Effect of Boundary Conditions on Drop Testing

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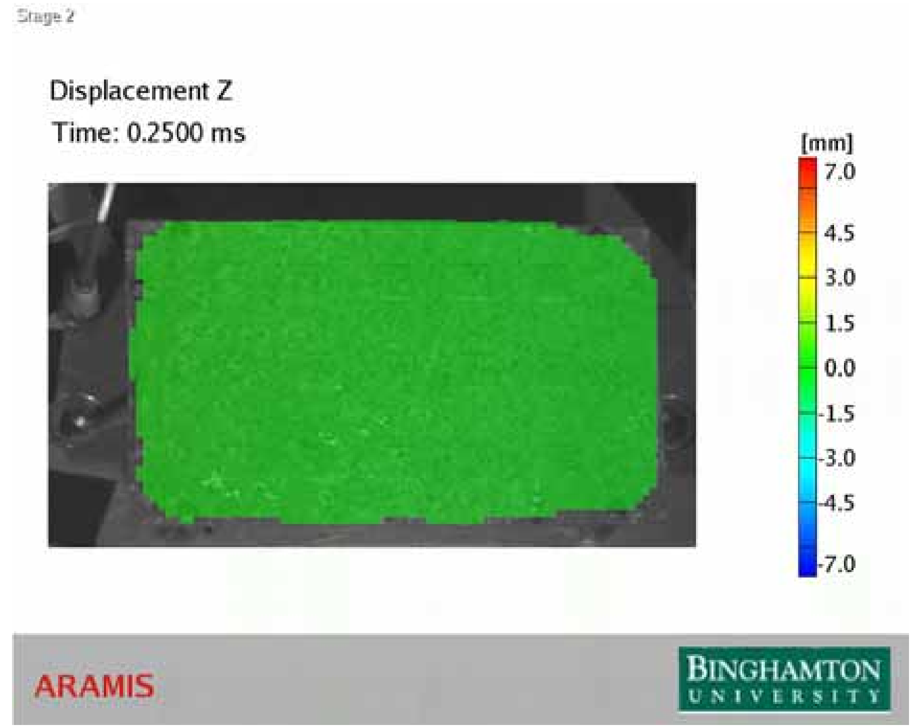
Outline

- Introduction
- Experimental Setup and Test Procedures
- Experimental Results and Discussions
- Summary & Conclusions
- Acknowledgements

Motivation

- Situation : Current drop test
  - Accelerometer and strain gage at a point are used to assure proper impact amplitude and duration.
  - Doubtful board to board repeatability
  - Drop impact life data tend to have big scatter
- Reasoning
  - Complex nature of drop impact life assessment
  - Various failure mode



Is that all?

Are we comparing apple to apple?

Experimental conditions:

Boundary Conditions …

Objectives

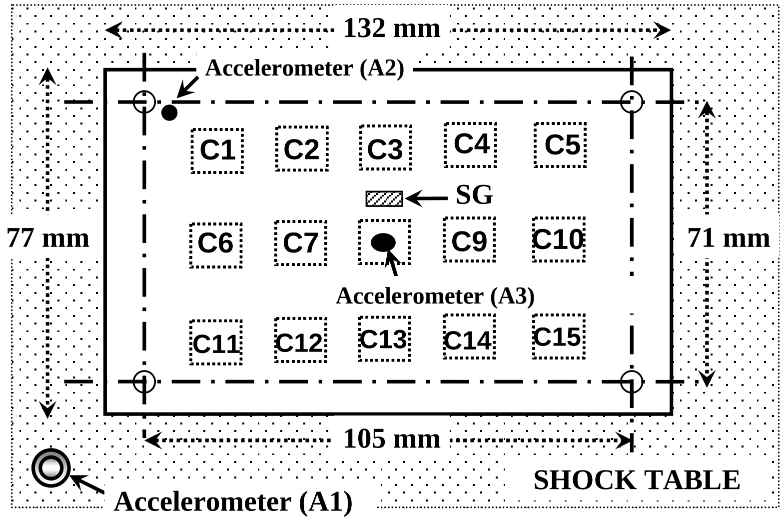
- Develop a non-contact 3D optical measurement technique by integrating high-speed cameras with 3D digital image correlation to characterize the *full-field* dynamic response of the board during drop impact.

- Characterize the effect of various boundary conditions on the PCB response experimentally.
  - Effect of tightening torque of mounting screws.
  - Effect of standoff height.
  - Effect of standoff stiffness evaluated by inserting a compressible material like rubber.

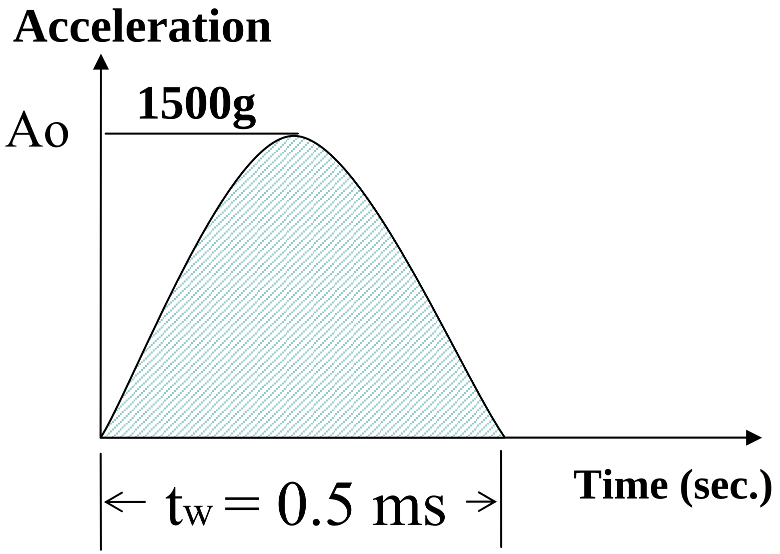
JEDEC Drop Test

Standard : JEDEC22B111

- **Standardizes test board and test methodology.**
  Measures relative performance of different test samples.



