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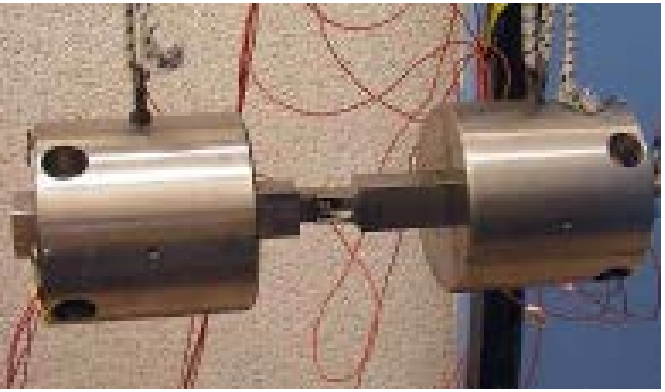

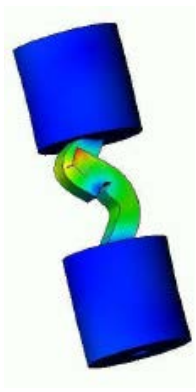

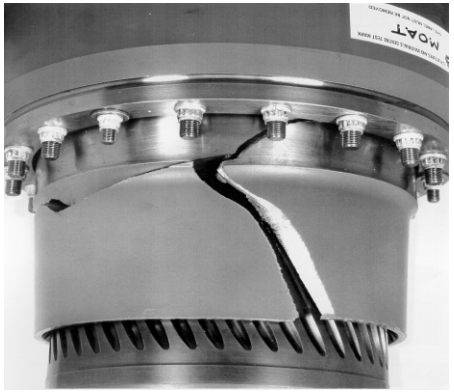

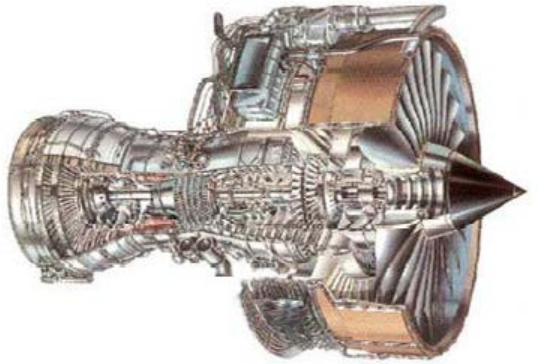

Experimental Determination of Friction Interface Models

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Outline

- Motivation
- Possible Joint Models
- Impact Hammer Setup
- Impact Hammer Results
- Interface Profile Test
- Joint Model Parameter Estimation
- Plasticity Effects
- Conclusions and Remarks

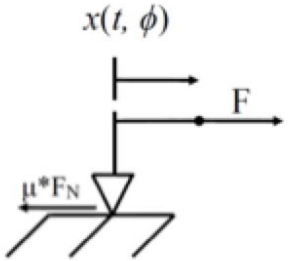
Motivation

- Joints are everywhere
- Current research focuses on a single joint in modeling and analysis
  - Most only valid in micro-slip region
- Desire to test for joint nonlinearity *in sitro*
  - Test desired system as is to best represent how system will act in real operation
- Quantify uncertainty in selected nonlinear joint model
- How does the surface roughness affect the joint model and uncertainty?

