Bolted Joints, Damping and Impedance

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Bolt Torque via Damping

- damping from a bolt is a matter of microslip
- there are 5 regions: rattle, slip-stick, Coulomb, viscous and negligible (only viscous considered here)
- in the viscous region, higher torque yields less slipping and lower damping
- experimental verification on a single bolted joint illustrates this
- these results are based on Eigensystem Realization Algorithm with force in, acceleration out, measurements.

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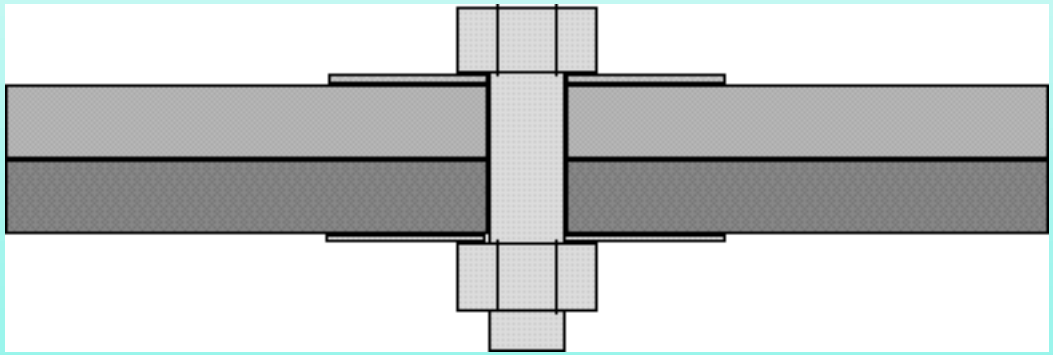
“Smart Joint” Concept

- Utilize PZT wafers as washers within a bolted connection: an example of self repairing structure
  - Actively adjust bolt torque (**Gaul: patented, CIMSS**)
  - Actively monitor joint integrity (**SAE - Inc**)



