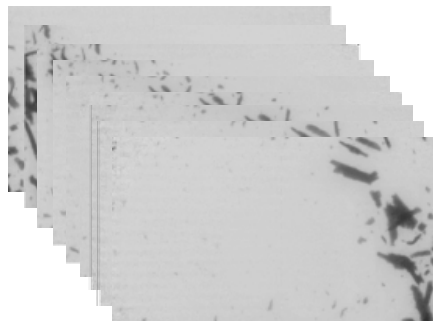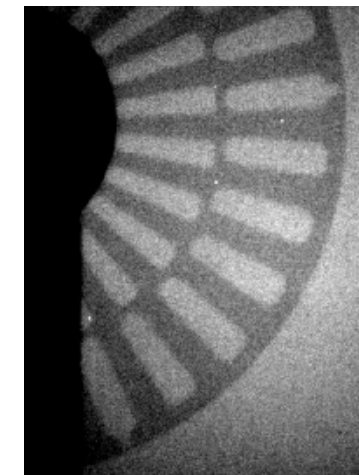
High Speed X-ray Diagnostic Development

Fragment Tracking

250kHz pulsed

High speed X-ray of Component Interior (25kHz continuous)

In collaboration with Benjamin R. Halls
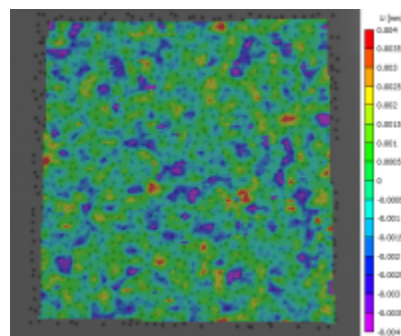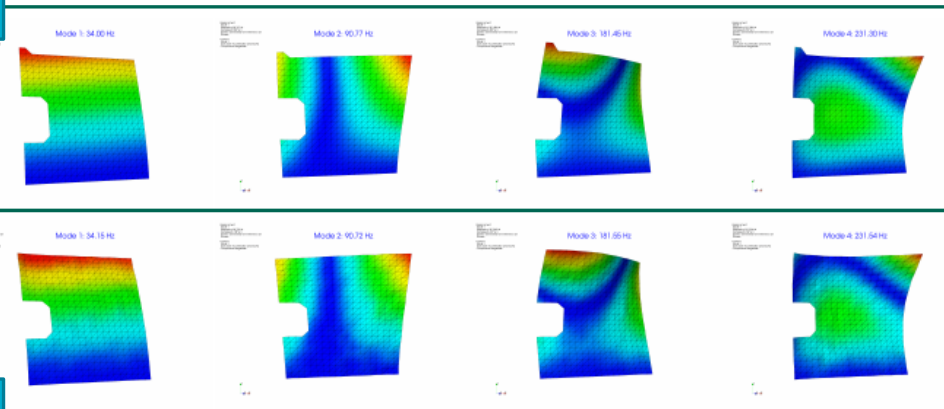
2008 ... 2014 2015 2016 2017 2018 2019 2020 2021

High-speed digital x-ray imaging

Development of high-speed X-ray DIC

In collaboration with Elizabeth M.C. Jones

Visible

X-ray

Modal analysis using high speed X-ray DIC

In collaboration with Daniel P. Rohe and Bryan L. Witt

X-ray Equipment

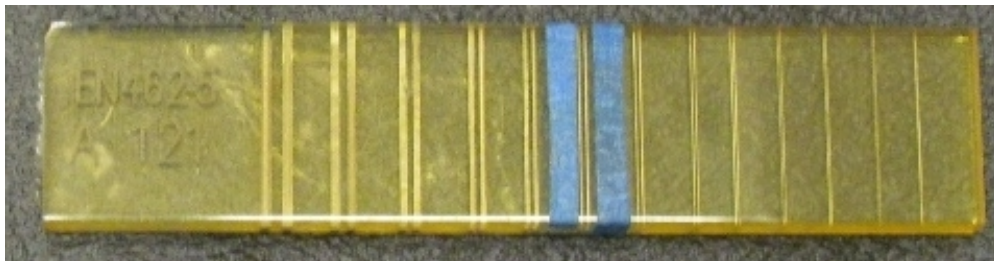Varian 150 keV X-ray tube w/ collimator
- Image contrast directly correlated to volta
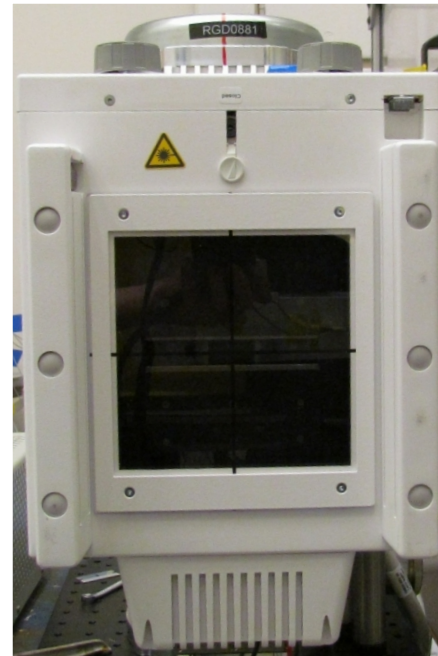- 400 micron spot size (affects image sharpne

GOS:Pr scintillator
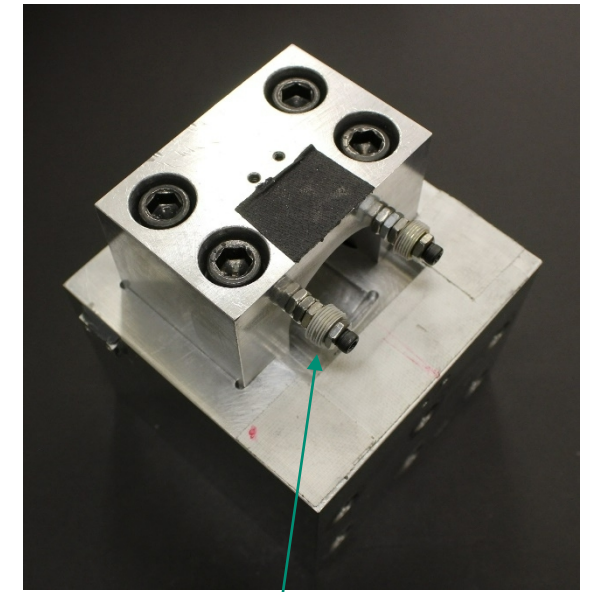- Rapidly decays visible light (4-7 μs)
- Phantom v2512

Setup tools
- X-ray source/detector alignment
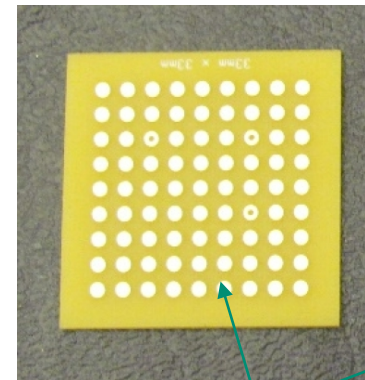- Line-pair gage (resolvable feature)
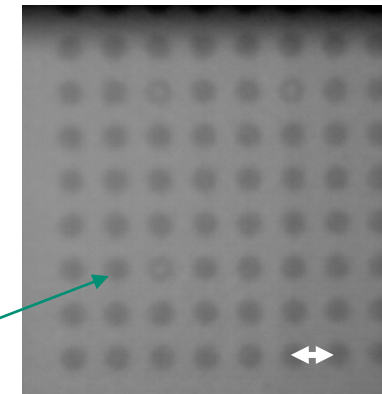- Calibration grid (spatial resolution)

Source w/ collimator
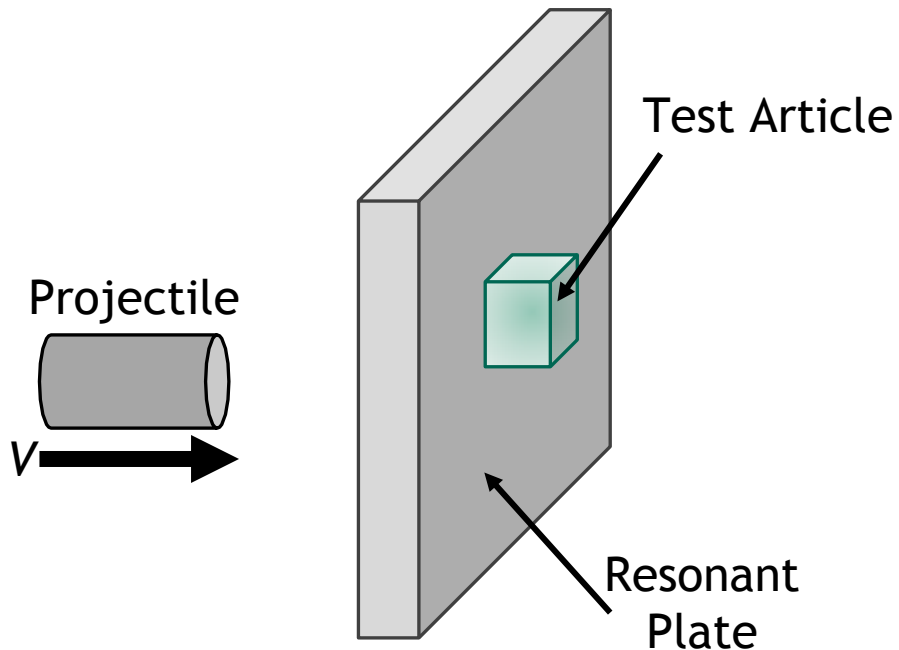
Alignment tool

Line-Pair Gage

Calibration Grid

Uniform Spacing

Resonant Plate Testing

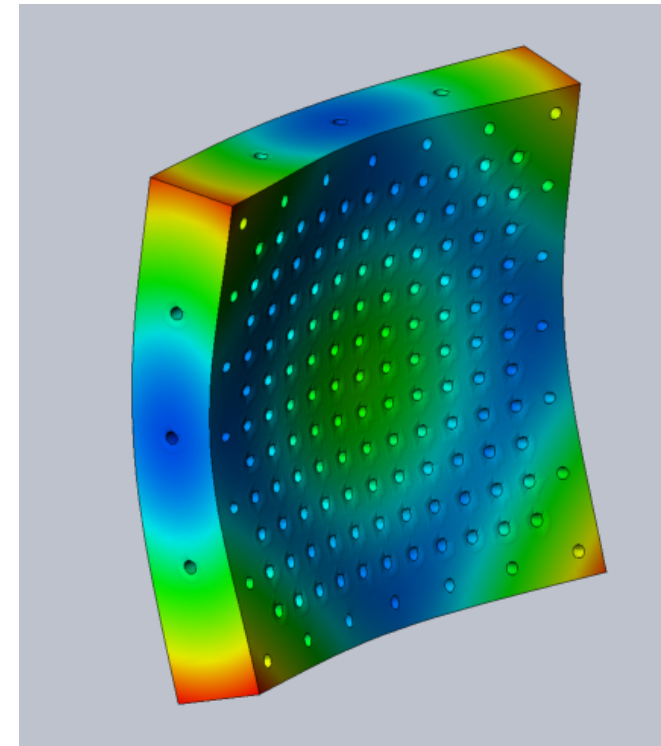Simulates mid-field and far-field shock events

