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An experiment setup for studying the effect of bolt torque on damping

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Experimental Vibration Analysis for Civil Engineering Structures

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Knowledge of Damping is Required in Prediction of Response

Mechanical environment:

- Collision/impacts
- Moving loads
- Base shaking
- etc

→

Structural Dynamics:

Natural frequency

Mode shapes

Nonlinearity

Contacts

Damping

→

Response:

- Deformations
- Resonant vibrations
- Stresses
- etc

→

Failure ?

- Fracture
- Non-function
- etc

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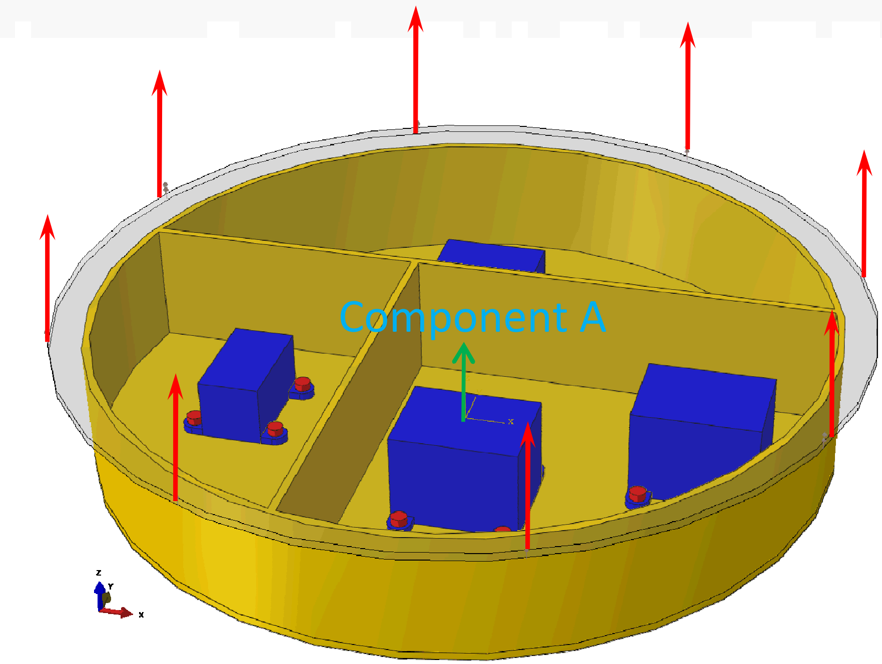
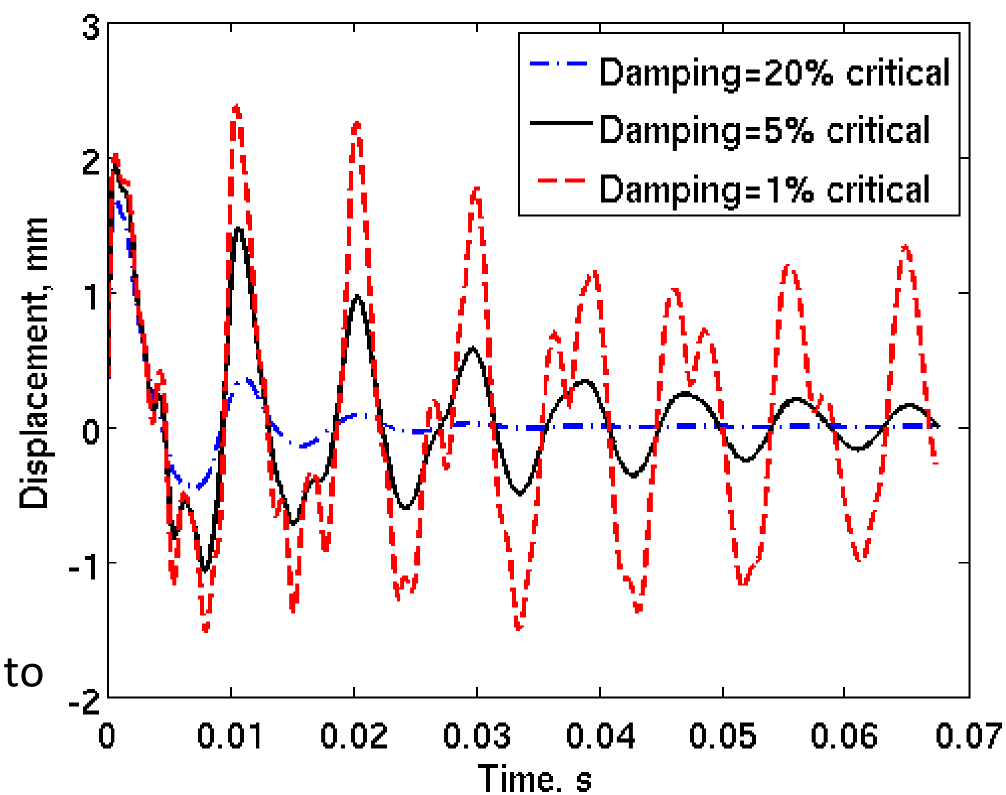
Damping determines shock transmission to components.