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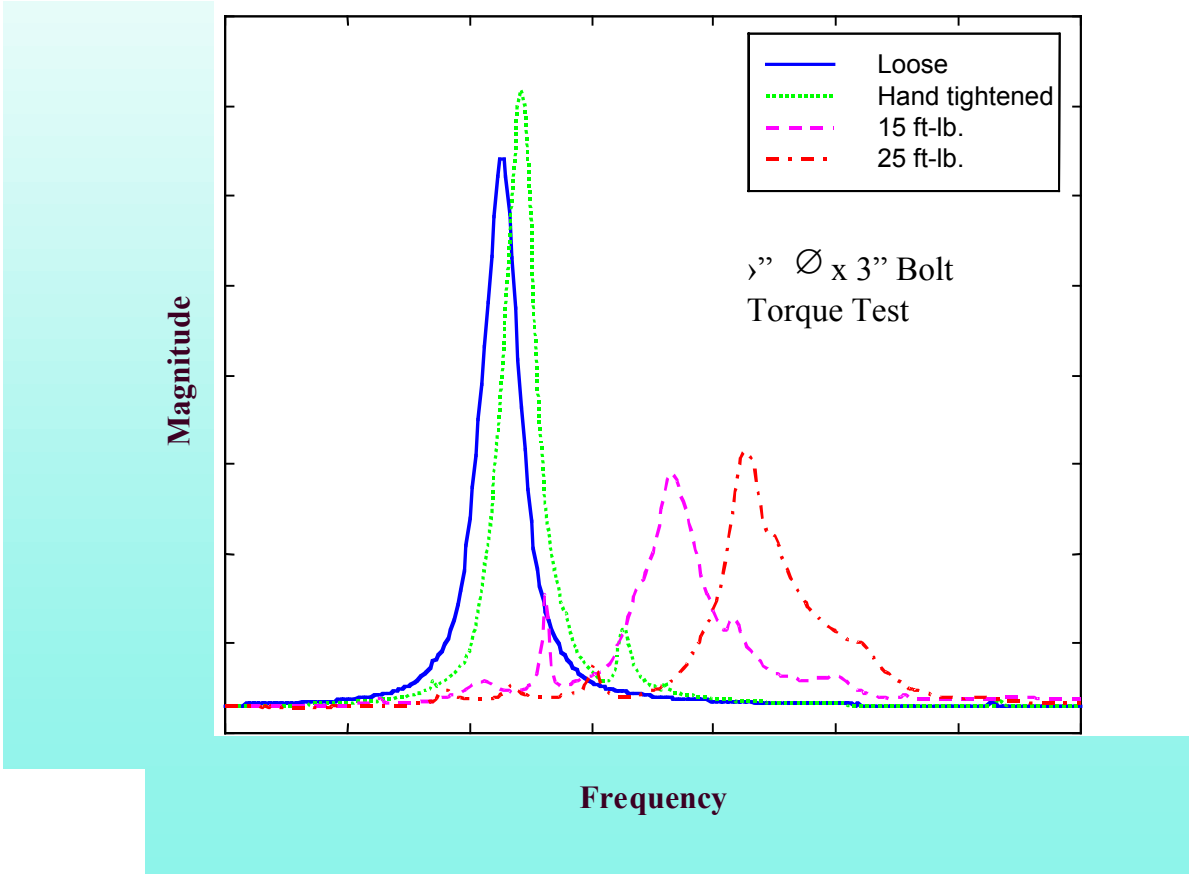
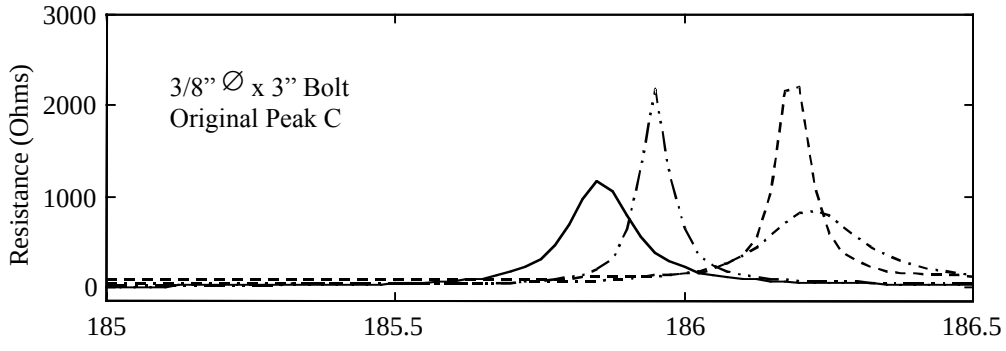
Smart Bolts - Results Overview

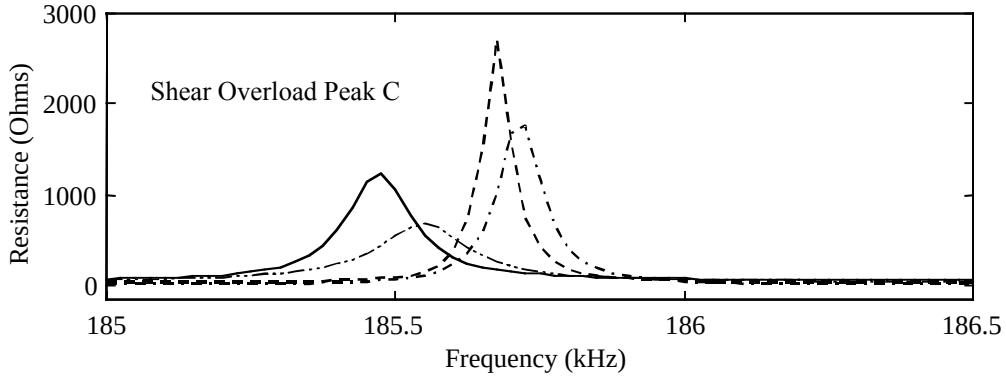
- The “Smart Bolt” detects changes in bolted joint stiffness and joint damping
  (results from SAE - Garman Systems Inc, Nashville, TN)