Excites 3rd natural frequency of a free-free square plate
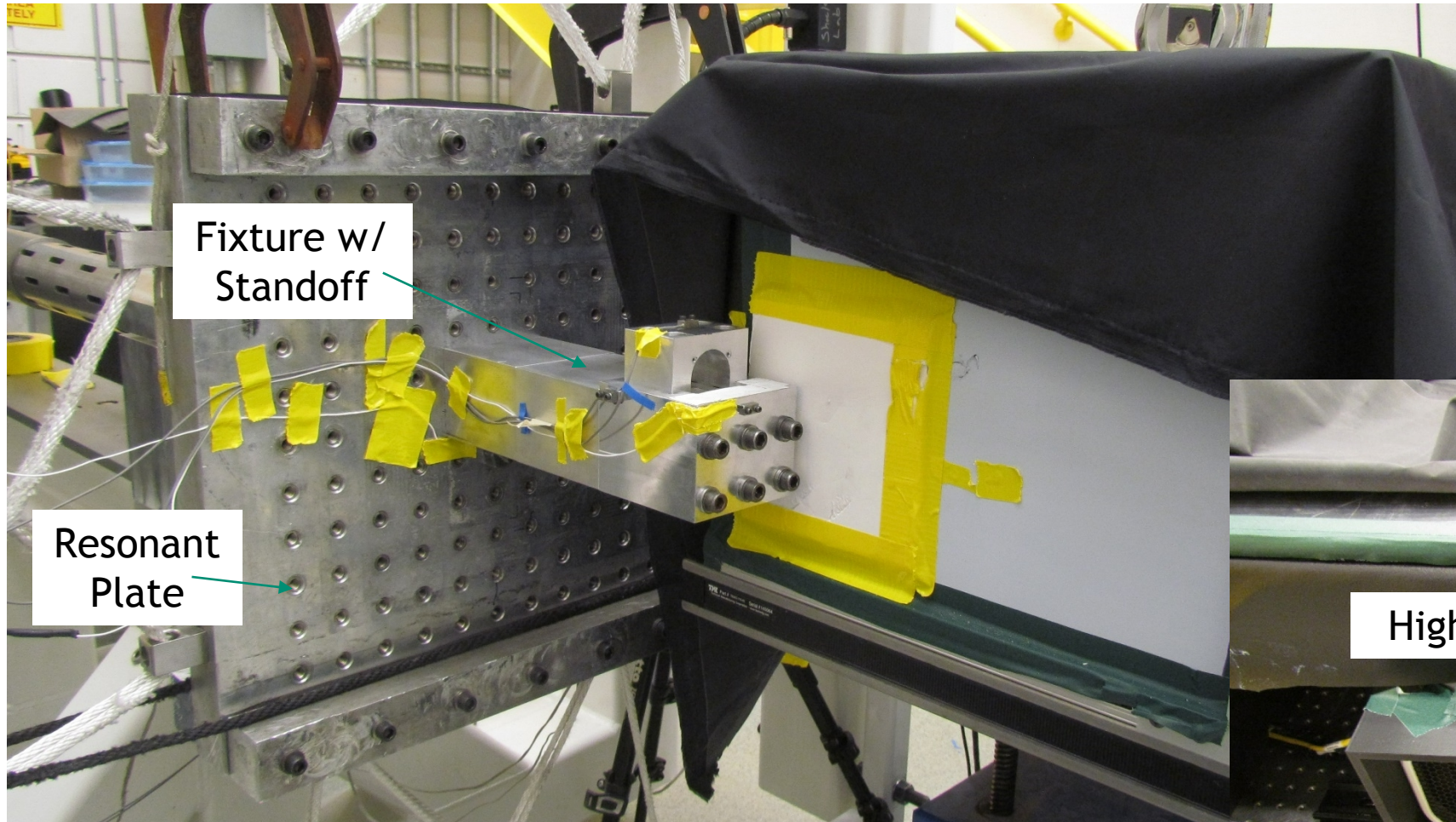- "Breathing," "drum-head," "oil-canning"

Region	Acceleration Amplitude (g)	Frequency (Hz)
Near-Field	>10,000	>10,000
Mid-Field	<10,000	3,000-10,000
Far-Field	<1,000	<3,000

MIL-STD-810H, Method 517 (2019)

Projectile

V

Test Article

Resonant Plate

High-speed X-ray/Pyroshock Test Setup

Fixture w/ Standoff

Resonant Plate

Resonant plate w/ damping bars

Offset fixture

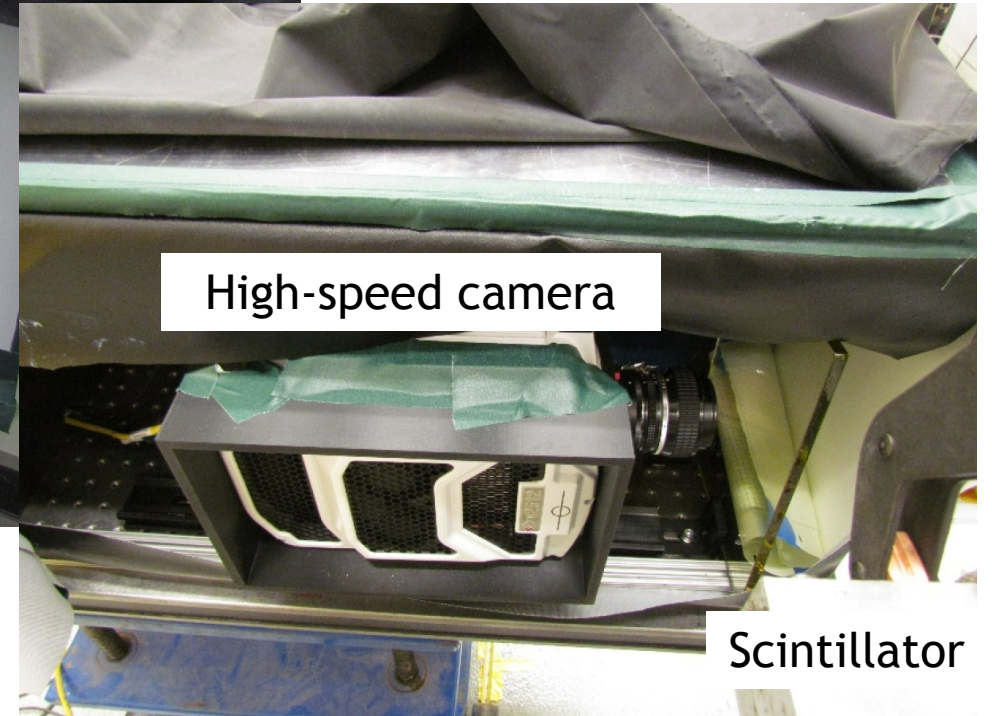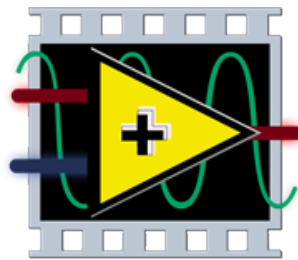Signals synchronized w/ Stanford Signal Generator

High-speed camera

Scintillator

Image Analysis

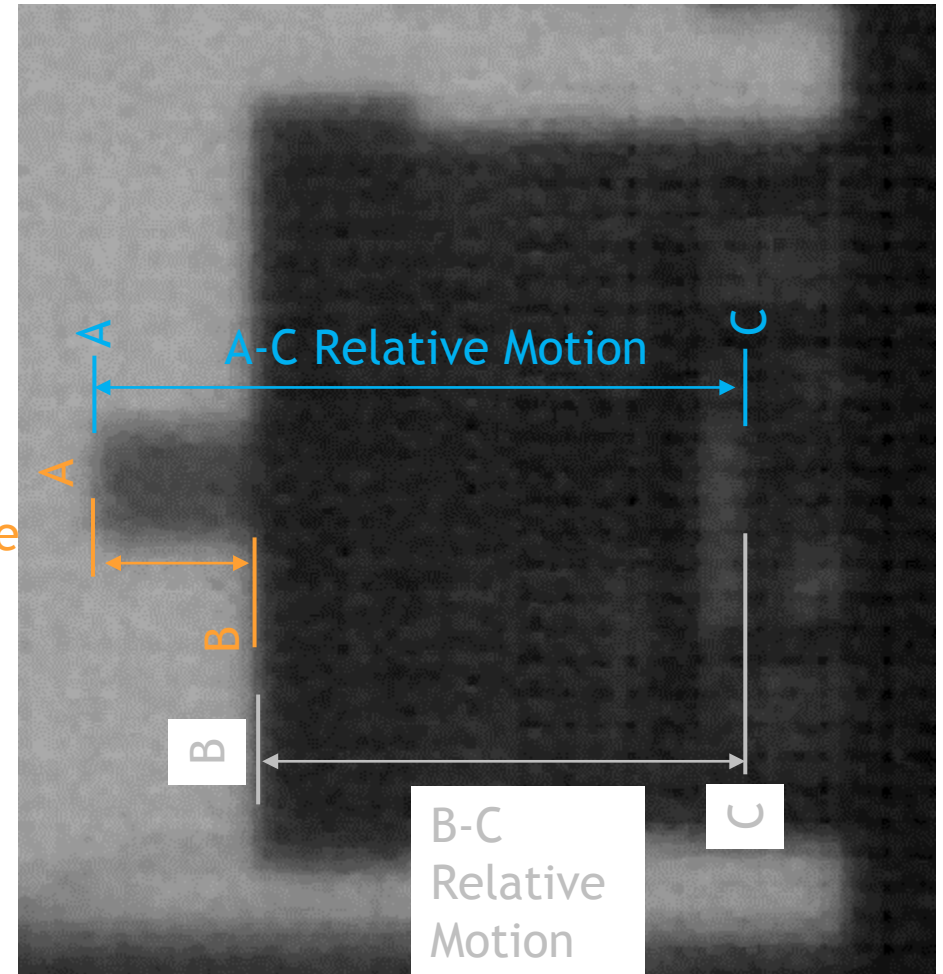Identify the relative motion between three pairs of surfaces (denoted A, B, and C)

Remove rigid body motion

Noise reduction
- Temporal filtering (average several frames)
- Gaussian spatial filtering

