Description of Timoshenko Model of a Bolted System

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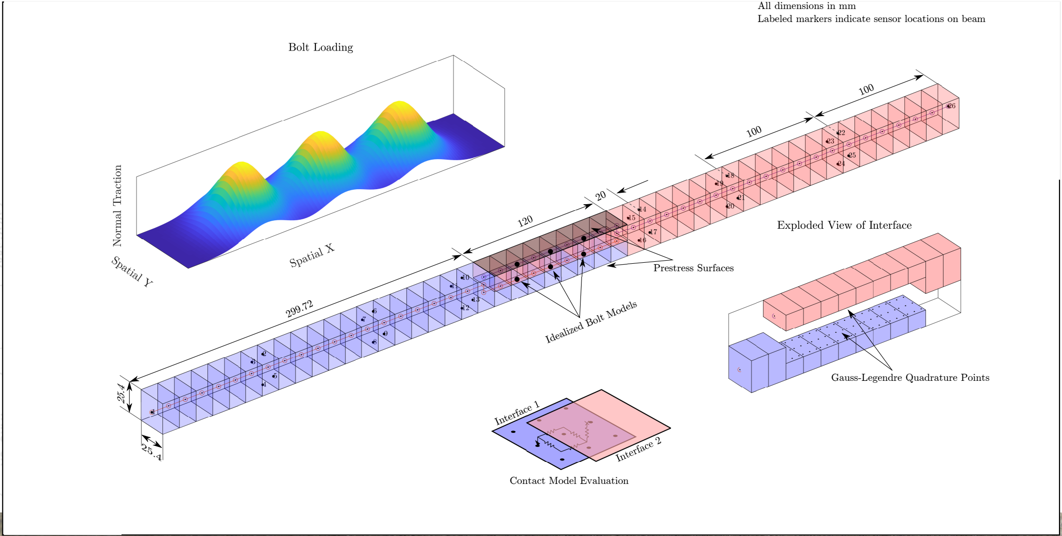
Overview


All dimensions in mm
Labeled markers indicate sensor locations on beam
Bolt Loading
Normal Traction
Spatial Y
Spatial X
100
100
20
120
299.72
25.4
25.4
Prestress Surfaces
Idealized Bolt Models
Exploded View of Interface
Gauss-Legendre Quadrature Points
Interface 1
Interface 2
Contact Model Evaluation

Numerical Description

Beam Models

- The model is a 3D Timoshenko finite element model discretized using C^0 shear elements (corrected for locking)
- See previous slide for the figure and dimensions
- The elastic properties are assumed to be:

  Young's Modulus $E = 2 \times 10^{11} Pa$
  Density $\rho = 7800 Kgm^{-3}$
  Poisson's Ratio $\nu = 0.3$
  Shear correction factor $\kappa = \frac{10(1+\nu)}{12+11\nu}$ (from Cowper (1966) for rectangular sections)
- The model is constructed with 8 elements in the "interface" region and 20 elements in the "far-field" region

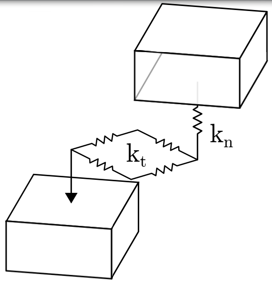
Numerical Description

Bolt Idealization

- Each bolts is built using a single Timoshenko beam element that connects the two beams in the locations indicated
- The shear terms in these elements are set to zero in order to ensure that attaching this does not violate any assumptions of the Timoshenko beam model
- The bolt therefore has axial stiffness and bending stiffness (no shear)
- The bolts are modeled as cylinders with diameter $8.42mm$ and length $25.4mm$ (one inch) with the same material properties as before
- In addition to the above, discrete masses are added to the bolt nodes in such a manner that the total mass of each bolt-nut-washer assembly is $28.64g$.
- Additionally, an axial stiffness of $1.2041 \times 10^9 Nm^{-1}$ is added between the bolt nodes in the bolt-axial direction

Contact Model

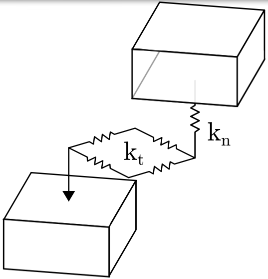
- A 3D elastic dry friction model, implemented at the "traction-level", is employed for this study



- The normal traction law is given as,

$$t_n = \begin{cases} k_n \delta u_n & \delta u_n > 0 \quad (\mathit{contact}) \\ 0 & \mathit{otherwise} \quad (\mathit{separation}) \end{cases}$$

Contact Model



- A 3D elastic dry friction model, implemented at the "traction-level", is employed for this study
- The incremental tangential traction law in x is given as,

$$\Delta t_t^x = \begin{cases} k_t \Delta \delta u_t^x & \textit{stick} \\ 0 & \textit{slip} \\ -t_{t0}^x & \textit{separation} \end{cases}$$

Contact Model

- A 3D elastic dry friction model, implemented at the "traction-level", is employed for this study
- As already mentioned, this is implemented at the traction level
- As shown in the figure, this contact law is evaluated between pairs of quadrature points on the interface
- The tractions evaluated at the quadrature locations are used to obtain nodal forces and moments through numerical integration (2D Gauss Legendre quadrature points used)