Smart Bolts - Results Overview

- The “Smart Bolt” detects overload damage in bolts (results from SAE - Inc, Nashville, TN)





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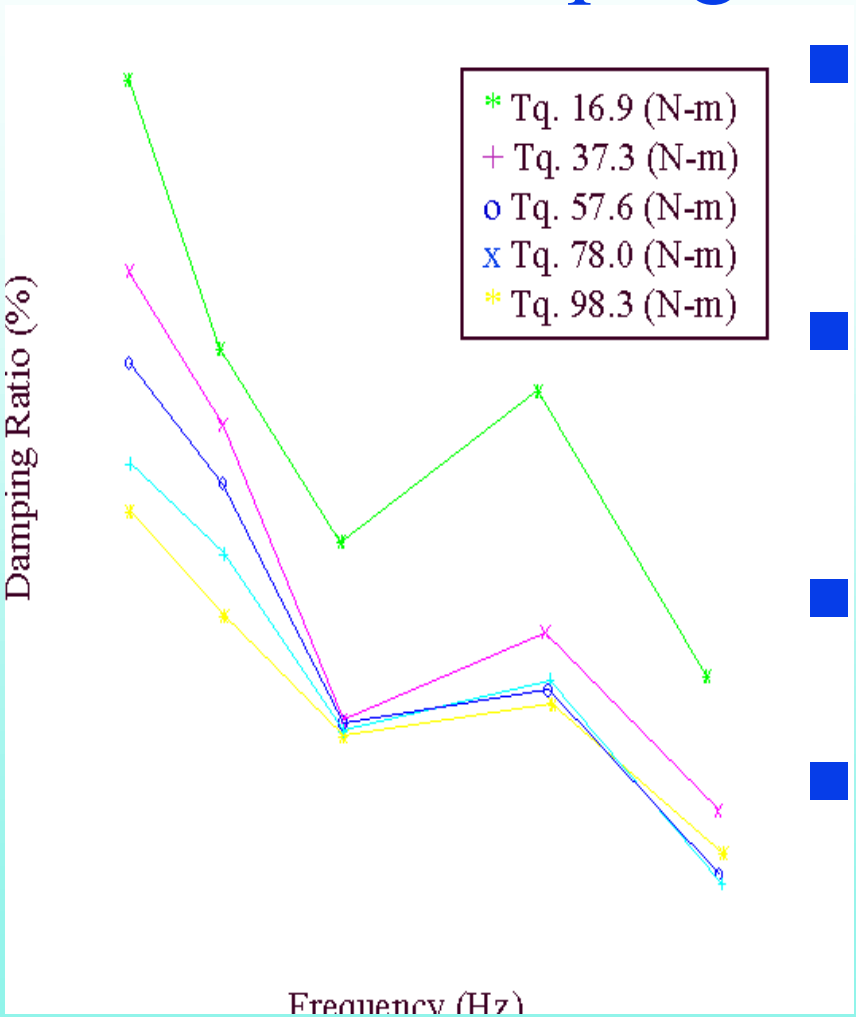
Torque levels in Bolted Joint by Measuring Damping Ratio



- Decreasing torque tends to increase damping in this region
- Lower frequencies more pronounced than higher frequencies
- Results for a single bolted joint
- Provides a connection between torque and damping

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Drawbacks

- Damping very hard to measure
- Damping measurements have a high variability
- Have been unable to solve the inverse problem of: given ζ_i, and FEM compute the damping matrix
- Approach has had limited success in low order numerical simulations (with noise), but no success yet in experimental systems

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Impedance measurements and bolted joint torque

- Impedance based method looks at low voltage (1 volt) high frequency (kilohertz) response of a joint
- Method used for a variety of health monitoring situations while in service
- Here we show some results on bolted joints
- Method successfully determines existence of out-of-torque bolts
- Method does not have a direct connection to an analytical model as of yet