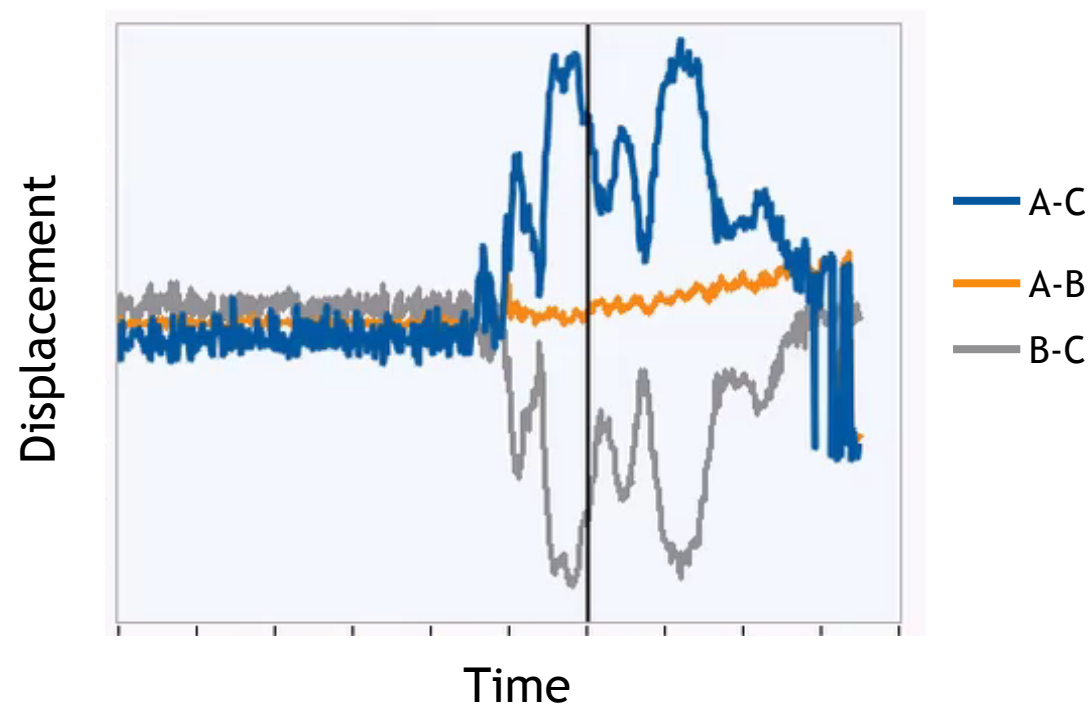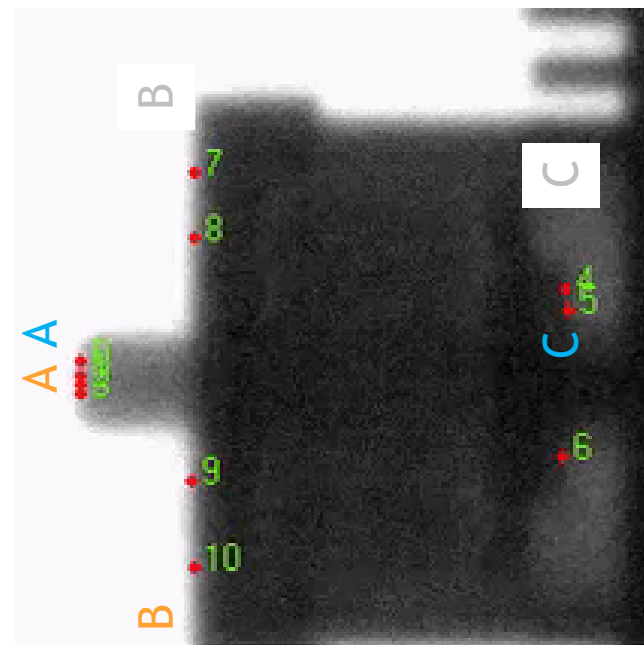Generic edge tracking algorithm in LabView

Typical Behavior During Shock
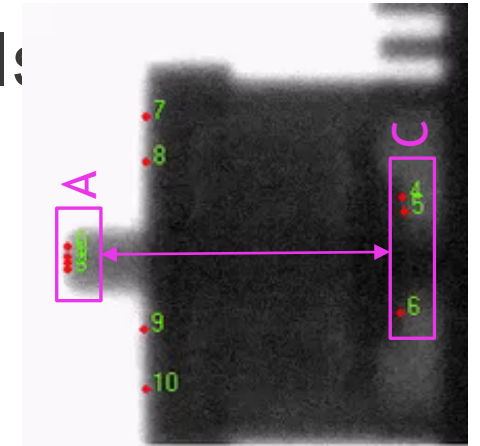
Possible to determine displacement from images

Average multiple points on a surface
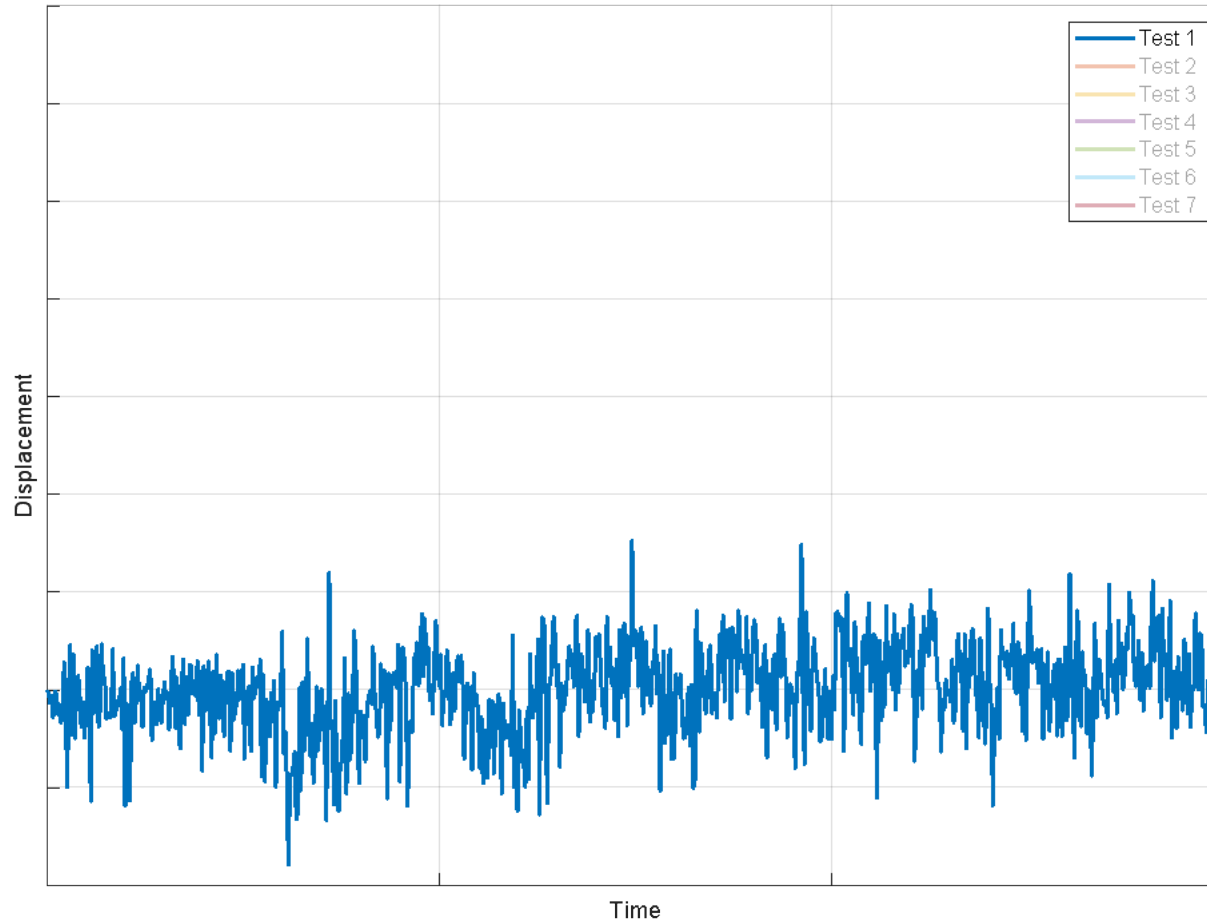
Displacement resolved on order of mils

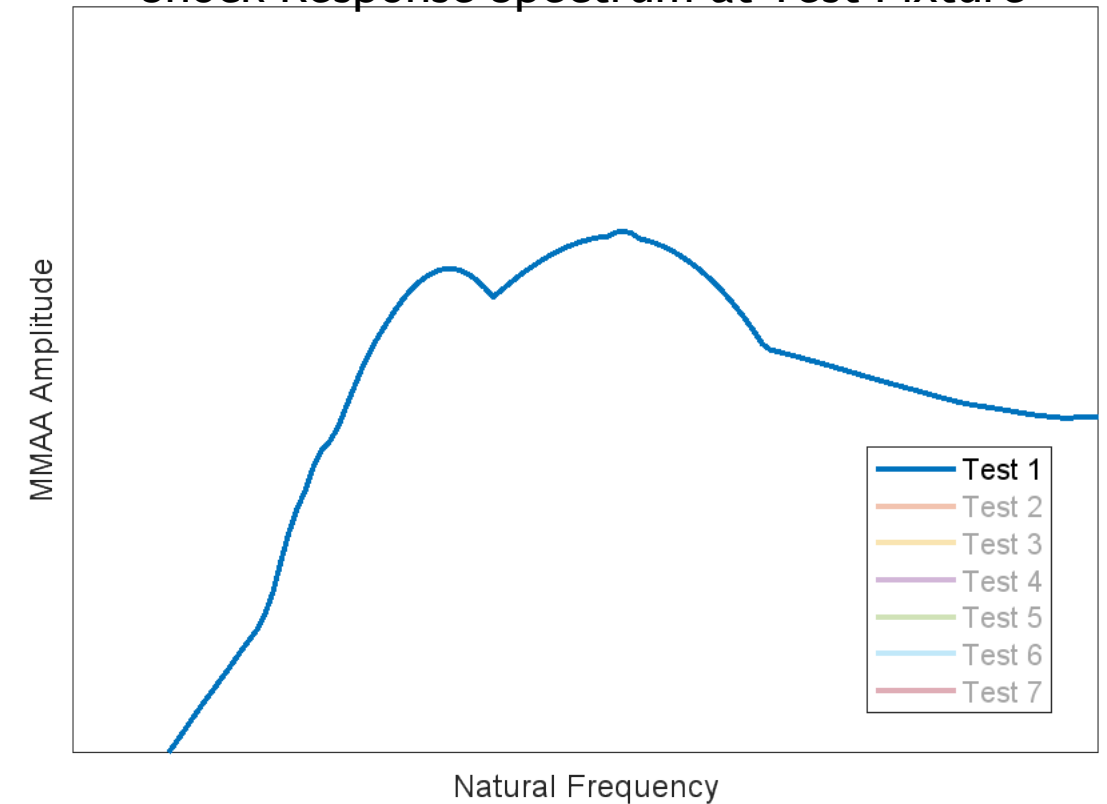Image rate: 25 kHz (image every 40 microseconds)