Test board layout



Half-sine input pulse

Drop test parameters

- **Peak acceleration**
- **Pulse duration**
- **Pulse shape**

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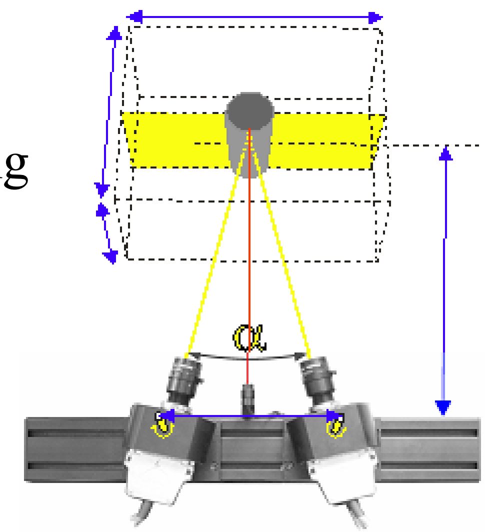
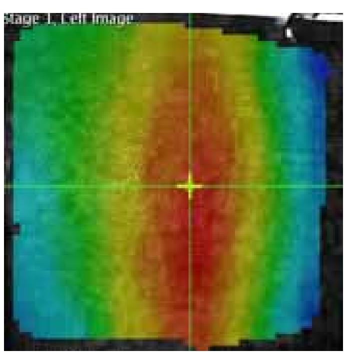
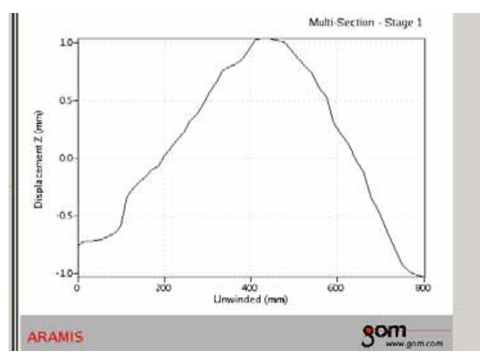
Digital Image Correlation (DIC)

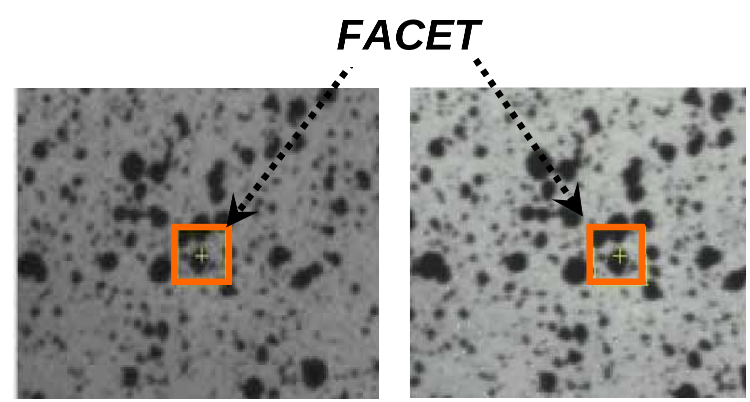
- An optical method to measure deformation on the surface of the specimen. Correlation of reference condition to a series of deformed conditions by tracking the changes in an applied micro pattern.



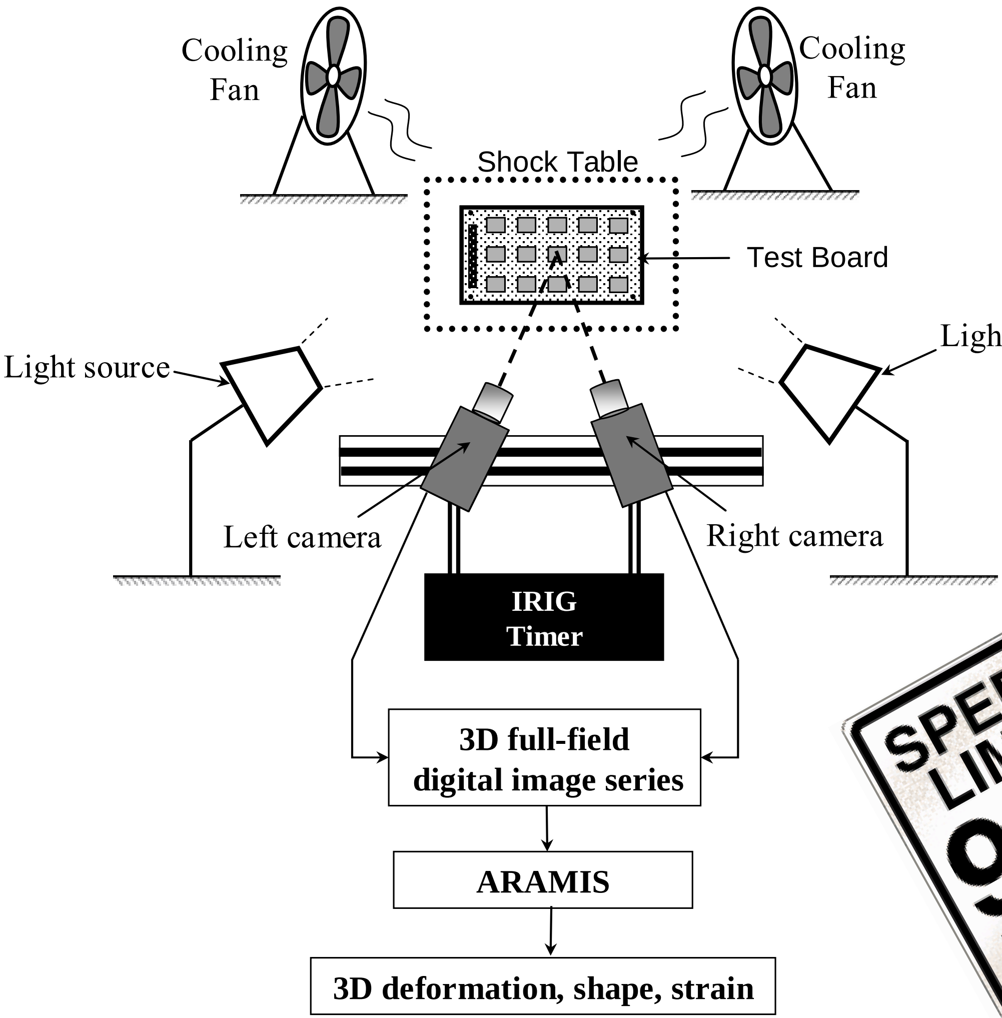
- The Intrinsic Measurement of 3D Coordinates of Virtual Gauge Boxes called Facets (or Subsets). Performs the image correlation algorithm: Pattern recognition, Sub-pixel interpolation and Coordinate triangulation.