Joint Models

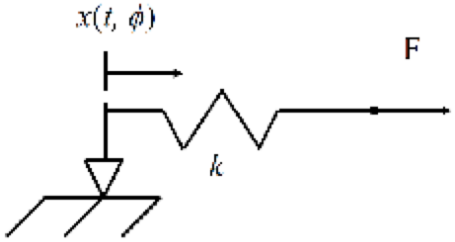
3 Different Joint Models

- Coulomb Friction



$$F = \mu * F_N$$

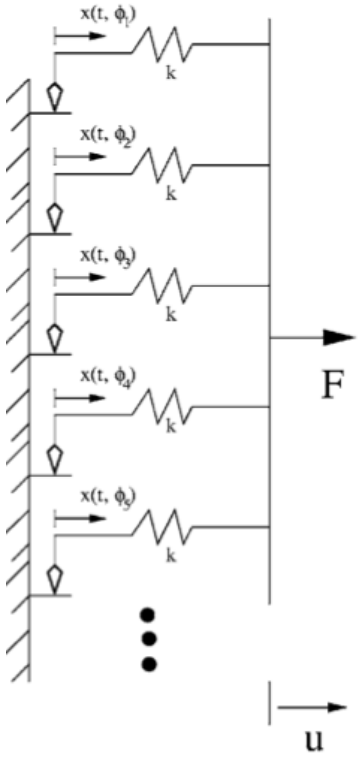
- Jenkin Elements



$$F = K_{spr} * x \ldots\ldots (stuck)$$

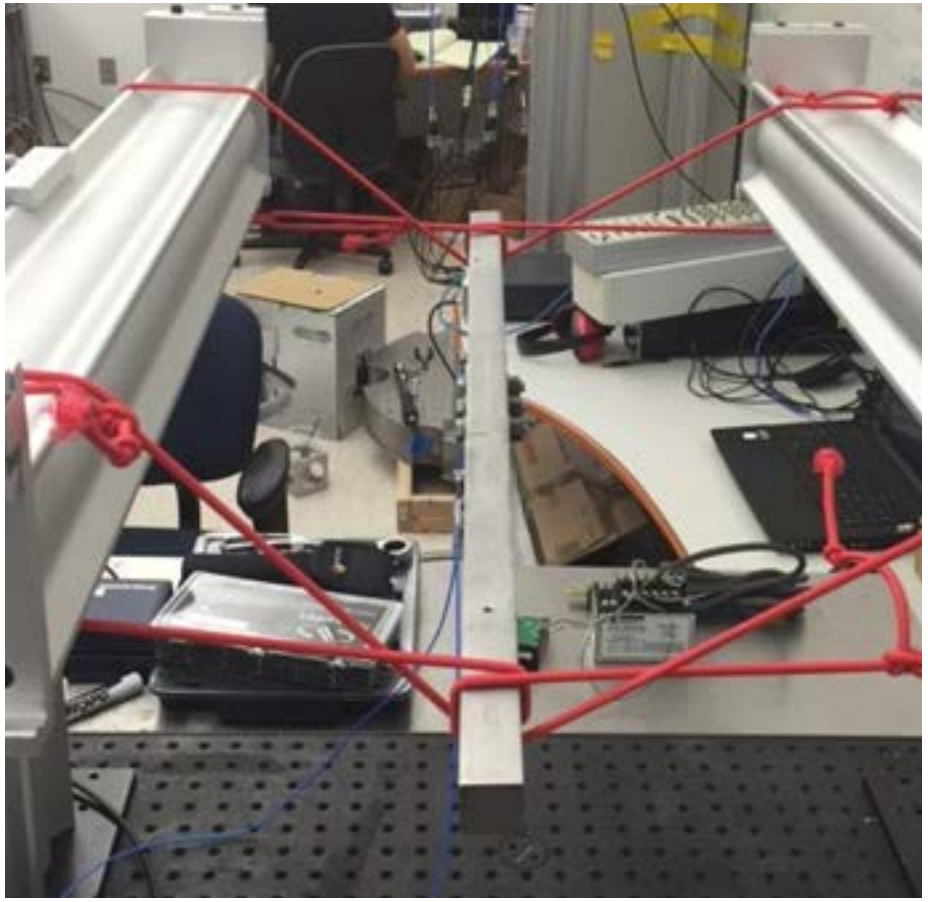
$$F = \mu * F_N \ldots\ldots\ldots (slip)$$