Shock acceleration around rim



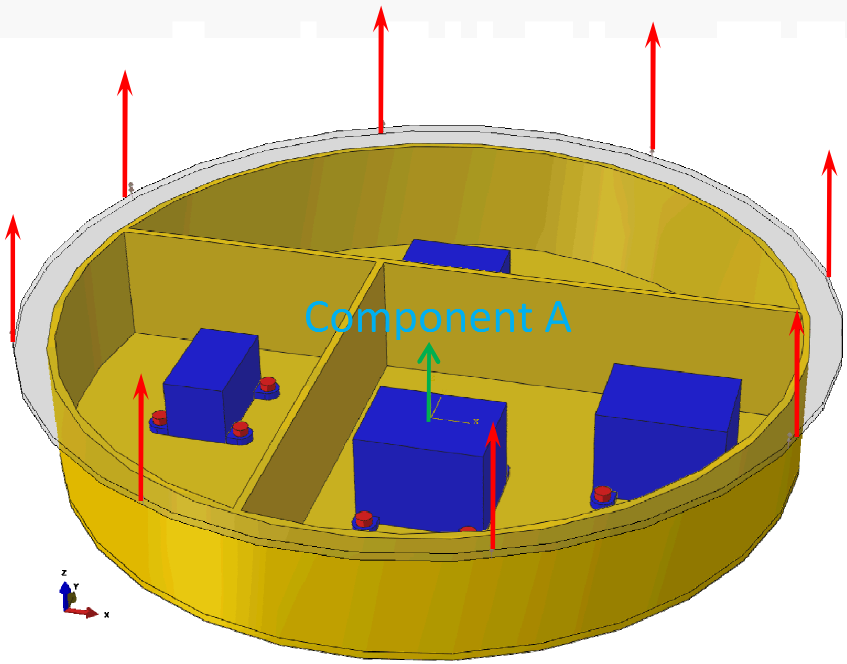
Displacement of component A



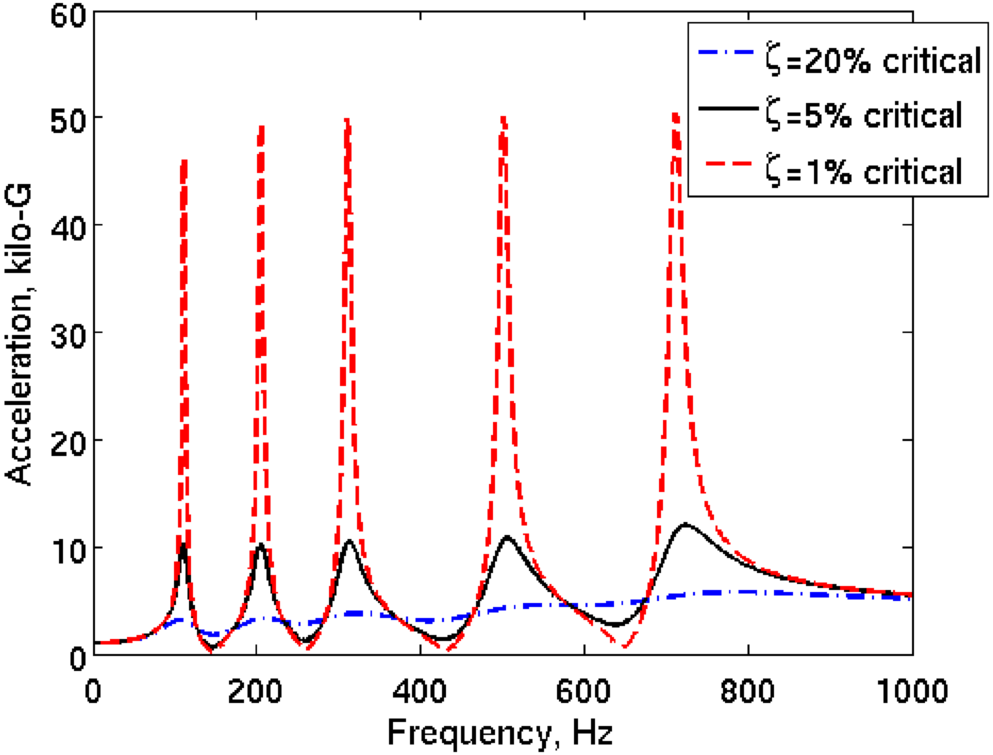
High, “lingering” vibration has been shown to cause damage to a component under resonant-plate test.

Damping determines resonant effects on components.