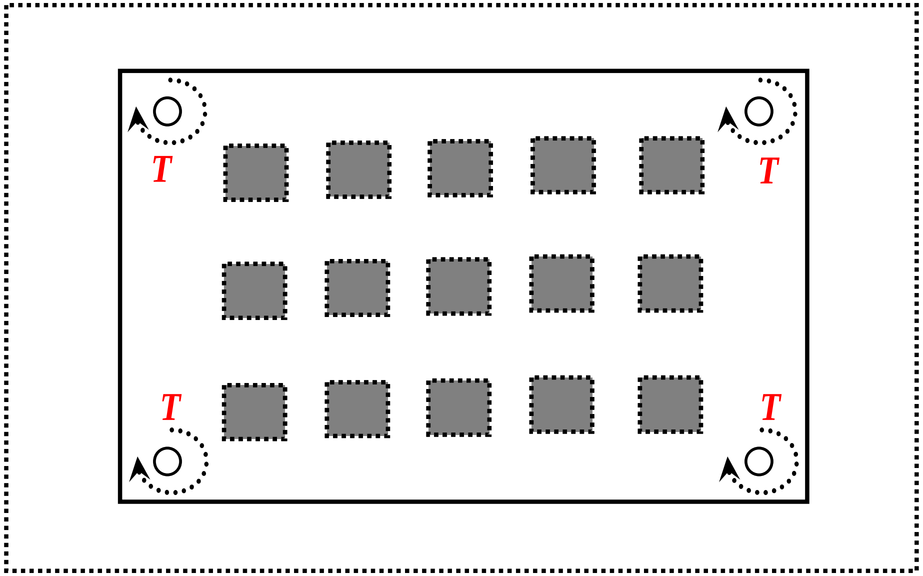


Integration of High-Speed Cameras



Resolution	Speed
1024x1024	1,200
1024x768	1,680
1024x512	2,500
768x768	2,140
768x512	3,190
768x256	6,200
512x512	4,380
512x256	8,550
512x128	16,200
256x256	13,400
256x128	24,900
256x64	43,300
128x128	33,900
128x64	56,300
64x64	66,300
64x32	95,000

Boundary Conditions

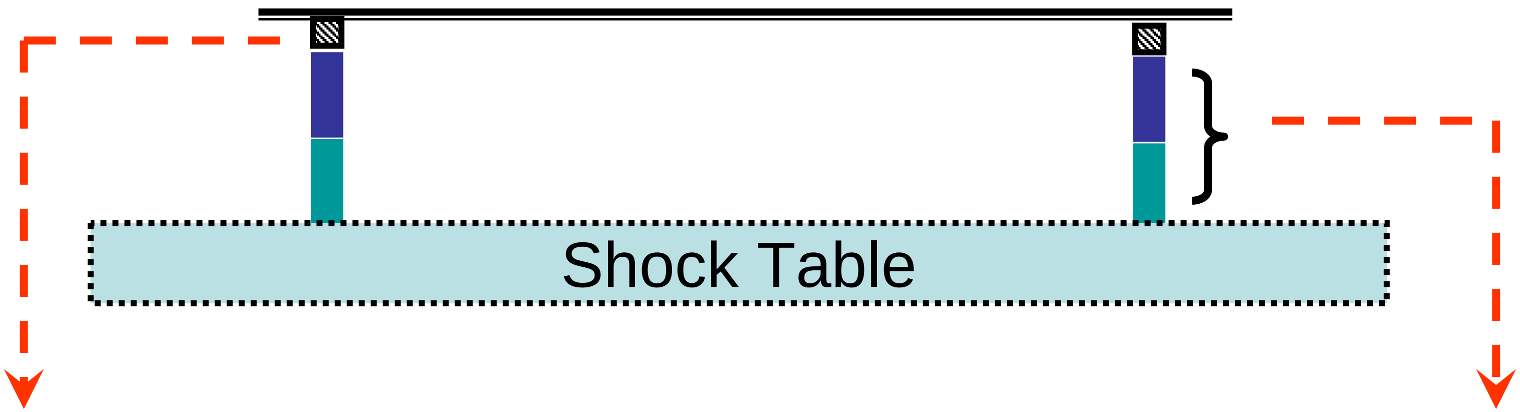


1. Effect of Tightening

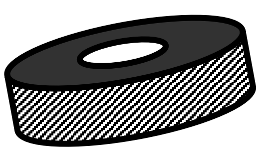
Applying a measured torque at all four Mounting screws of the standoff. Max. Permissible torque ~ 75 oz.-in. for this Design of standoff.