- Modal Iwan



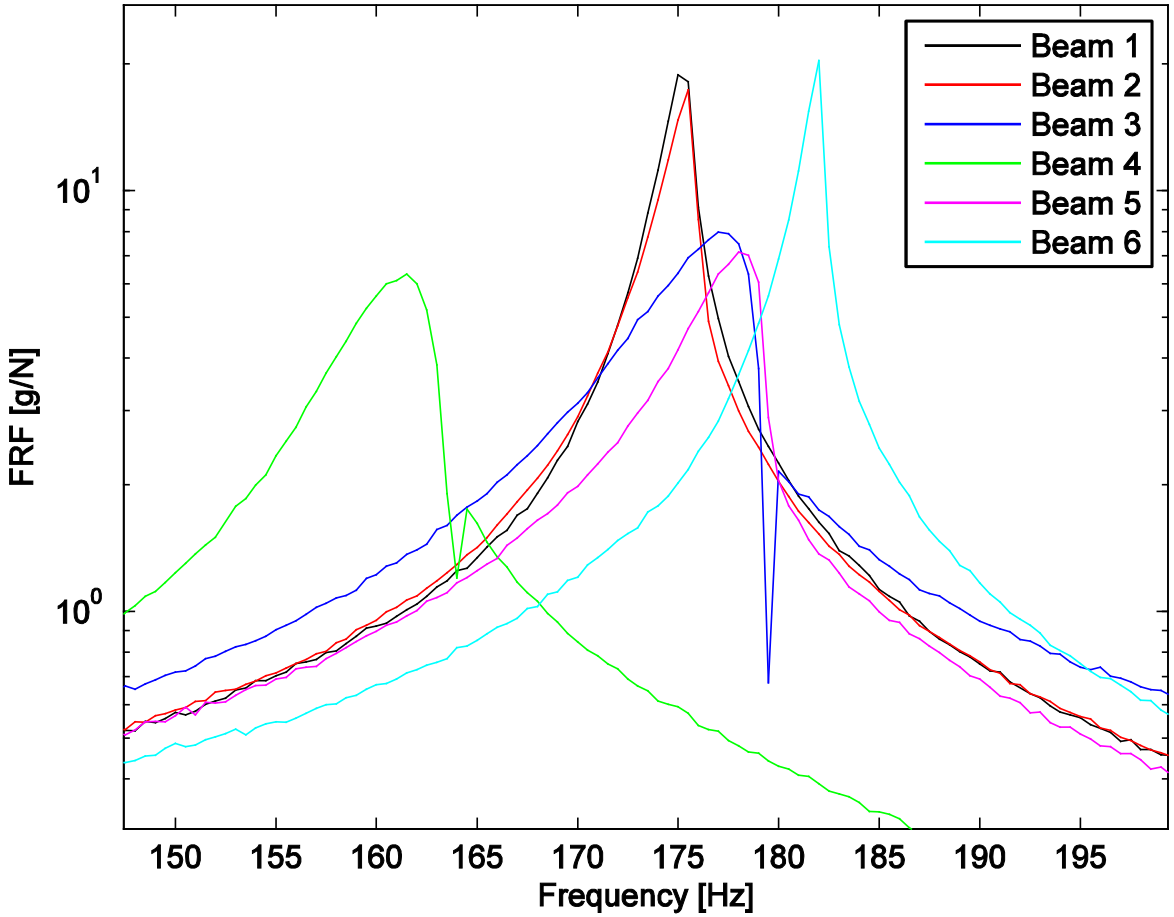
Impact Test Setup

- Brake-Reuss beam
  - 3 Bolts
  - Varied Torque
  - 3 Surface conditions
- 2 tri-axial Accelerometers
- Low sensitivity impact hammer
  - Force levels up to 8 KN



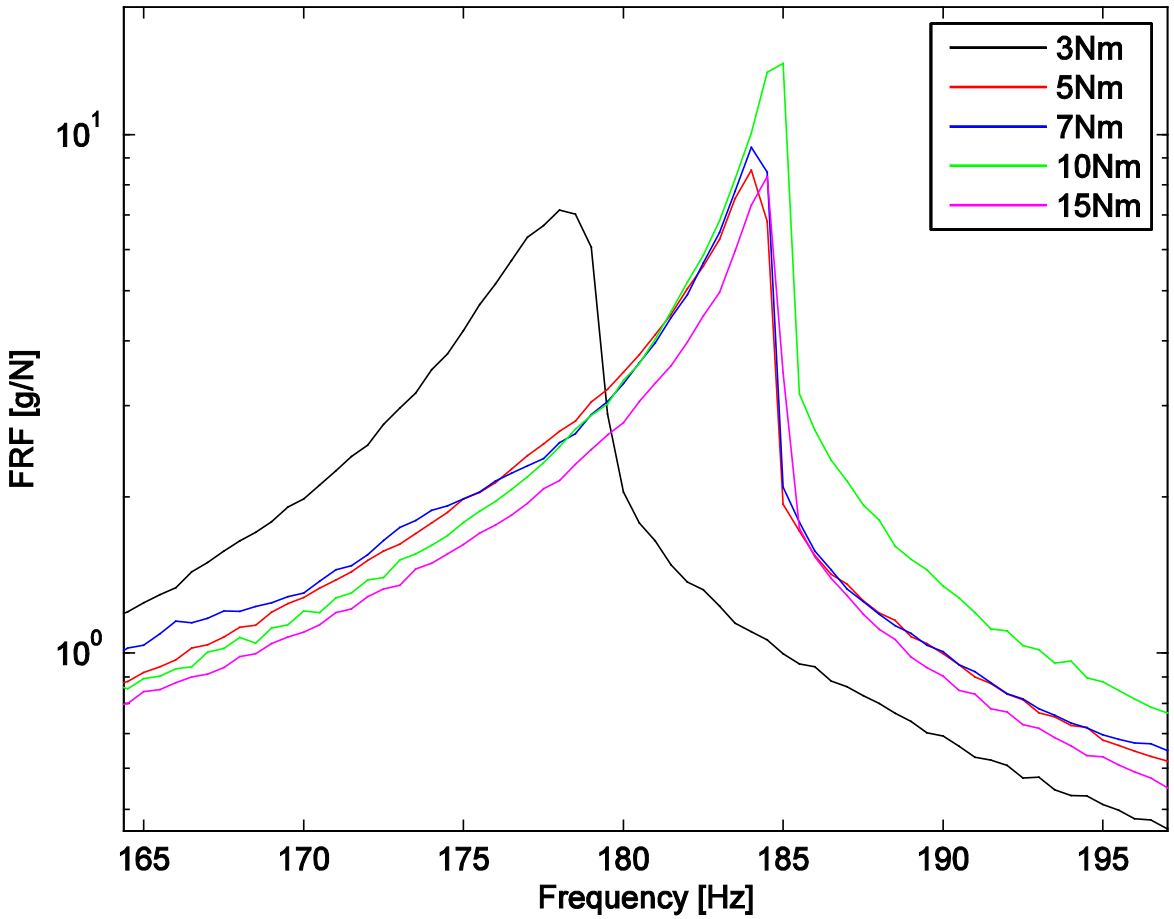
Impact Test Results

- Linear Range
- 3 Nm Bolt torque
- Fundamental frequency
  - 1st Bending
- Beam 1,2 have smoothest interface
- Beam 5,6 have roughest interface
- Anomaly in beam 4
  - Discussed later but believed to be due to plasticity