1 kilo-G oscillation around rim



Acceleration at component A



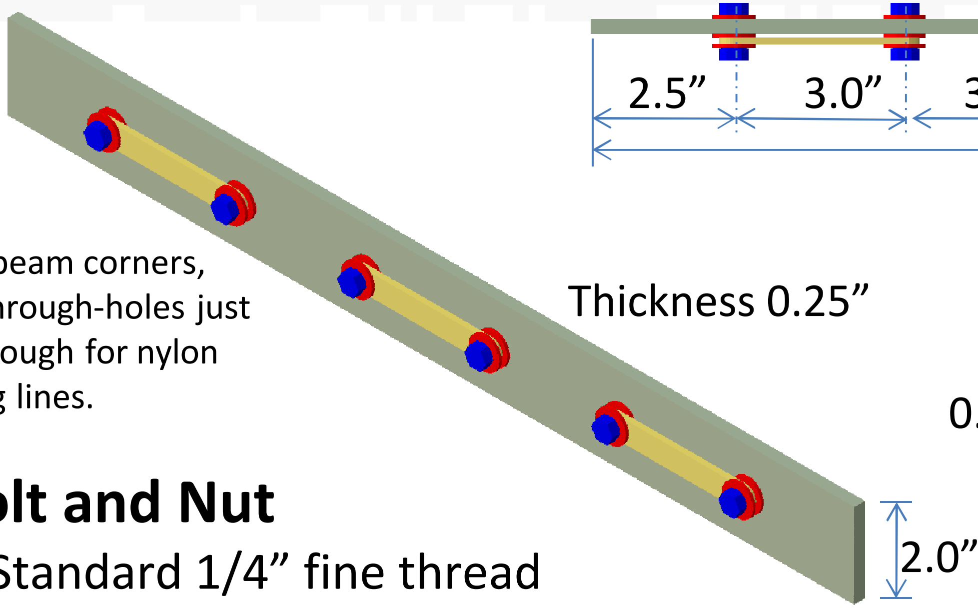
Damping is the only factor that limits the resonant response.

Bolted joints dominate damping in many cases

- Damping sources:
  - Energy dissipation within material: small in metals.
  - Joints, especially those that undergo macro-slip/rubbing
  - Other interfaces
- The research was on a structure with many bolted joints.
- Damping due to joints has been studied at Sandia for almost a decade, mainly on rigid members.
- The experiment discussed here was done on a *flexible* structure with *numerous* bolted joints with *washers.*
  - Only preliminary look at such structures
  - Washers add interfaces.

Test object is a beam with three links bolted with a washer in every interface.

Assembly



Near beam corners, drill through-holes just big enough for nylon fishing lines.

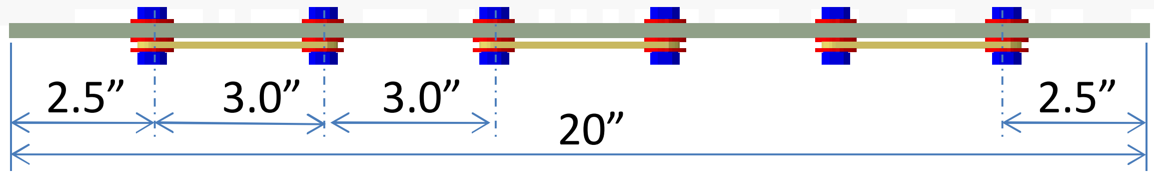
Bolt and Nut

- Standard 1/4” fine thread

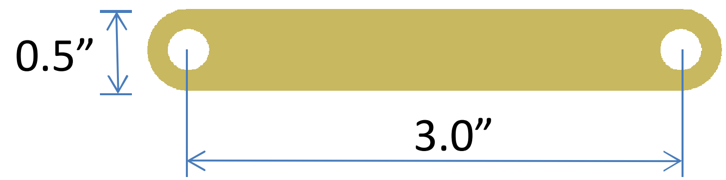
Washer

- Standard 1/4”, smallest diameters
- Must not contact bolt thread

Beam dimensions



Link



Hole diameter must match washer ID.
Make 3 links for assembly, plus 3 spare.

- Material 304SS.
- Distance between holes +/- 0.002.
- All contacting surfaces to be mirror-finished.