- Case 1: Tight Screw Case
  70 oz.-in. torque
- Case 2: Average tightening,
  40 oz.-in. torque
- Case 3: Loose Screw Case
  5 oz.-in. torque

Boundary Conditions



2. Effect of Rubber Shim



- Compressible material
- Type: Circular cylindrical
- Thickness: 1.5 mm
- Outside diameter : 0.25”
- Inside diameter: based on

Screw size of 4-40.

3. Effect of Standoff height

Hex Standoff like JEDEC

- Screw size: 4-40
- Type: Hex
- 18- 8 Stainless steel
- Outside diameter : 0.25”
- Body length: ½”

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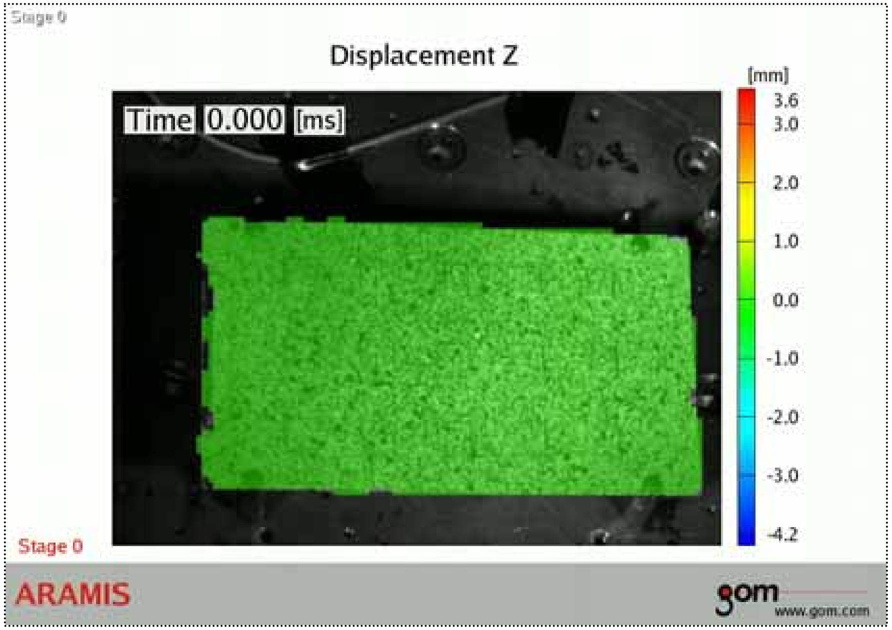
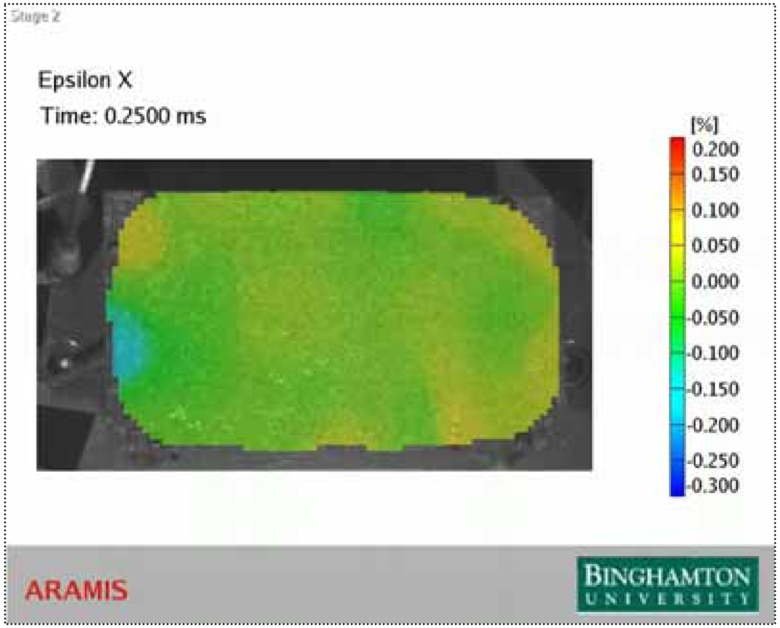
Measurement Results

<u>Full-Field Dynamic Data collected by high-speed cameras at average tightening torque</u>