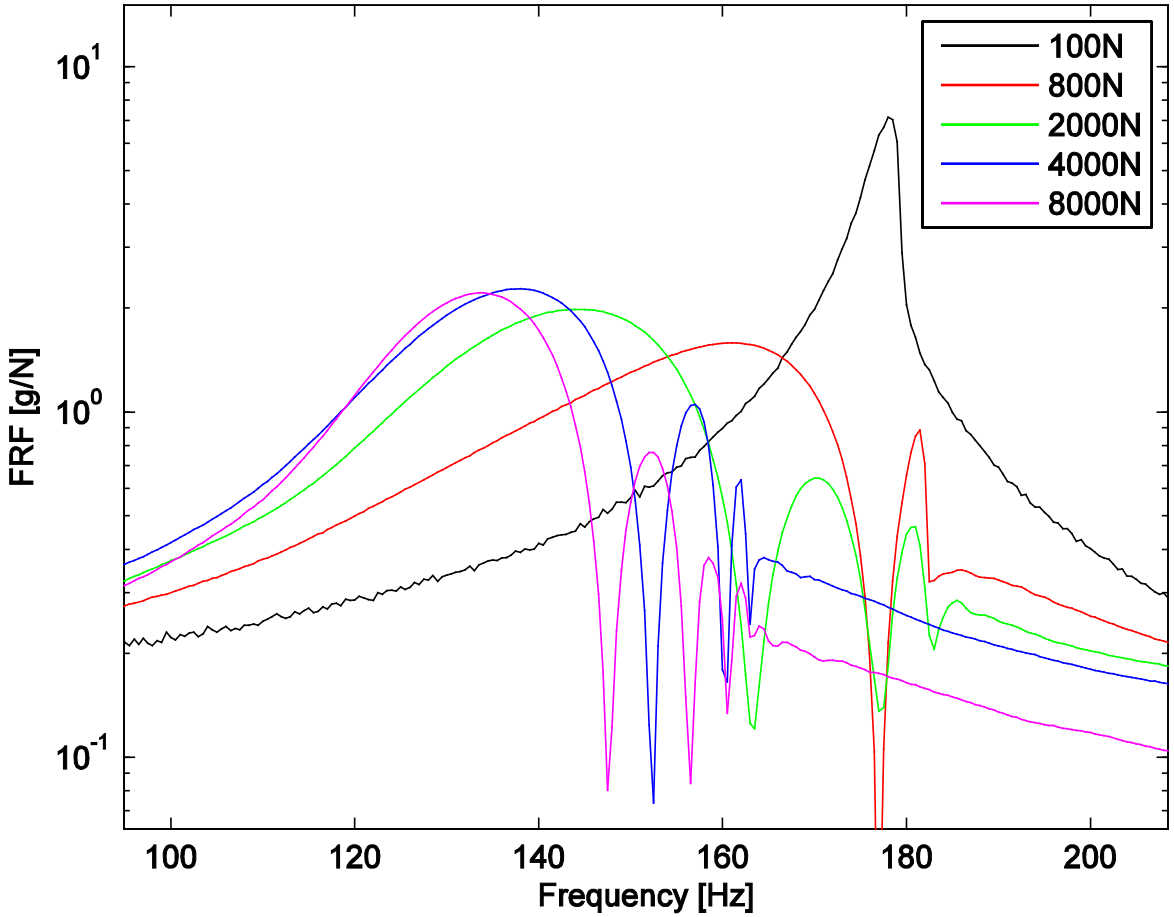
Impact Test Results Cont.

