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Estimating bolt tightness from measured vibrations: Influence of boundary nonlinearity

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A technique is proposed to assess the level of bolt tightness and to quantify the tension based on measured natural frequencies and damping ratios of the bolt. This technique is investigated experimentally and theoretically. A simple model for the bolt that consists of a pre-stressed one-dimensional beam linear equation with nonlinear stiffness and damping at its boundaries is investigated to explain experimental results.

Figure 1a shows the squared first bending natural frequency for a bolt as function of bolt tension. At low tension the squared natural frequency rapidly increases with tension. As the bolt is gradually tightened the frequency starts changing approximately linearly with tension [1, 2]. Figure 1b shows the first mode damping ratio of the bolt as function of the bolt tension. At low tension the damping ratio decreases rapidly with tension and then starts slowly decreasing for higher tension.

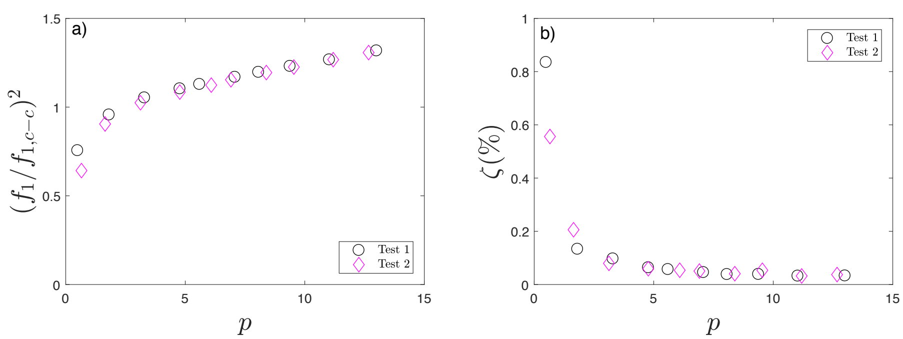

Figure 1: Nondimensional first transverse frequency squared (a) and damping ratio (b) of a bolt M12x260 as function of nondimenisonal tension.

In reality the boundaries stiffness and damping are expected to be nonlinear functions of bolt's displacement at the local (micro) scale. However analytical results showed that linear boundaries stiffness and damping can explain experimental data. An attempt is made to explain this phenomenon by considering a linear one-dimensional beam model with nonlinear stiffness and damping at its boundaries. These nonlinear boundary effects are then averaged over space and time to yield linear effective boundary stiffness and damping that explain the experimental results.

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