Monitoring Displacements at Different Input Levels
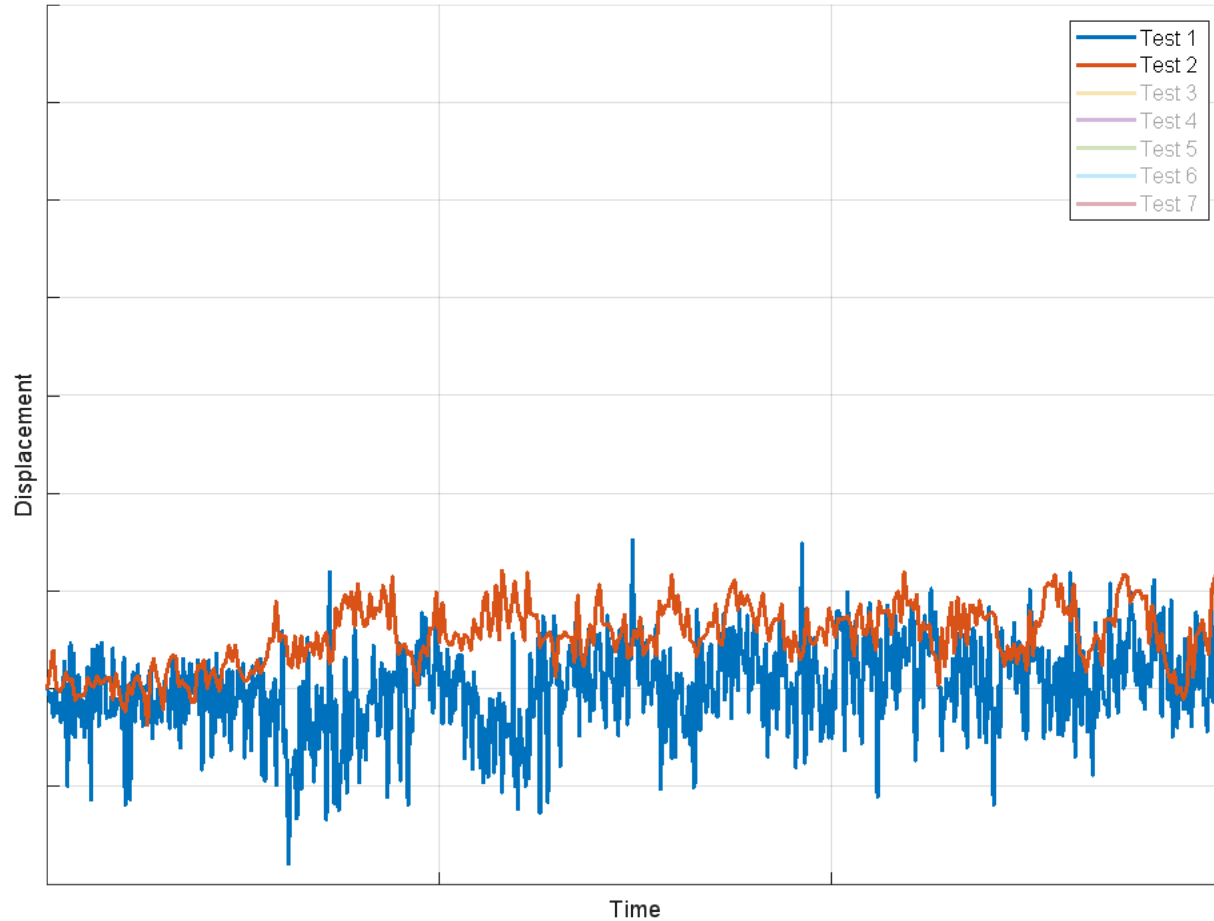
Relative Motion Between Surfaces A & C

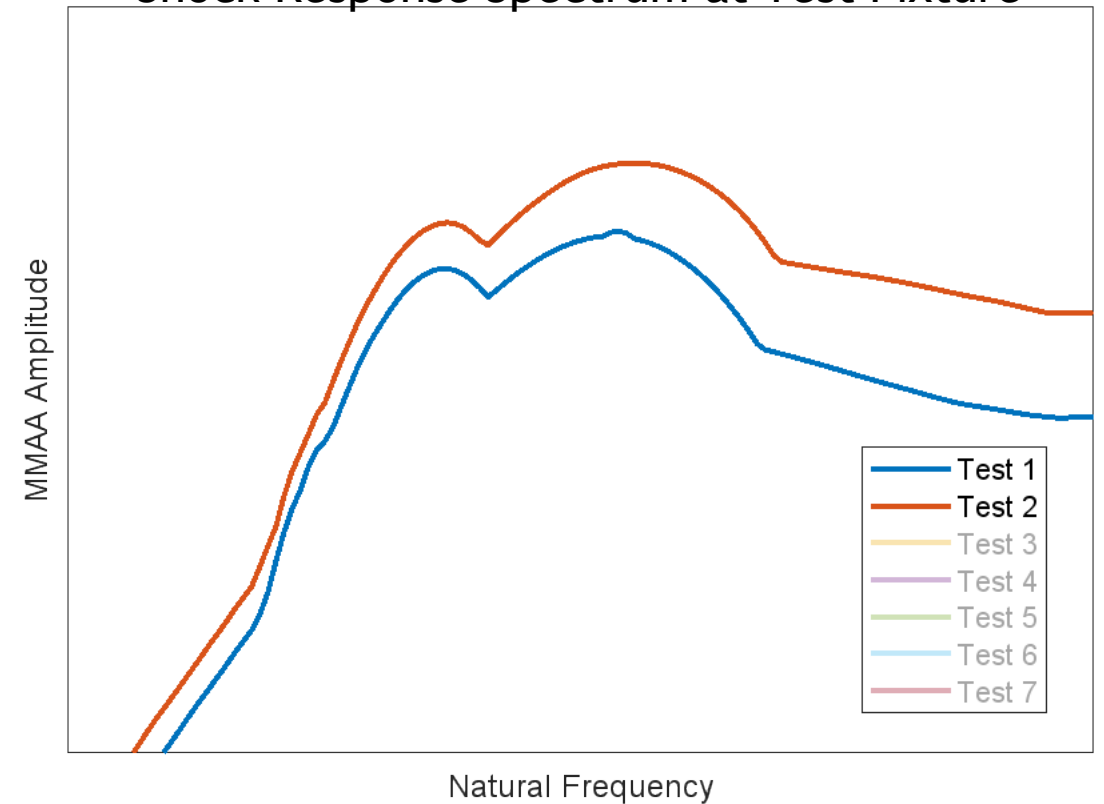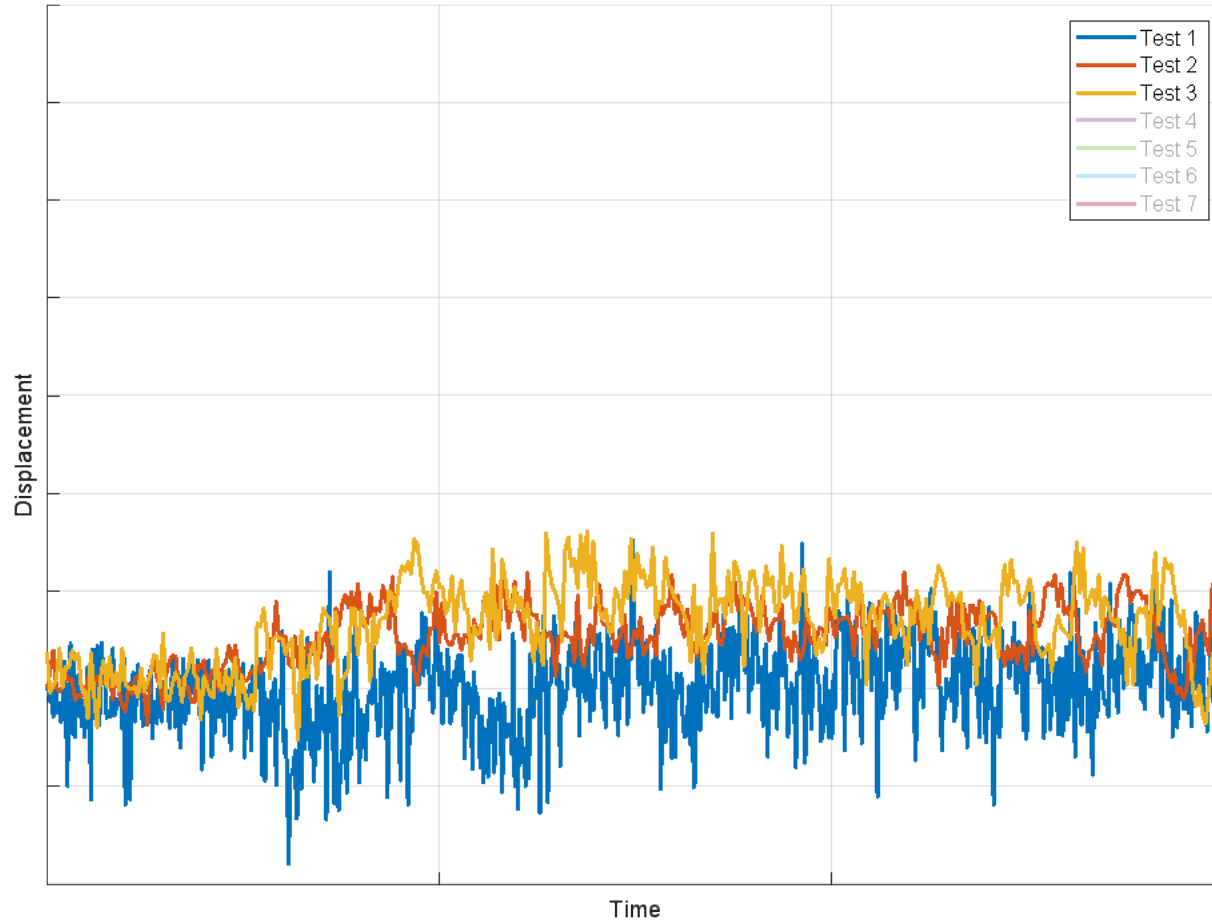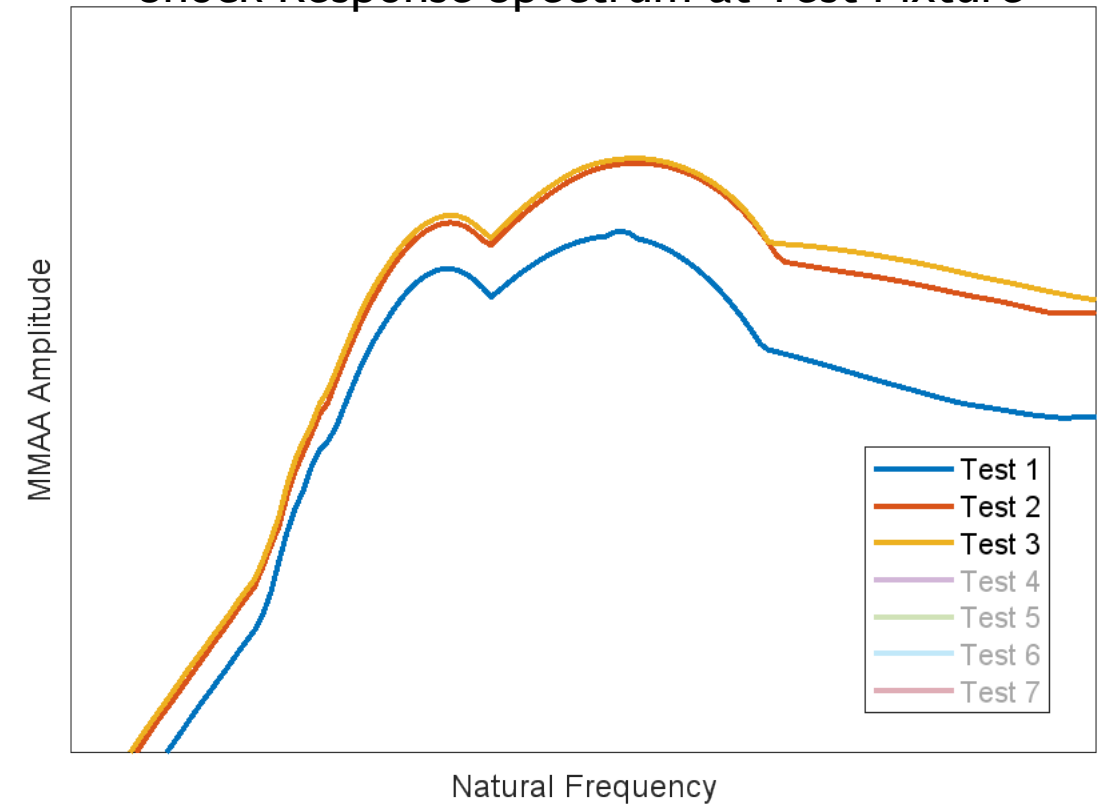### Shock Response Spectrum at Test Fixture