- Linear Range
- Beam 5
- Fundamental frequency
  - 1st Bending

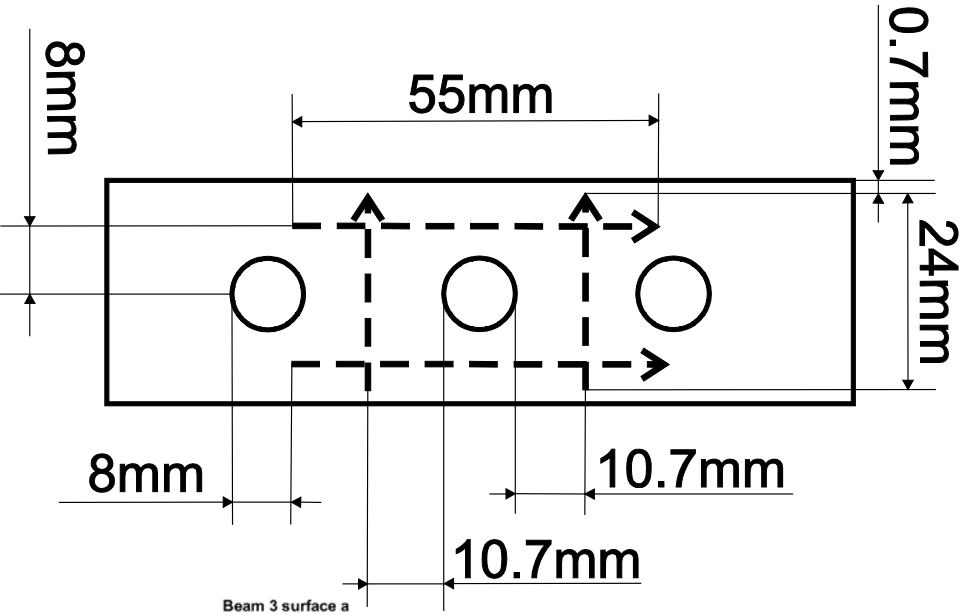


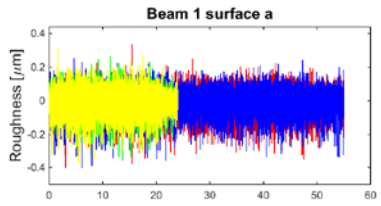
Impact Test Results Cont.

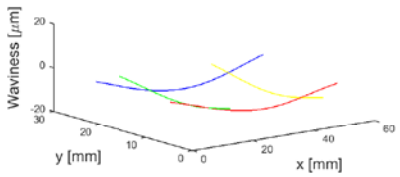
- 3 Nm Bolt torque
- Beam 5
- Fundamental frequency
  - 1st Bending