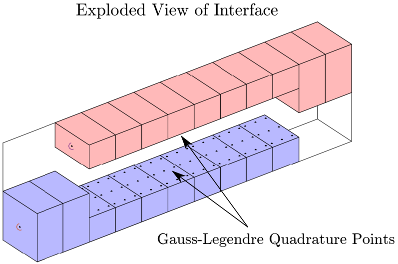
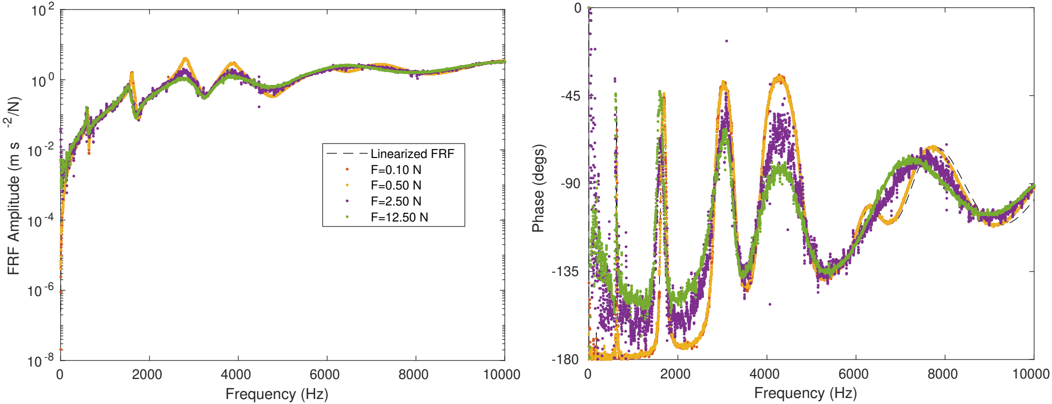


Figure: Interface implementation Schematic

Frequency Response Estimates

X Direction Excitation (at Sensor 1)

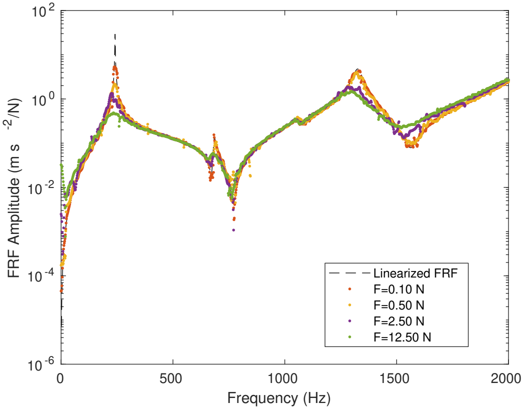


(a) Amplitude (b) Phase

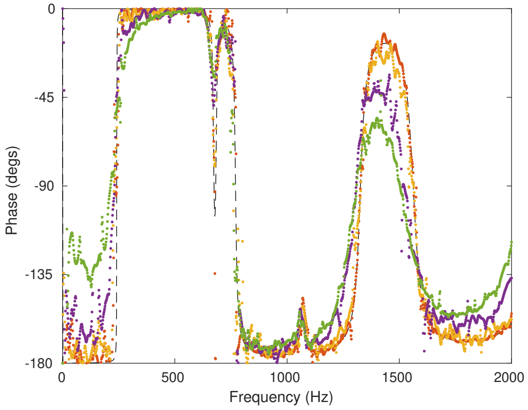
Figure: Frequency Response Estimate From White Noise Excitation

Frequency Response Estimates

Y Direction Excitation (at Sensor 3)



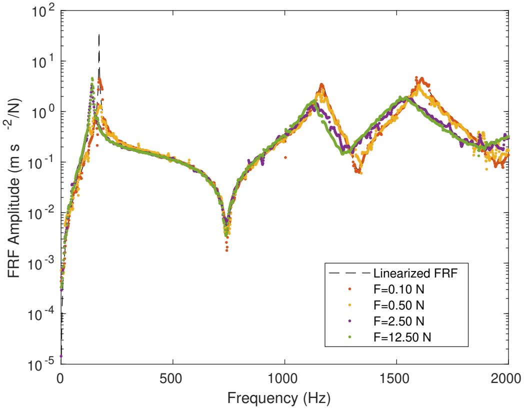
(a) Amplitude



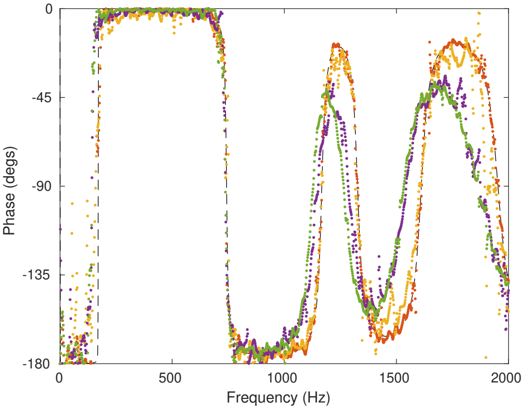
(b) Phase

Figure: Frequency Response Estimate From White Noise Excitation

Z Direction Excitation (at Sensor 2)



(a) Amplitude



(b) Phase

Figure: Frequency Response Estimate From White Noise Excitation