Monitoring Displacements at Different Input Levels

Relative Motion Between Surfaces A & C

Shock Response Spectrum at Test Fixture

Monitoring Displacements at Different Input Levels

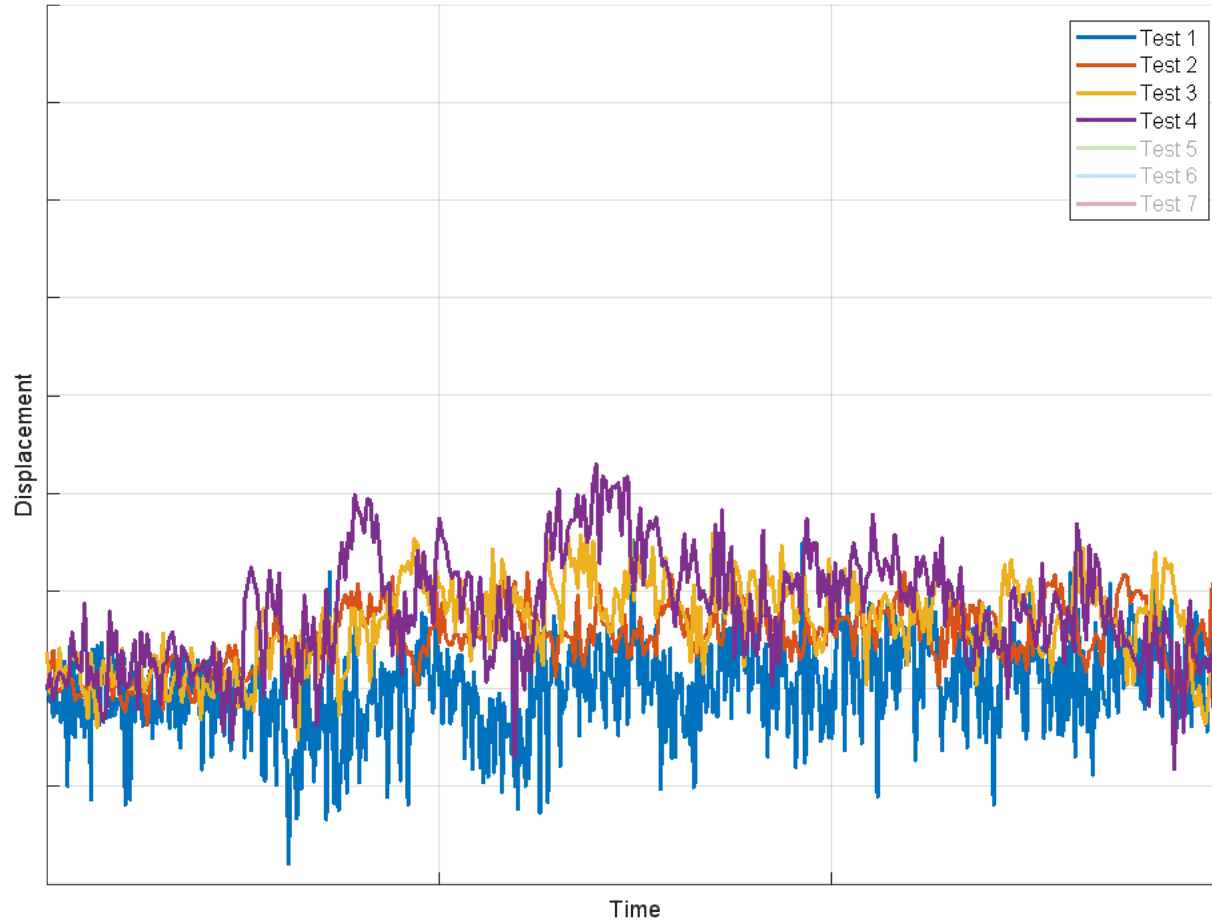Relative Motion Between Surfaces A & C

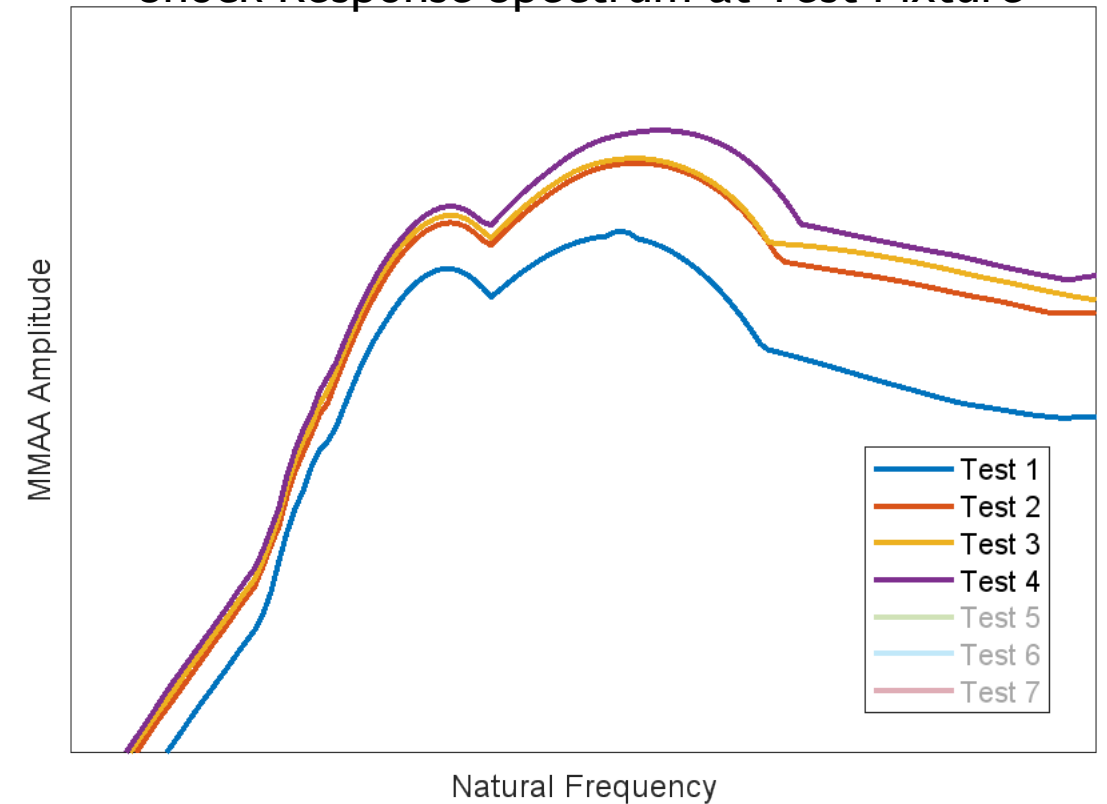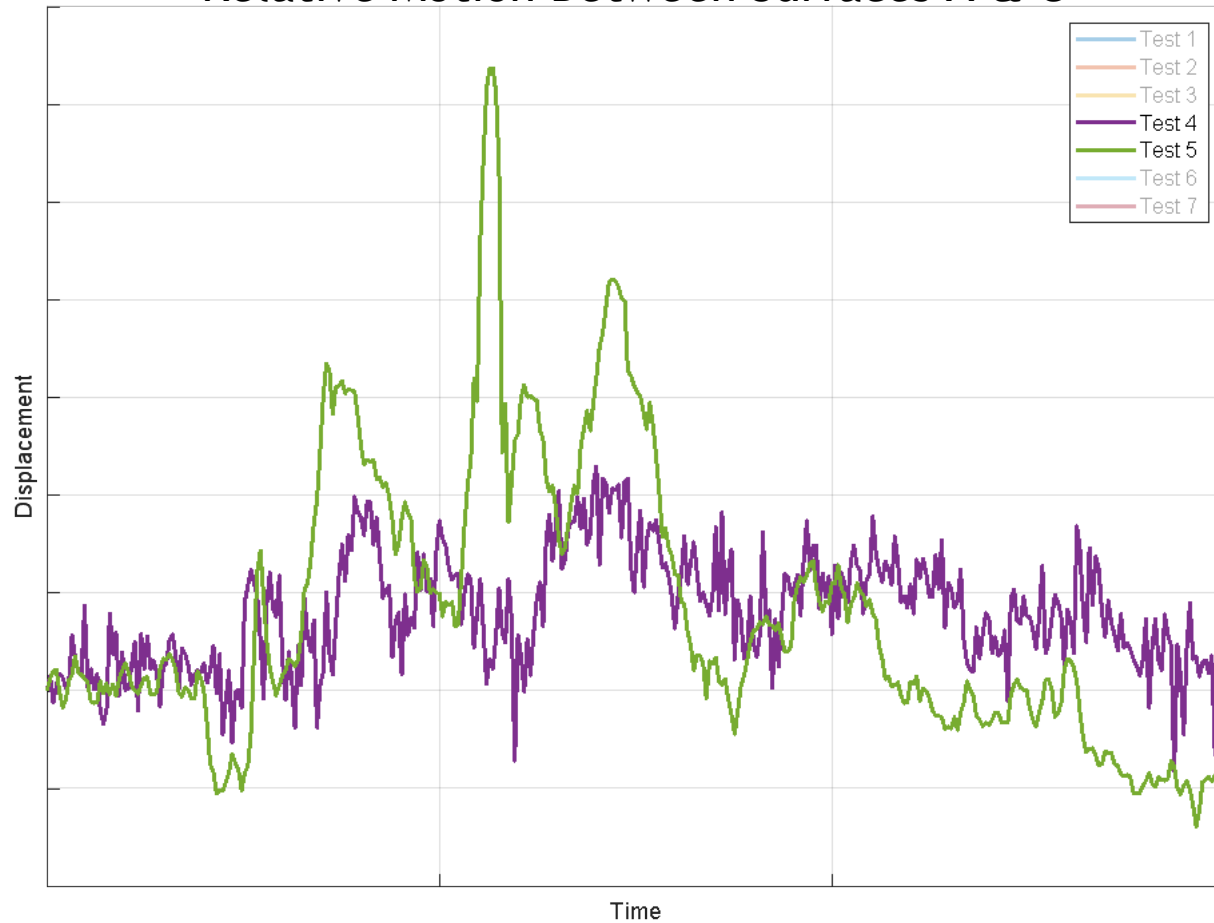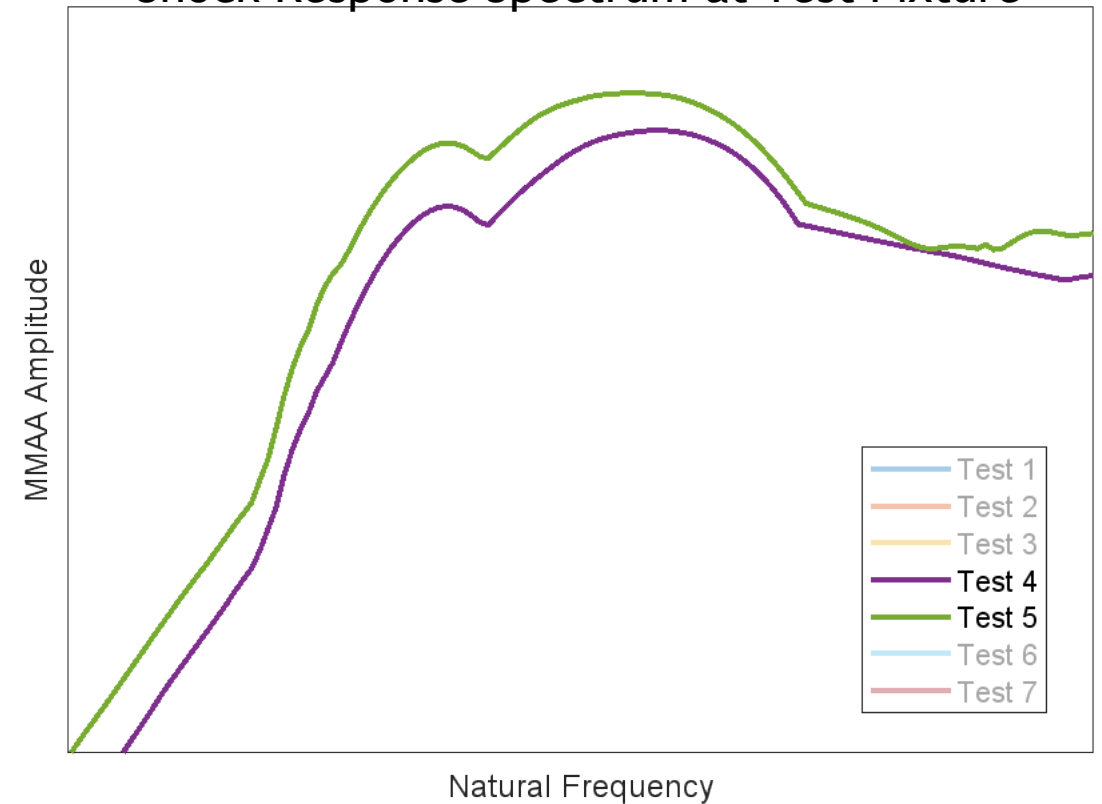Shock Response Spectrum at Test Fixture