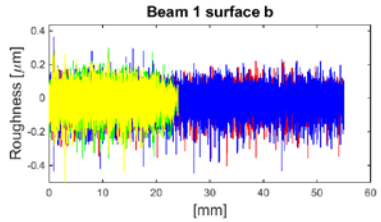


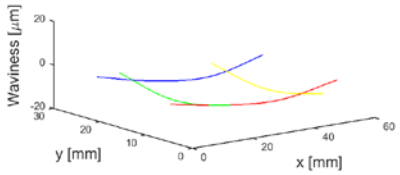
Interface Profile Measuring

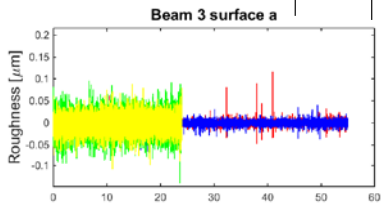


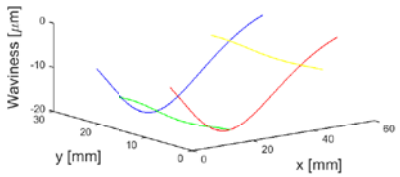


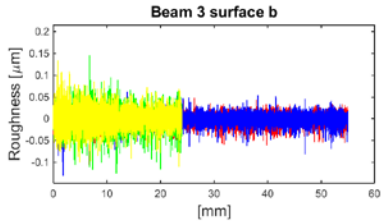


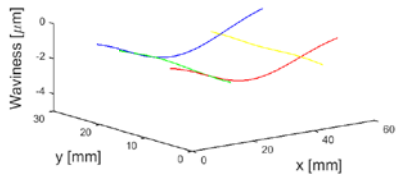


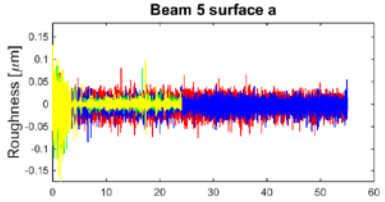


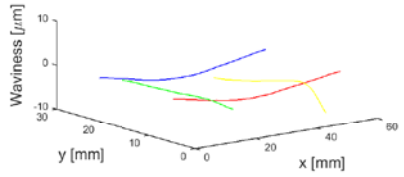


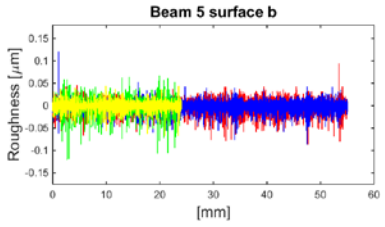


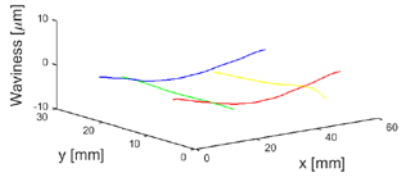






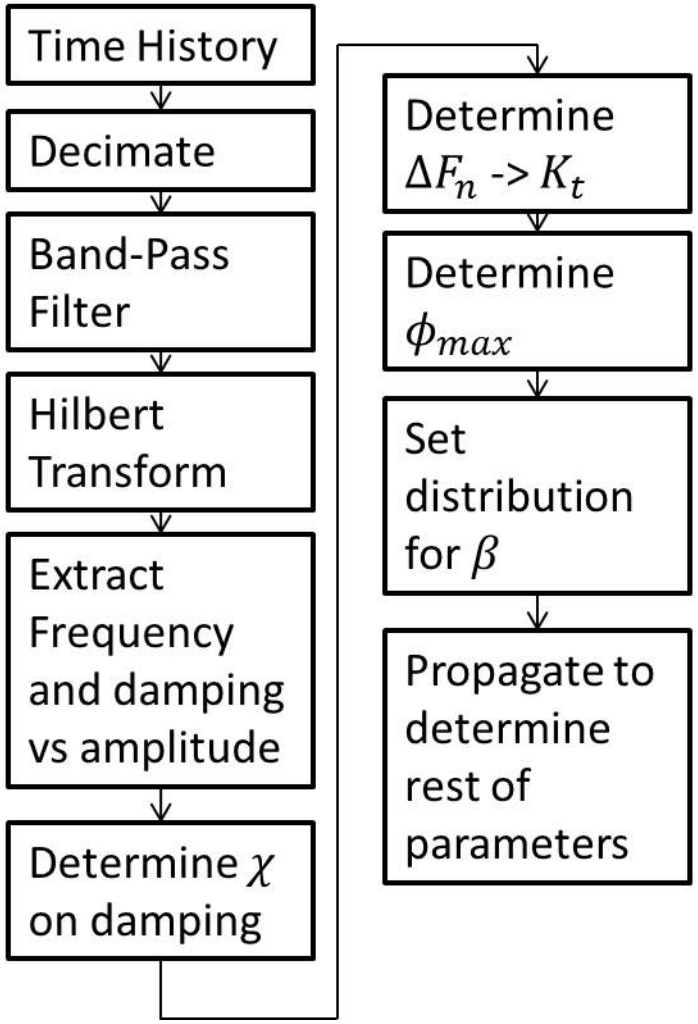




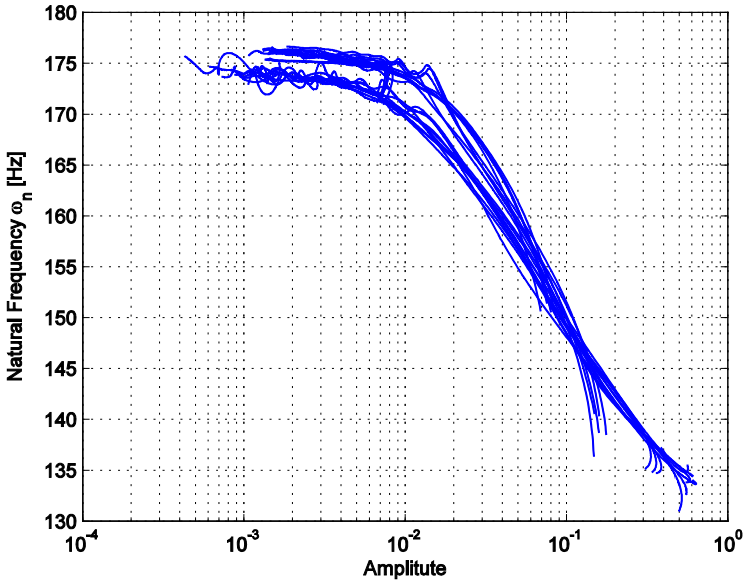


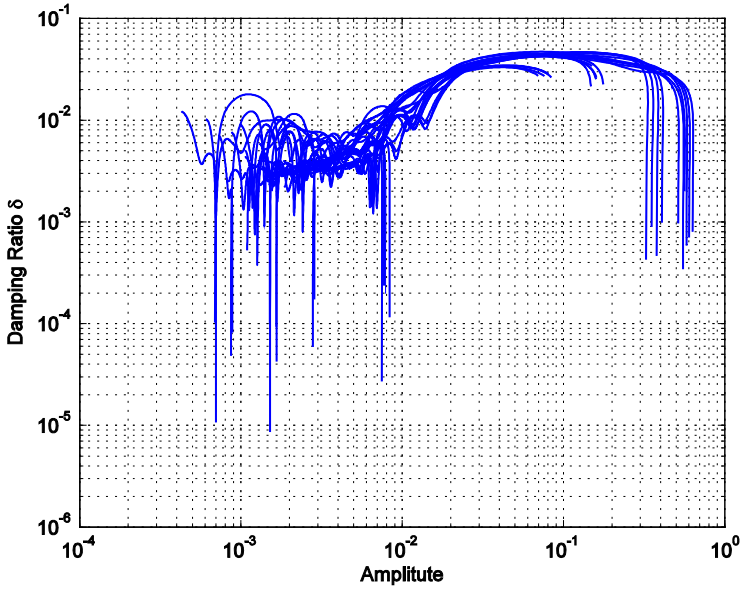
Joint Parameter Estimation

- Use modal Iwan for preliminary analysis
- Able to calculate some physical and some mathematical parameters
- Assume distributions that fit data
  - $\chi \sim Modified\ Beta$
  - $K_t \sim Exponential$
  - $\phi_{max} \sim Gamma$
  - $\beta \sim Gamma$