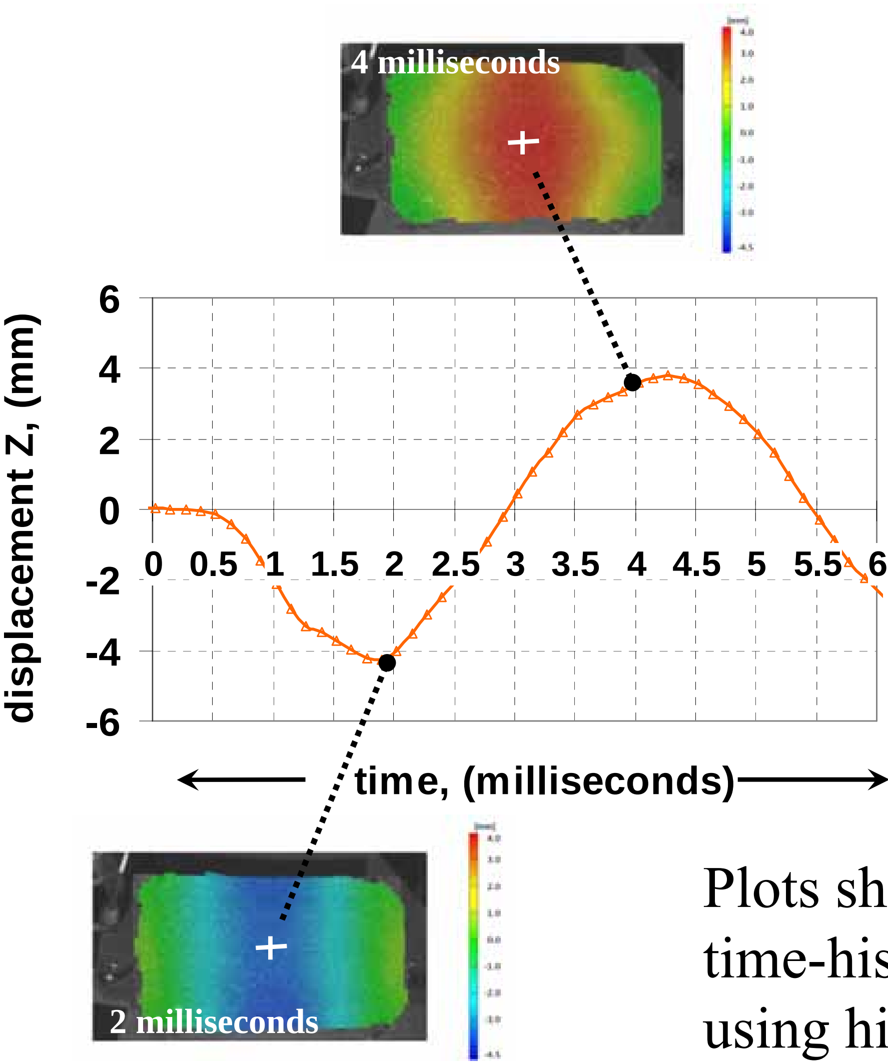


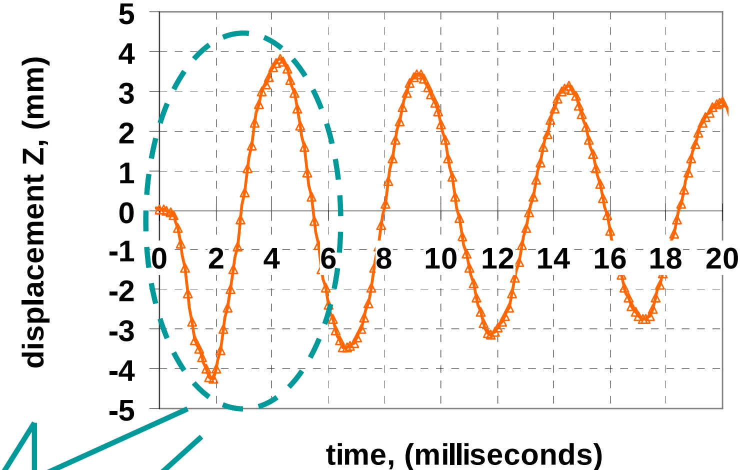
Board Warpage Time-History



Longitudinal Strain Time-History

Warpage Time-History at Average Torque

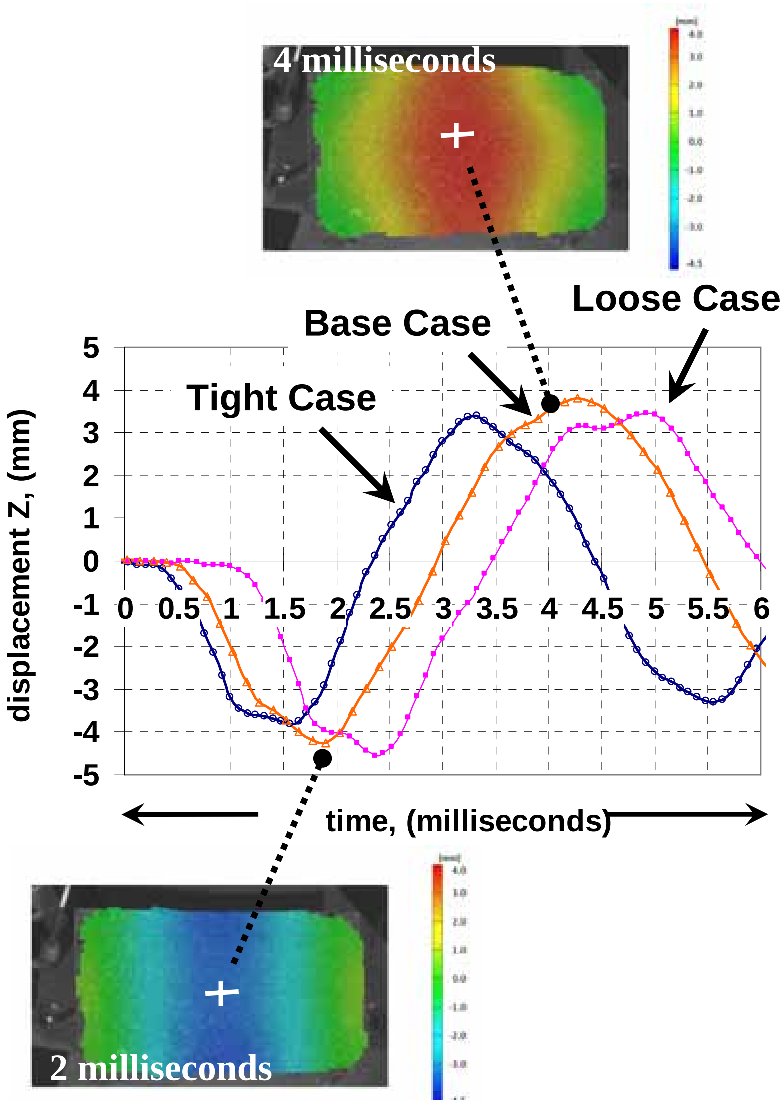




Decay in vibration amplitude with time after impact

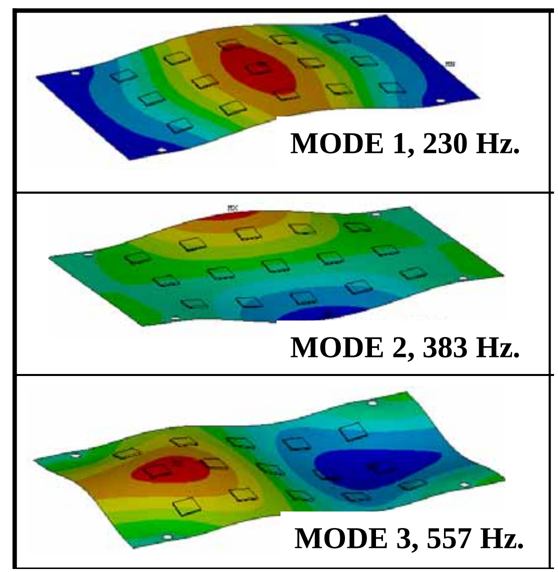