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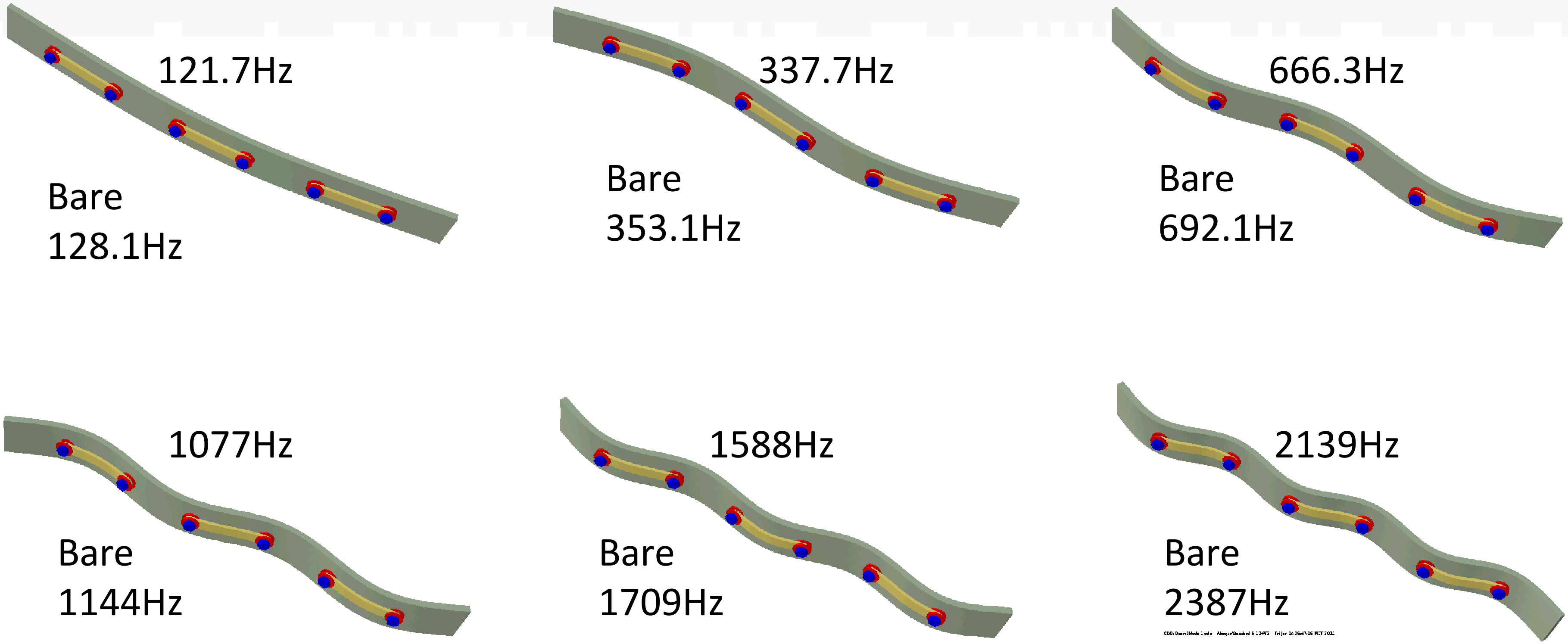
Estimated Bending Modes



“Bare” denotes Euler-Bernoulli frequency computed for a bare beam, without the bolted attachments.