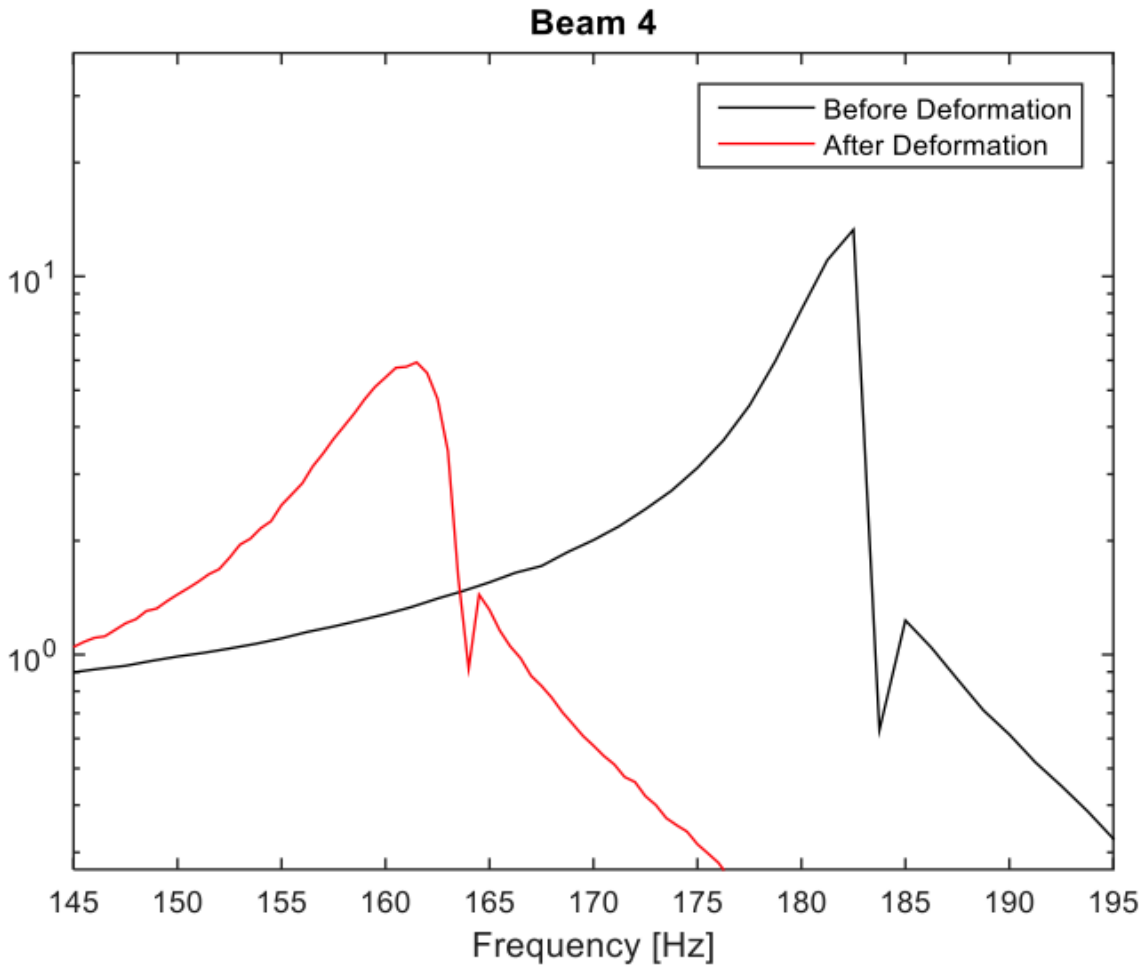
Joint Parameter Estimation Cont.