Plots showing the out-of-plane displacement time-history obtained at center of board using high-speed cameras

Effect of Tightening Torque



- Tight Screw Case allows no relative motion Between the board and standoff.

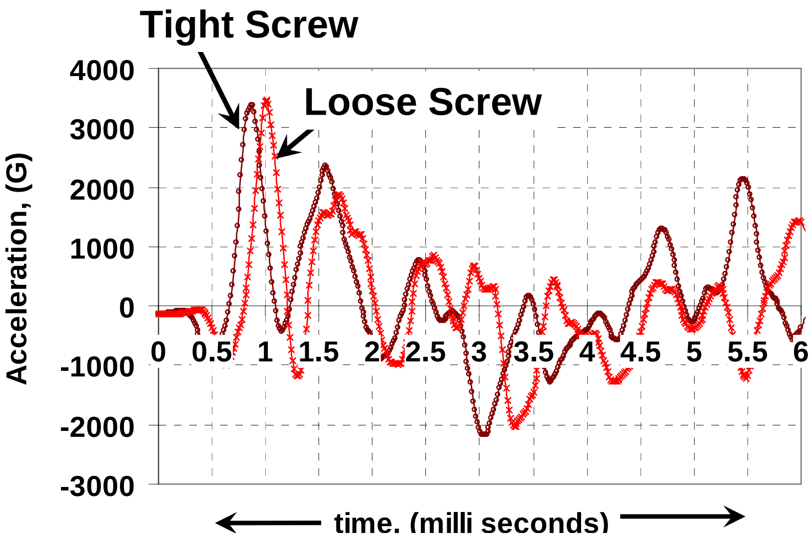
- A modal analysis with all nodes at standoff Constrained for all DOF shows a frequency Close to tight-screw case.