Monitoring Displacements at Different Input Levels

Relative Motion Between Surfaces A & C

Shock Response Spectrum at Test Fixture

Monitoring Displacements at Different Input Levels

Relative Motion Between Surfaces A & C
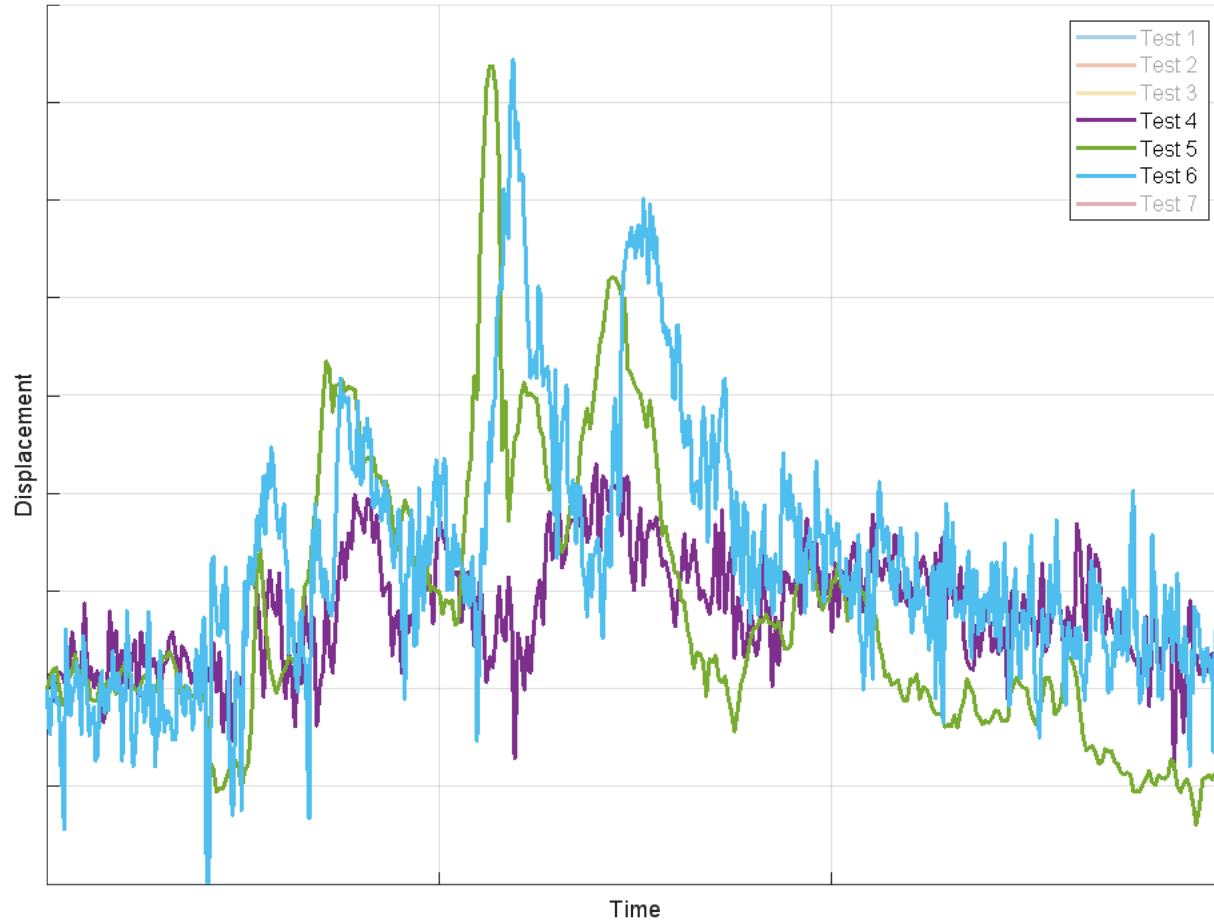

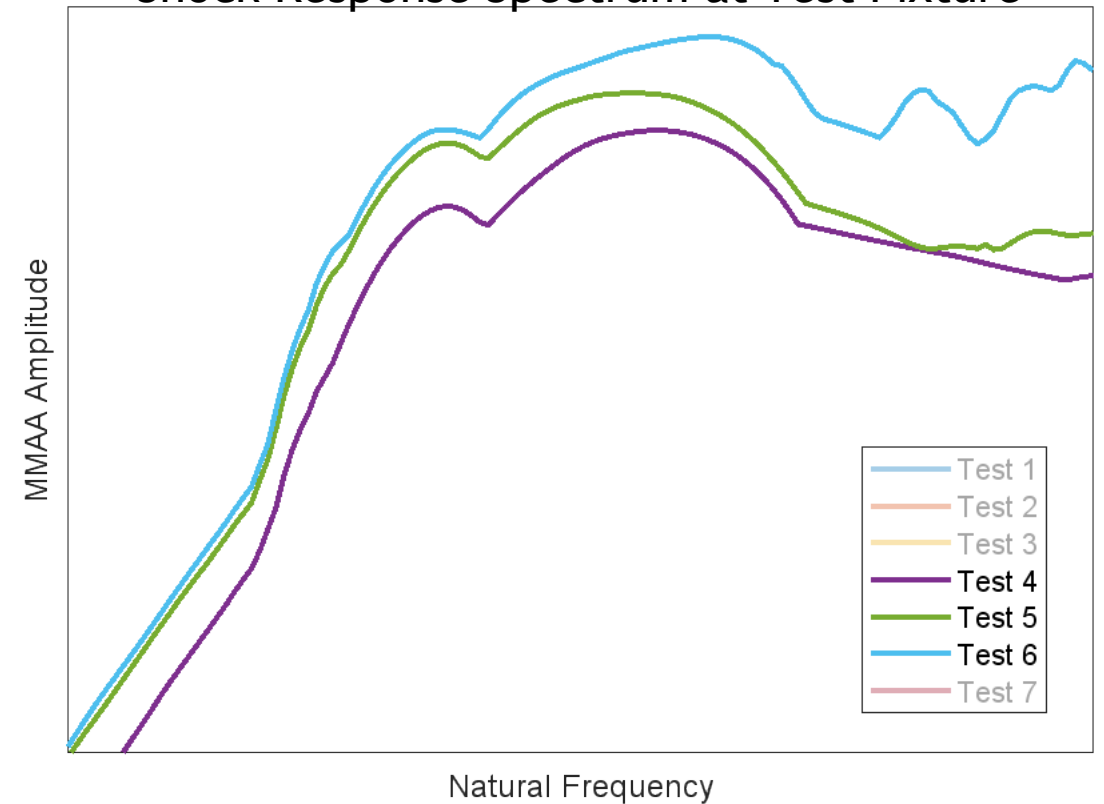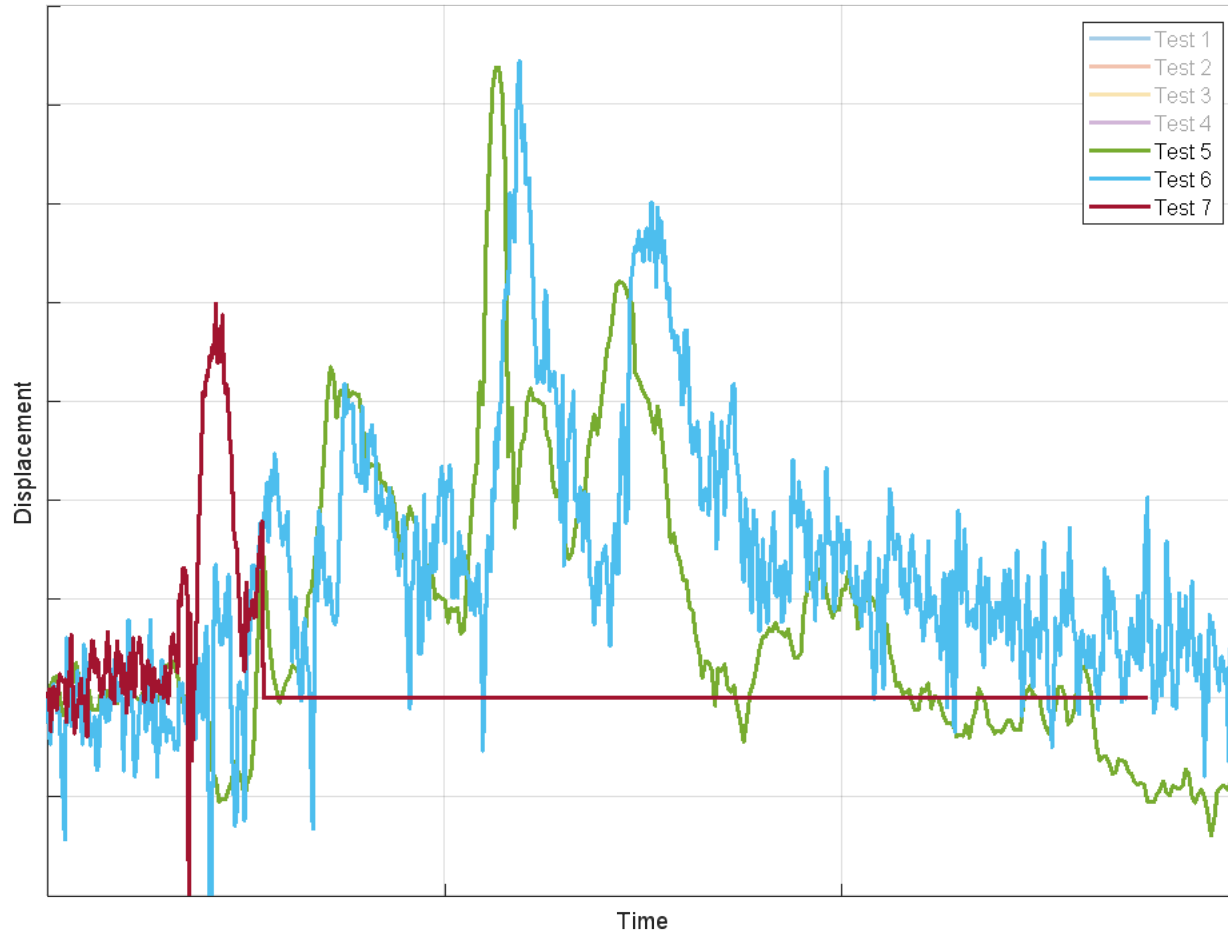### Shock Response Spectrum at Test Fixture