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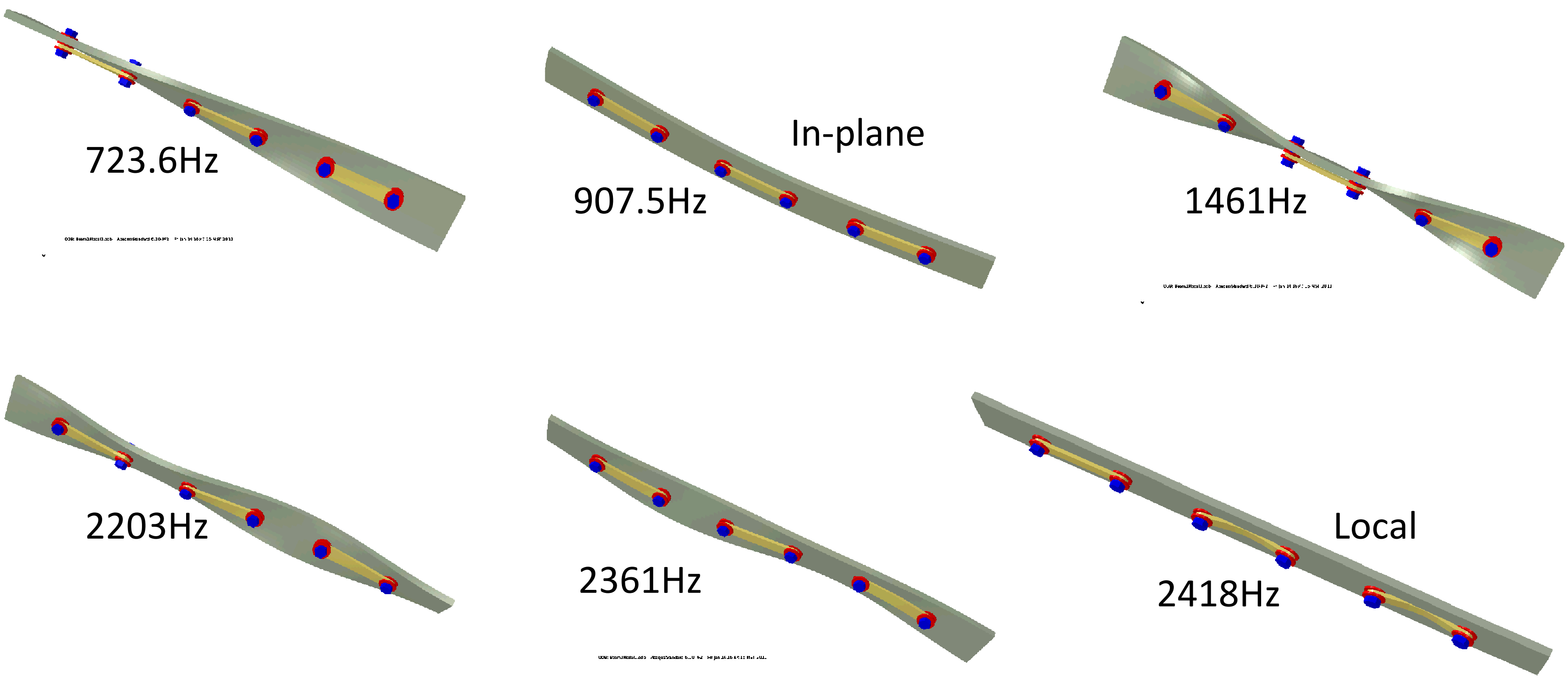
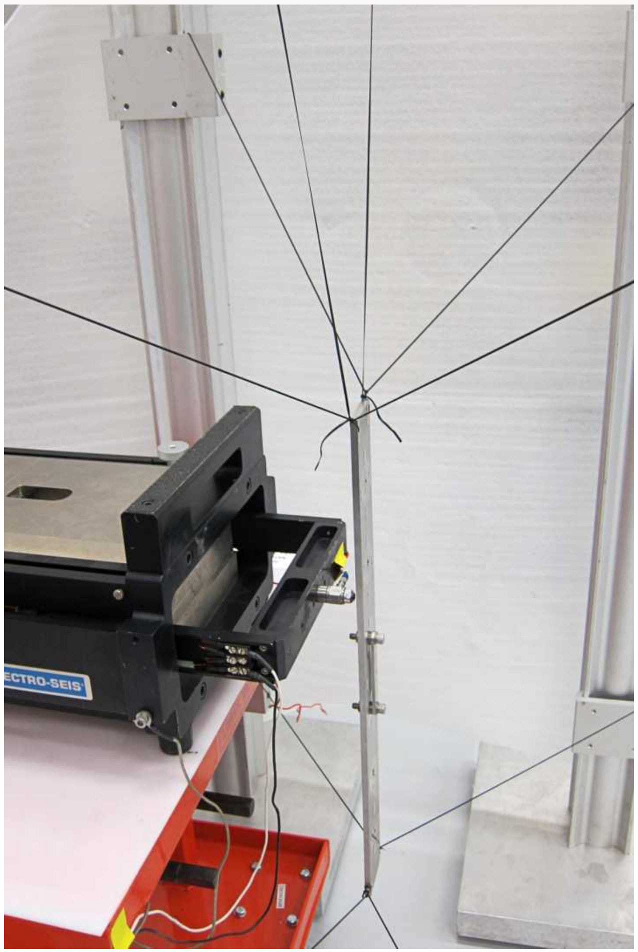
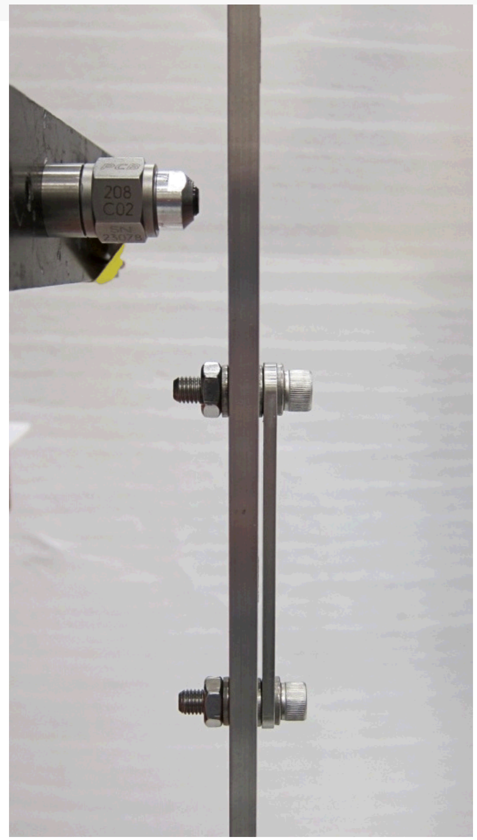
Other Modes Predicted



The excitation was measured impacts from a long-stroke shaker





The bolt torques were varied from 9.04Nm to 10.2 Nm to 12.04 Nm.