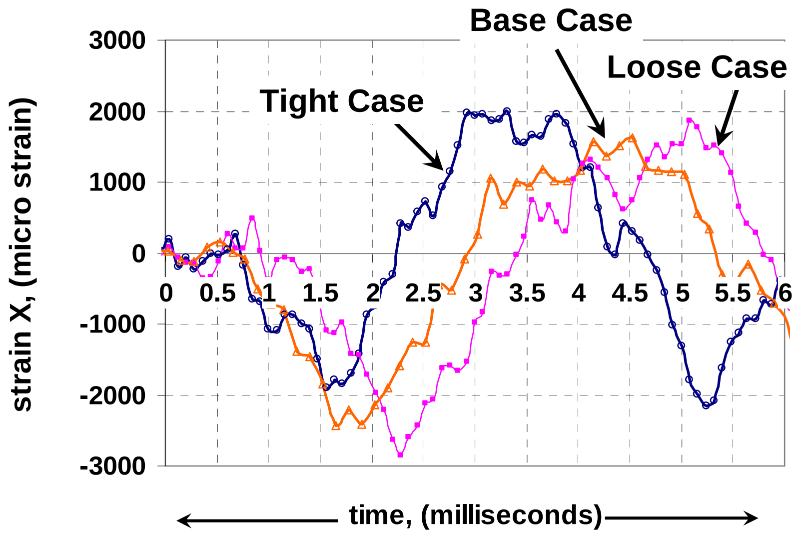


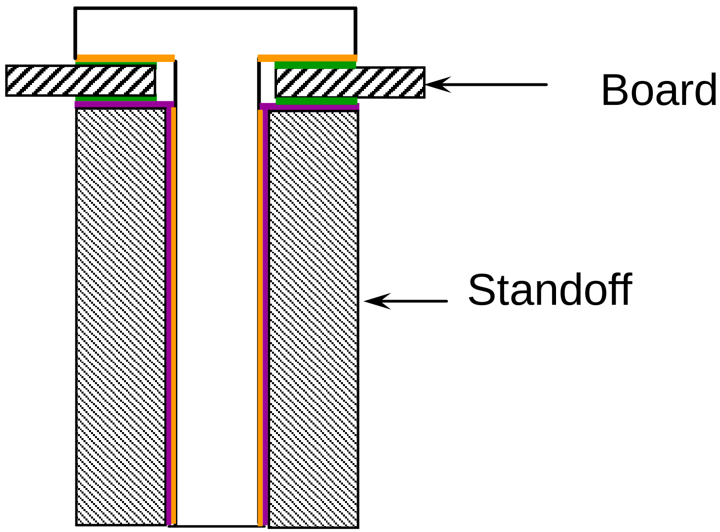
$$\frac{1}{230\ Hz.} \approx 4.35\ ms$$

← Tight Screw

Effect of Tightening Torque

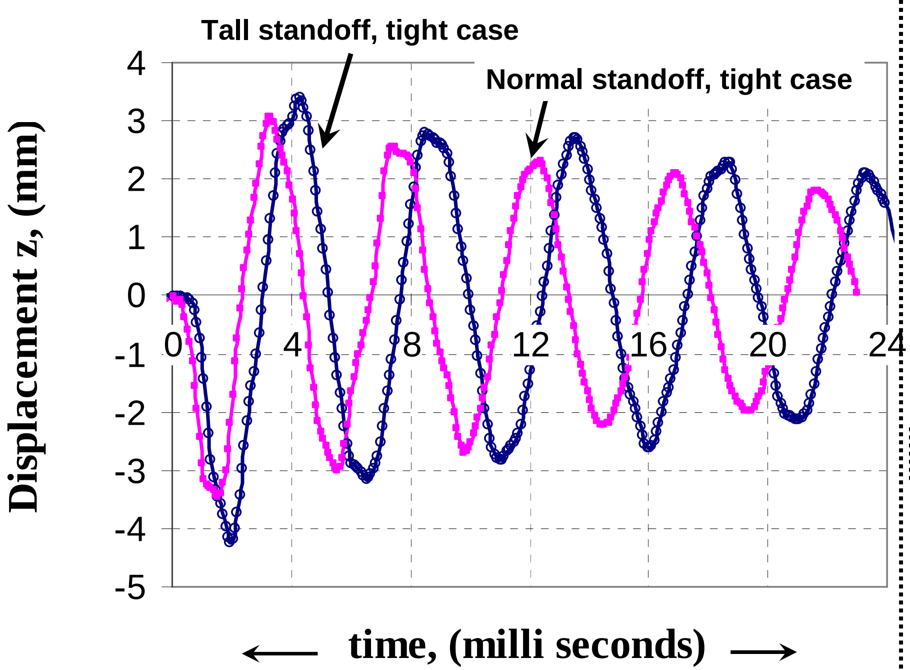






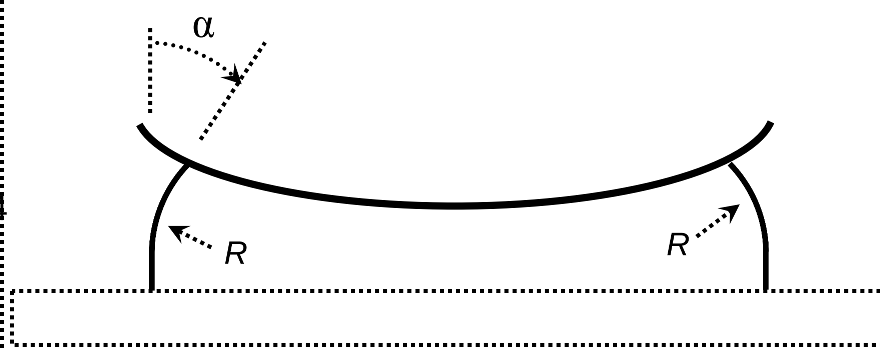
- Higher tightening restricts the relative motion between the board and the standoff.
- The tighter torque case has about 30% higher frequency compared to the loose case.

Effect of Standoff height



- Tall standoff – 25 mm height
- Normal standoff – 12.5 mm height
- Tight Case – 70 oz. in. tightening torque for all screws

Effect of standoff height for Tight Case:

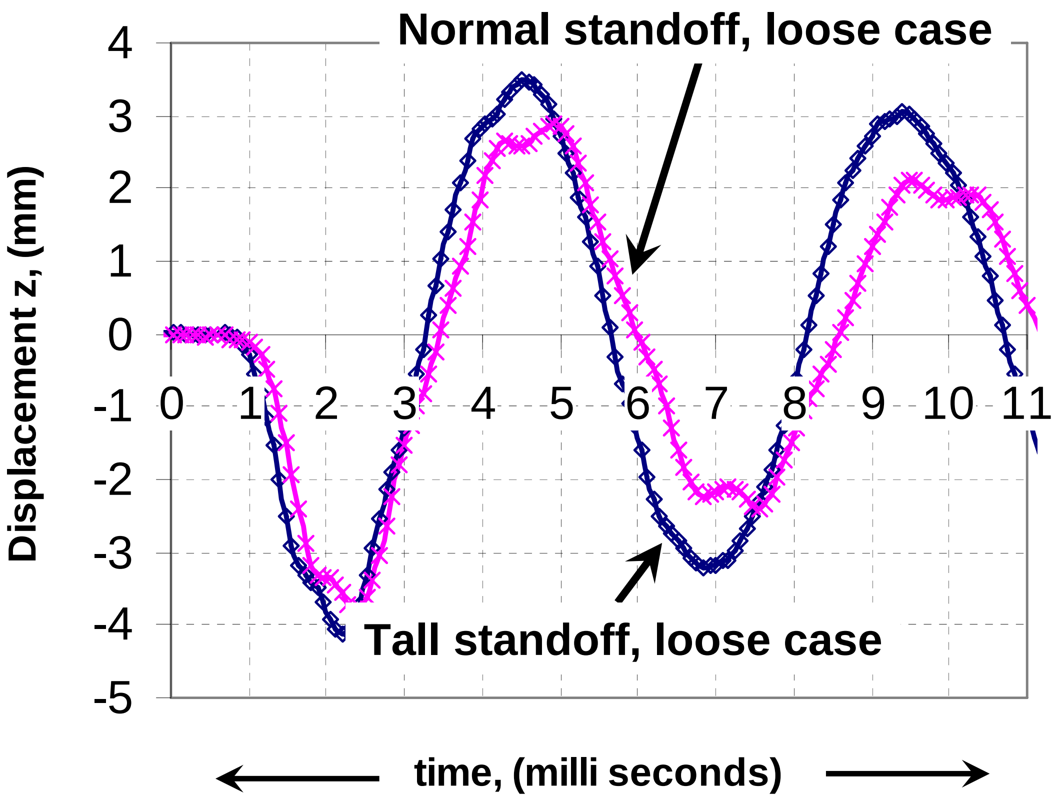


Greatly exaggerated bending of board

- Shorter standoffs tend to resist the board bending and so decrease the peak response and increase the cyclic frequency.

- About 13% decrease in the cyclic frequency for taller standoffs

Effect of Standoff height



Tall standoff – 25 mm height

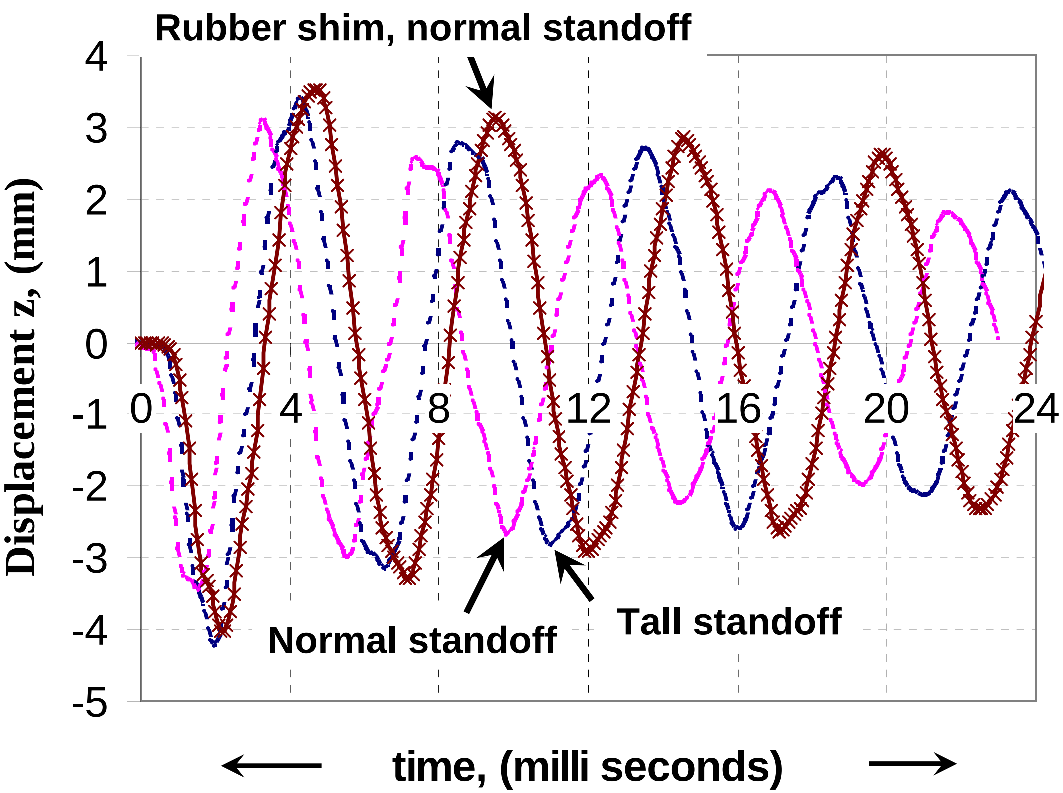
Normal standoff – 12.5 mm height

Loose Case – 5 oz. In. torque for all screws

Effect of standoff height for Loose Case:

- Standoffs try to bend-in while the board undergoes vibrations due to drop impact.
- The effect of height of standoff is not significant for a 'Loose Case'.
- The 'Loose Torque' permits enough relative motion to offset the effect of standoff height.

Effect of Rubber Shim



Tall standoff – 25 mm height

Normal standoff – 12.5 mm height

Rubber shim – 1.5 mm thick

Effect of Rubber shim on Tight Case:

- Rubber shim compresses, thereby enabling higher initial tightening
- The frequency starts relaxing with passing time. Meaning each bending cycle takes longer time to complete.
- The rate of decay in response magnitude is higher for 'rubber shim' case.

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Summary and Conclusions

- A 3D non-contact optical measurement technique has been developed by integrating high-speed cameras with digital image correlation to accurately measure the *full-field* dynamic response of board during impact

- Effect of Boundary conditions were quantified
  - Tightening torque resists the board bending. 'Tight screw' case has a frequency 30% higher compared to a loose screw case. Also the magnitude of response is larger for a 'Loose Screw' case.
  - Height of standoff contributes to the resistance of board in bending. Taller standoff gives a higher response magnitude and smaller cyclic bending frequency compared to a shorter standoff.
  - Standoff height had no effect on the bending frequency for really loose screw condition because of higher relative motion present due to lower tightening.
  - A compressible material like rubber lowers the cyclic frequency. Initially, the material allows higher tightening.

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