Monitoring Displacements at Different Input Levels

Relative Motion Between Surfaces A & C

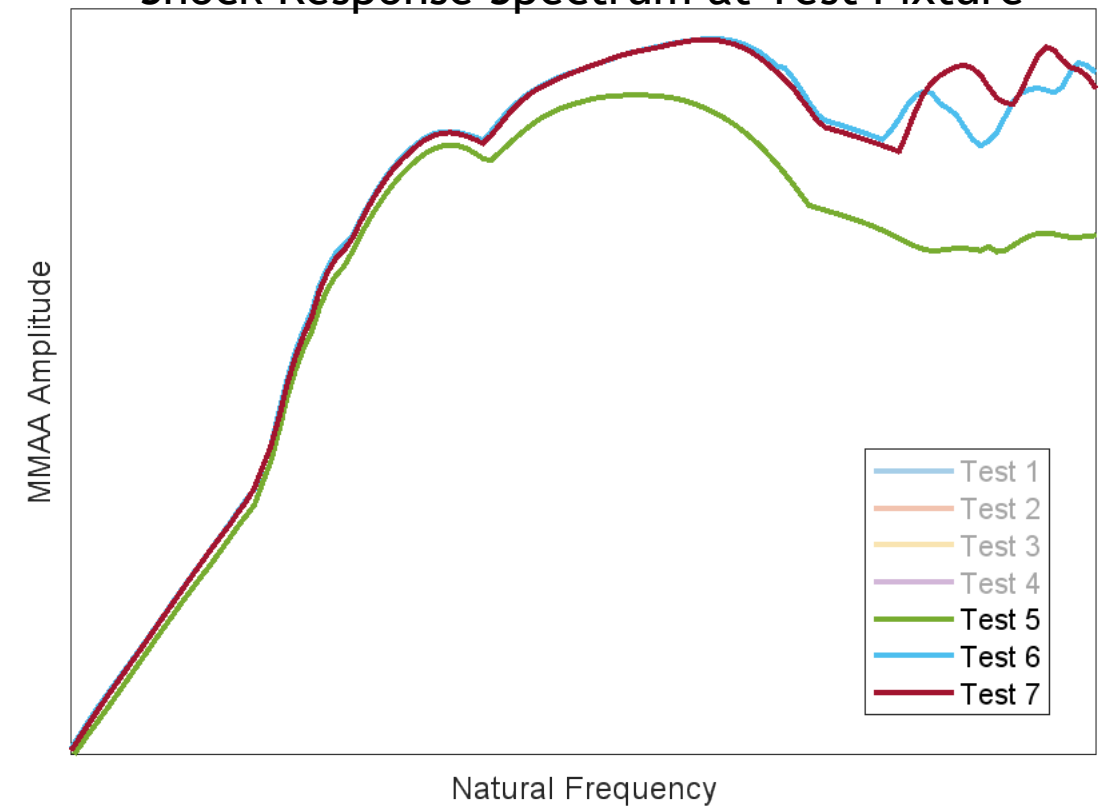Shock Response Spectrum at Test Fixture

Monitoring Displacements at Different Input Levels
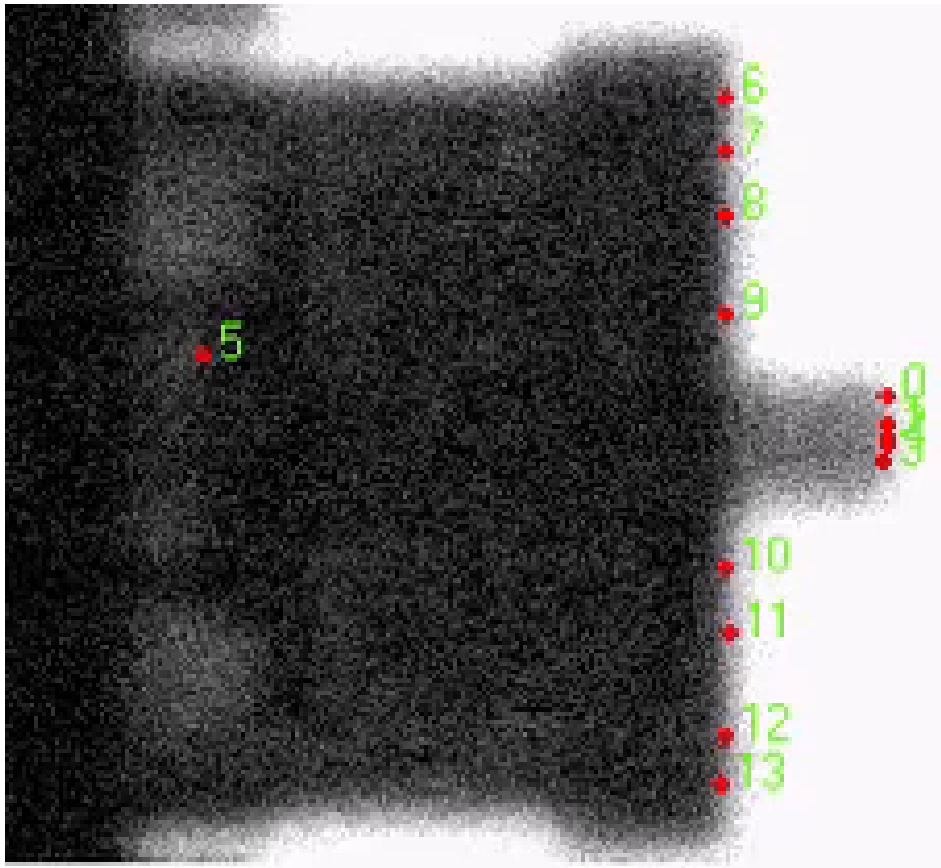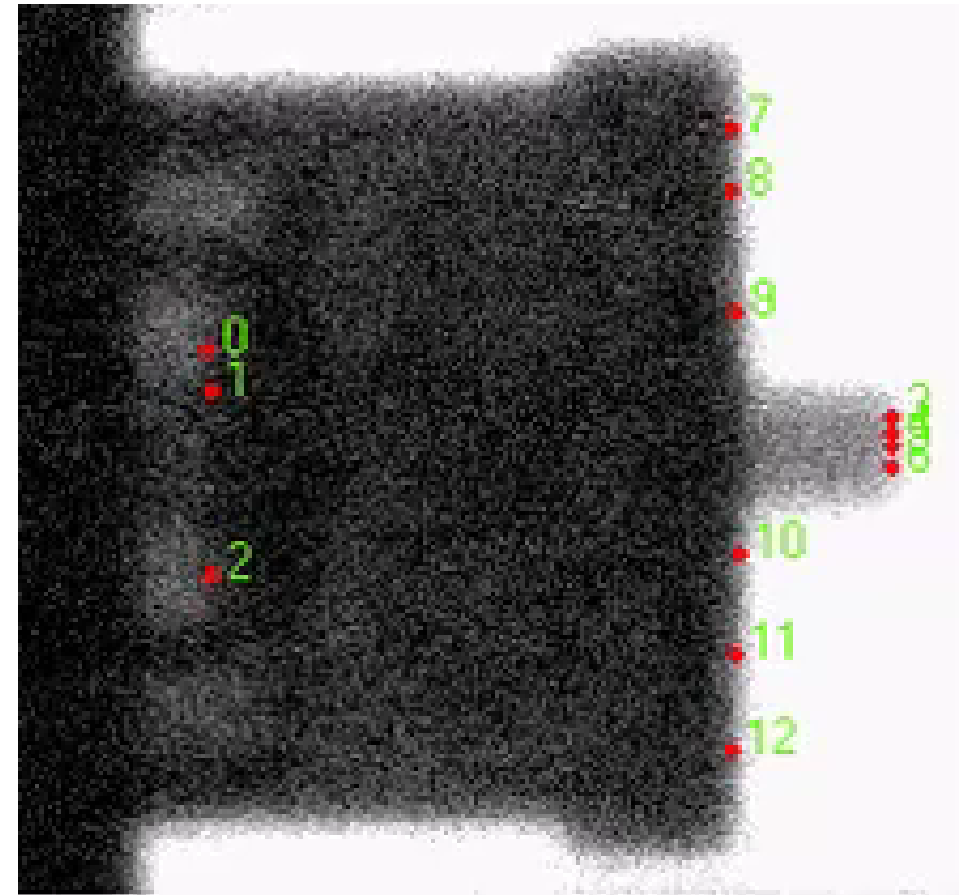