Close up: Shaker impactor with force transducer tip

Test structure suspended by two upward strings and four sideway elastic strings

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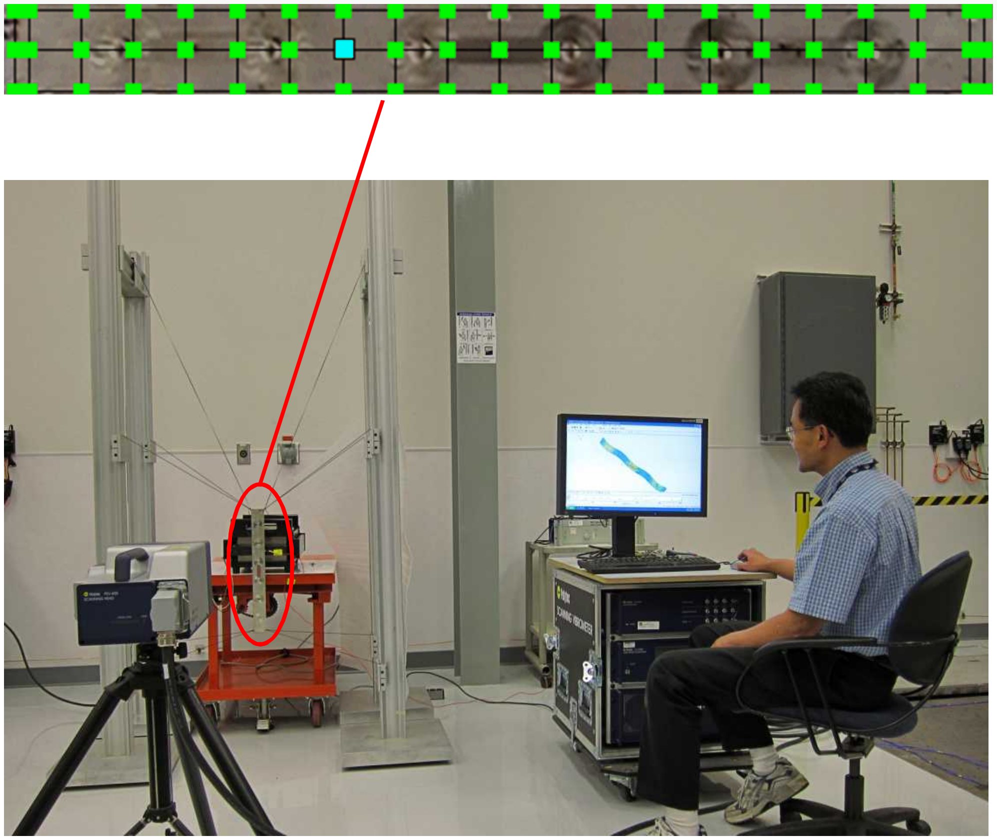
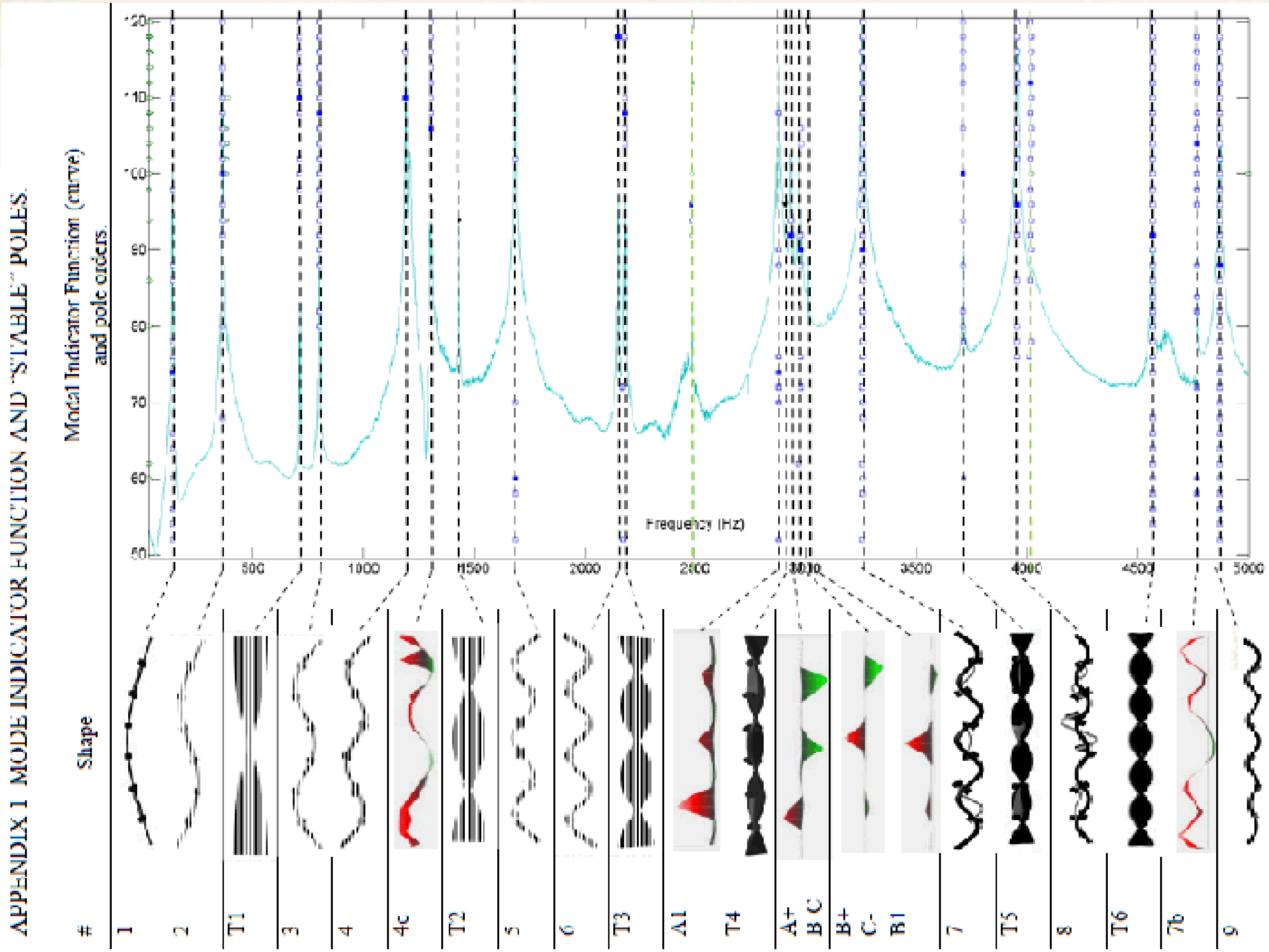
A scanning laser Doppler vibrometer (LDV) measured velocities at many points