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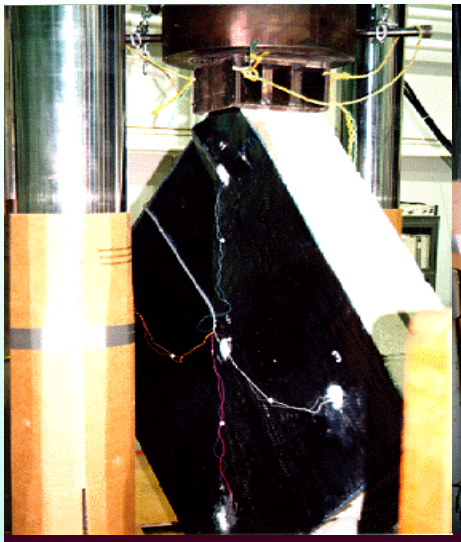
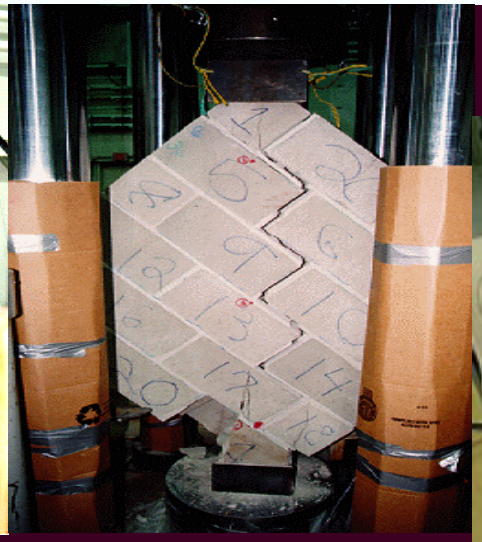
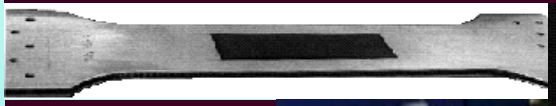
Previous work done at CIMSS



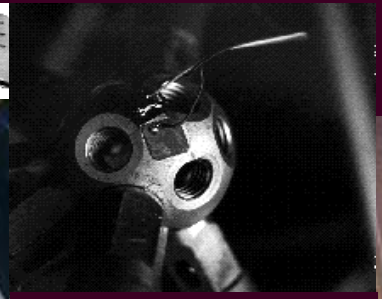


Inspection of composite reinforced concrete walls

Inspection of a cylinder header



Detecting delamination of composite patches



Inspection of space structures

Monitoring structures at high temperature (1000 F)

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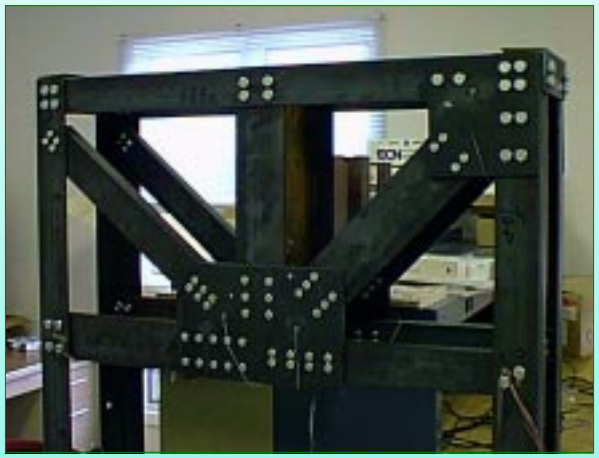
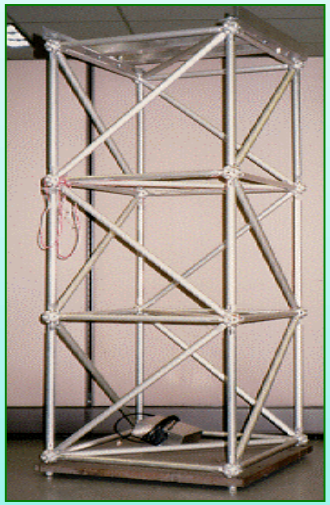
Integrated Health monitoring - with Neural Networks

- Developing an analytical model of the structures is NOT always possible.
- The integration of impedance methods and neural networks avoids the complex computation and provides the effective means to estimate the nature of damage





- The extent of damage was identified with reasonable accuracy.