Relative Motion Between Surfaces A & C

Shock Response Spectrum at Test Fixture

Device Responses for Similar Input

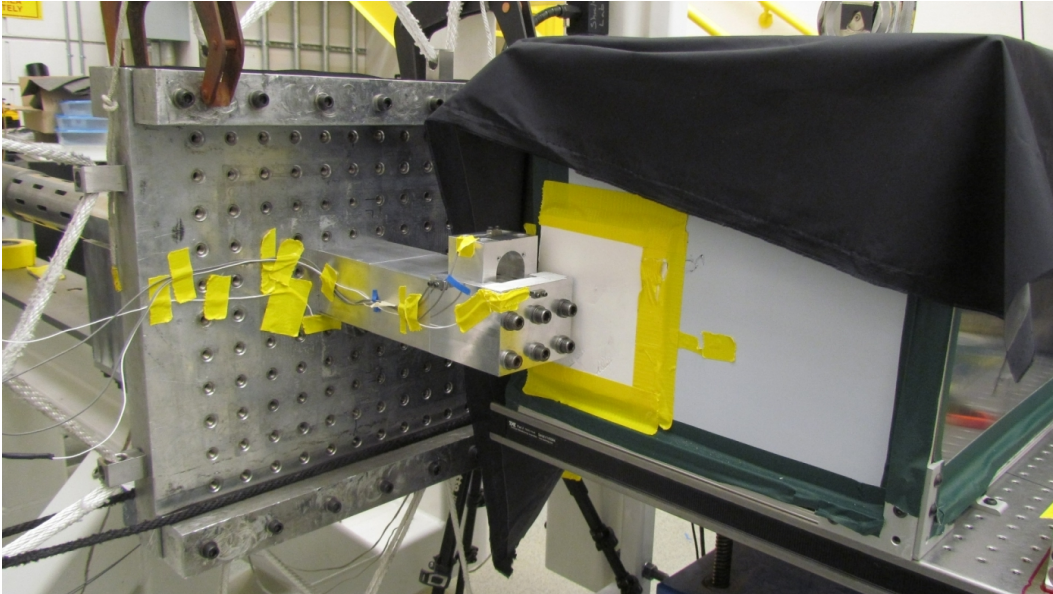Separation occurs in Test 7 (Watch points 0, 1, 2)
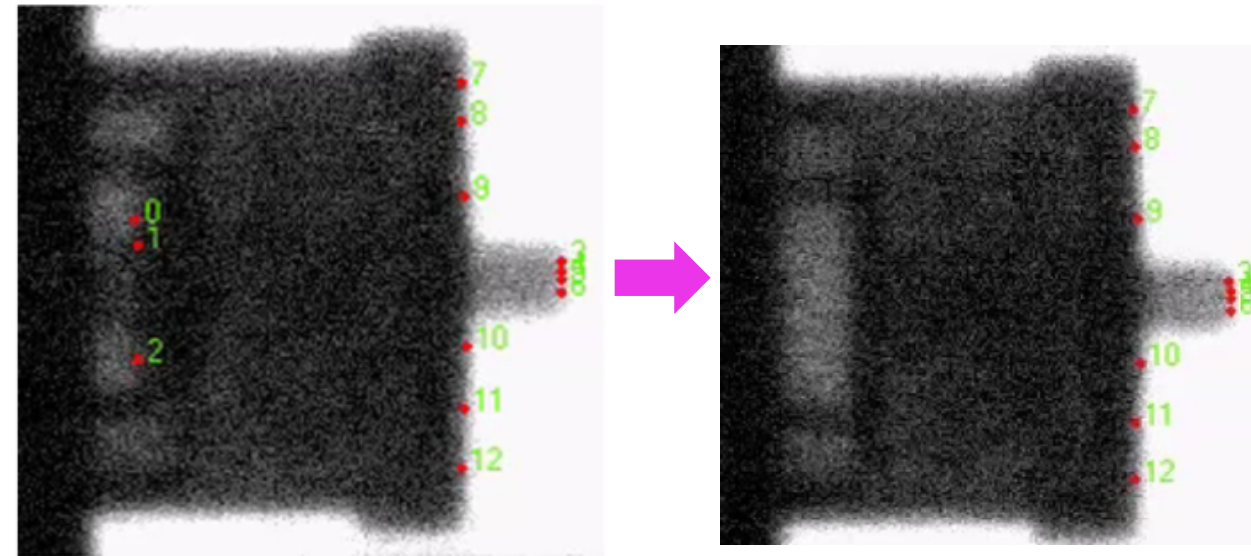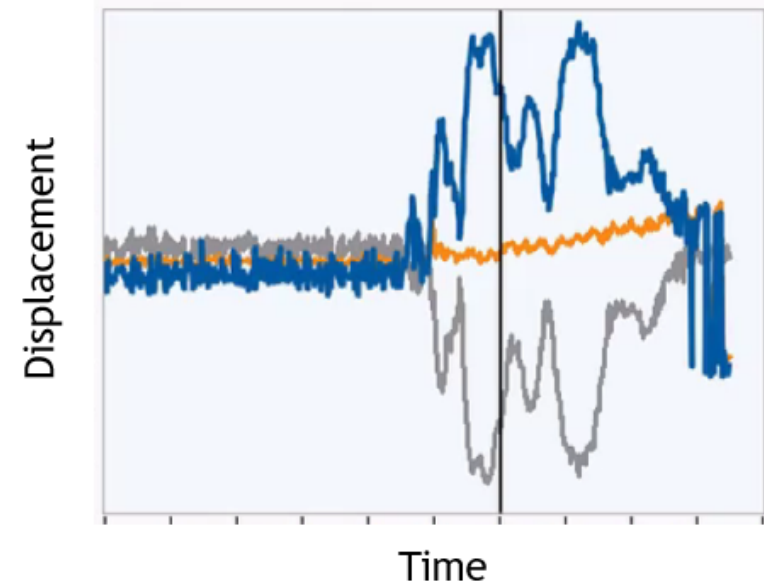

Test 6

Test 7

Summary

A high-speed camera successfully capture x-ray images of a device under test
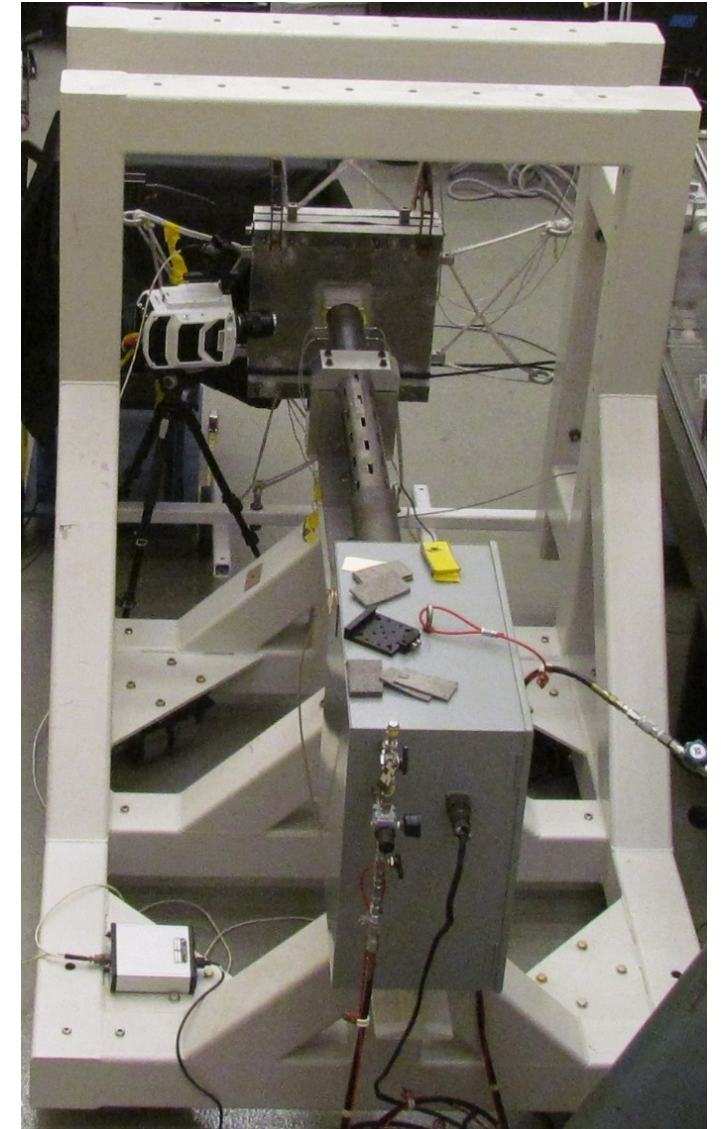

The relative displacement of two surfaces was quantified and increased with increasing SRS amplitude.

A threshold was identified at which the surfaces separated.

Extra slides

Test Setup

All SRS Curves on Same Plot