- 5600 samples/second.
- Scanned 63 points all over the beam and links.

The natural frequencies are well separated



- Local link resonances create a very high modal density around 3000Hz.
- Low damping allows curve-fitting to separate modes.

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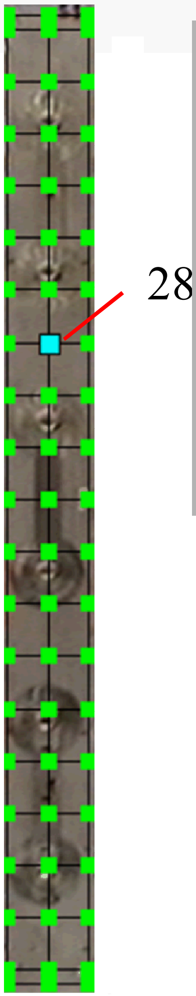
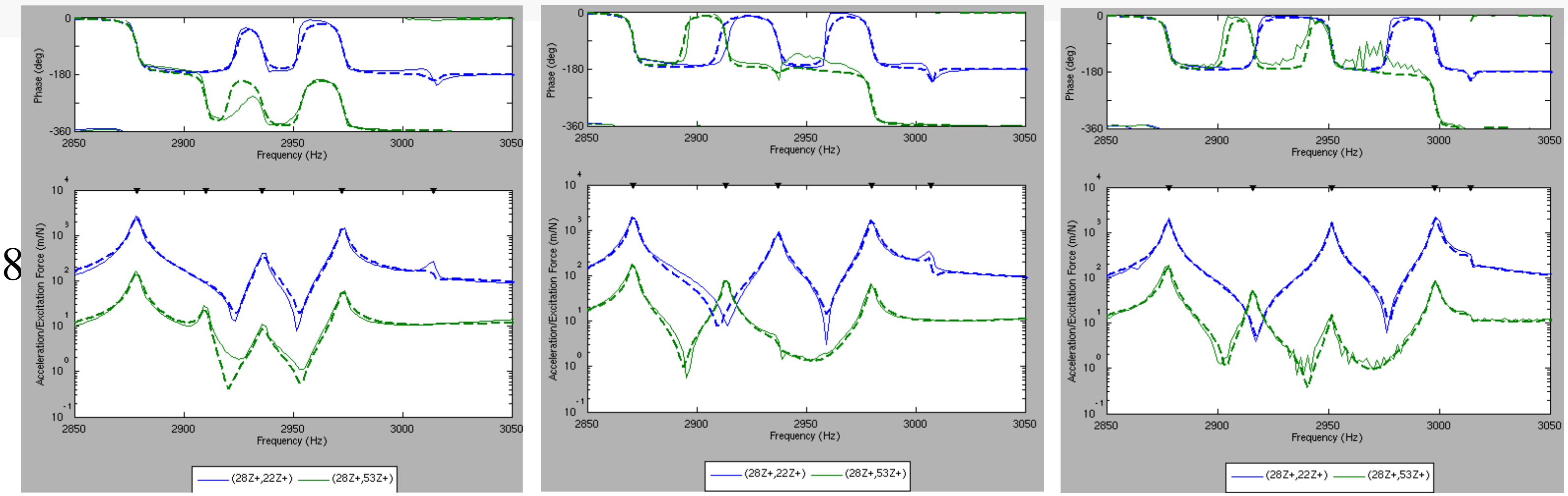
Curve fitting obtained natural frequencies and damping accurately





- Local link resonances create almost-repeated roots.
  - Five modes in 2850Hz-3050Hz range.
- Accelerances are captured accurately, even at those natural frequencies.