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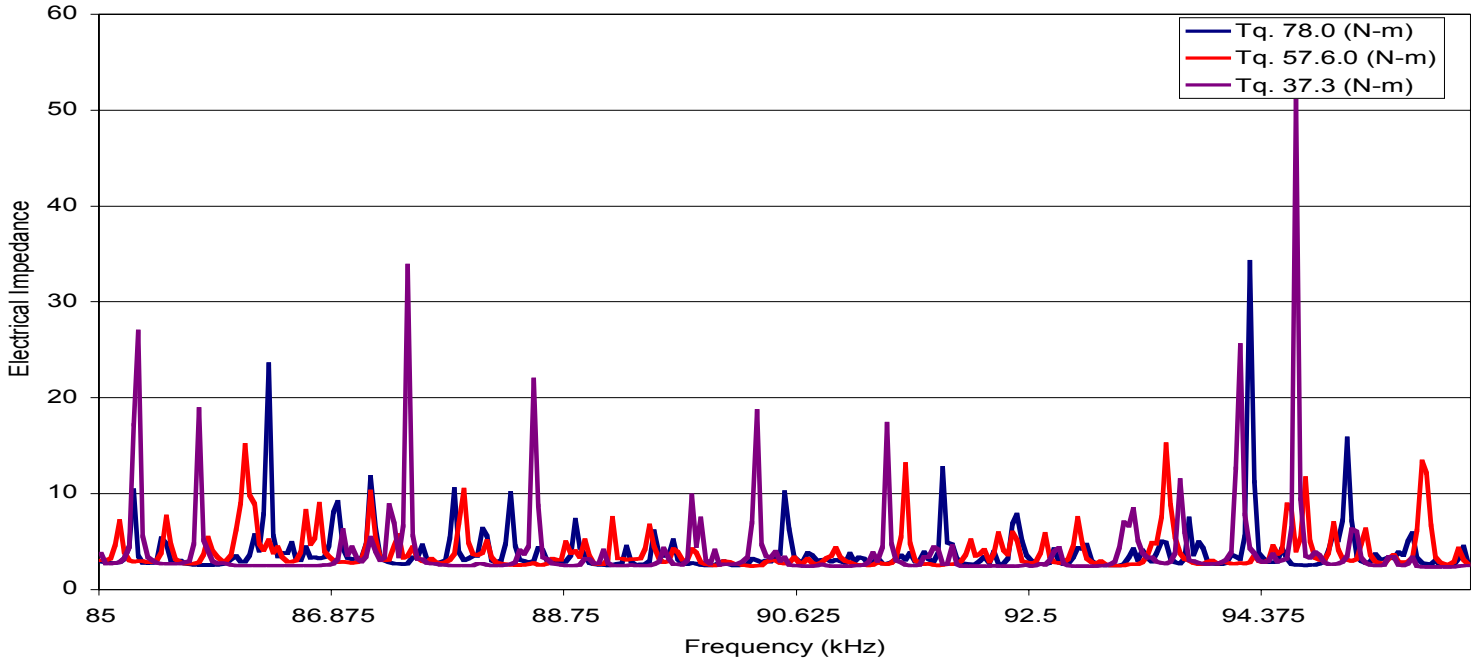
Electrical Impedance versus Torque levels for a Single Bolted Joint



- Complete pattern changes in electrical impedance with torque changes
- However, can not correlate because of extreme sensitivity
- Qualitative assess only

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Plans for bolted joint modeling

- Integrating methods
  - Electrical (mechanical) impedance monitoring
  - Damping changes
  - A wave propagation-based modeling
- Neural networks and fuzzy logics will be added as an interface between methods and users for more complex structures.
- Use of spectral element modeling may lead to numerical modeling results