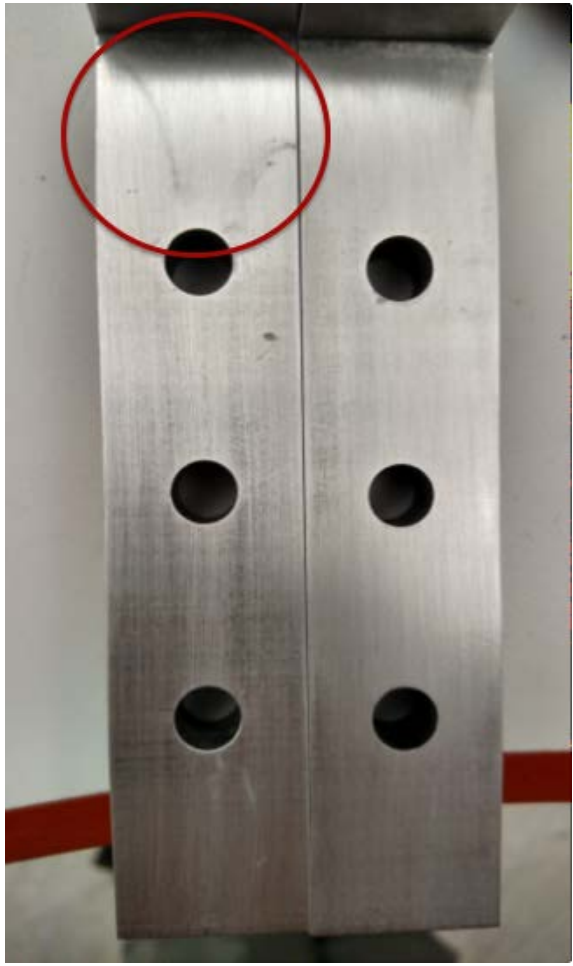




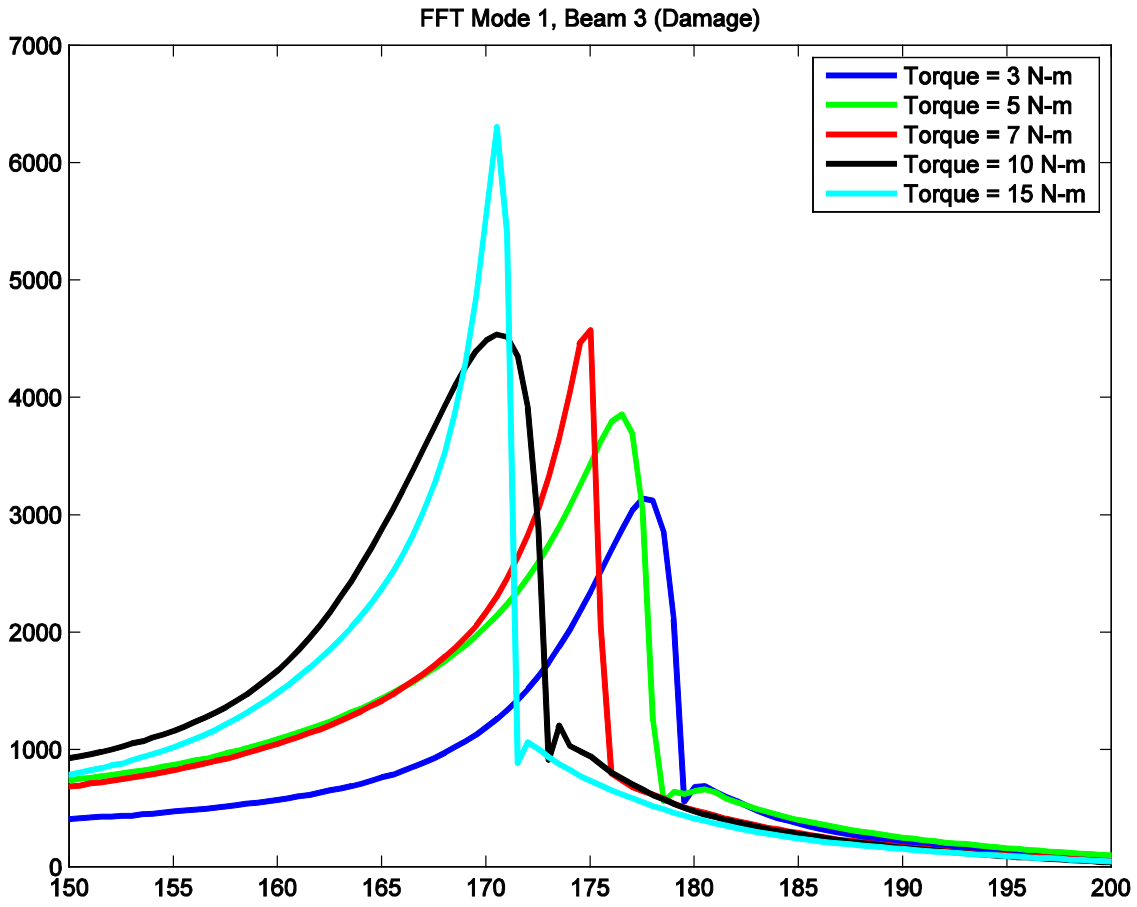
Parameter	3Nm torque		5Nm torque	
	Mean	Standard Deviation	Mean	Standard Deviation
ϕ_{max}	$1.68 * 10^{-4}$	$1.955 * 10^{-5}$	$1.62 * 10^{-4}$	$1.01 * 10^{-5}$
K_T	$4.47 * 10^5$	$\sim$	$6.048 * 10^5$	$\sim$
χ	-0.179	.0044	-0.480	0.062
F_s	54.5	6.42	65.8	4.60

Plasticity Effects





Plasticity Effects Cont.



Conclusions

- Large data set was collected for Brake-Reuss beam
  - 6 beams
  - 3 surface conditions
  - 5 torque values
  - Forcing level up to 8000 N
- Data is available upon request
- Tested surface roughness to verify manufacturing
- Preliminary modal Iwan parameter estimation
- Our macro-slip hits can cause some plasticity affects in beam

Special Thanks

- Advisors
  - Marc Mignolet
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Questions?

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