Bolt torque affects damping significantly.

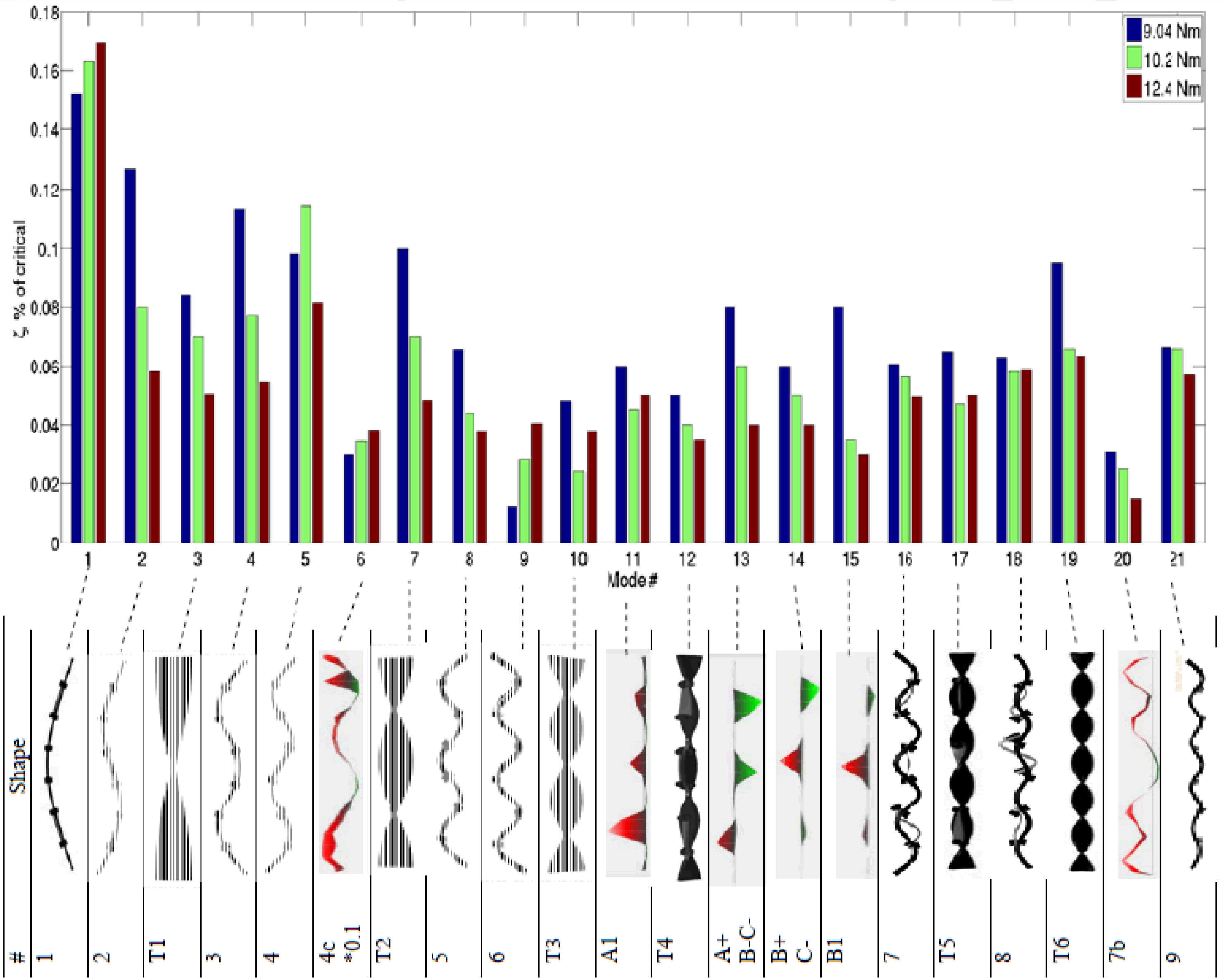


Figure 5: Damping as a function of bolt torque.

- Generally, the lowest torque results in the highest damping
- Except a few modes.

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Conclusions

- The method quantifies the effects of bolt torques on modal damping
- in a steel beam with three links bolted on it.
- The bolt torques were varied from 9.04Nm to 10.2 Nm to 12.04 Nm.
- Twenty one modes were analyzed.
- In all but three modes, the lowest torque results in the highest damping, and the highest torque the lowest damping.
- Future work
  - re-test to assess the repeatability and variability
  - Measureme at lower and higher bolt torques to give a bigger picture of the trends.
  - Various combinations of link attachments (e.g., A, B, C, AB, AC, and ABC) will give more insight into how bolted joints contribute to the structure-level damping.
  - Time histories of the force and velocities from the experiments have been recorded to provide data for research on the nonlinear behavior of bolted joints.
- The work presented here is only part of a much larger effort towards understanding energy dissipation in structures with joints.

Acknowledgment

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THANK YOU

QUESTIONS?

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