Finite element modeling and experimental testing of cantilever beams with bolted joint connections

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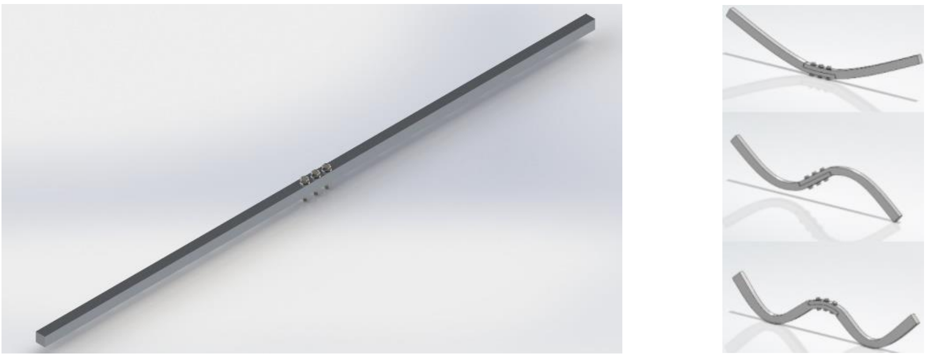
Abstract. The Brake-Reuß beam has been used throughout the literature to characterize bolted joint nonlinearities. However, researchers have focused solely on the free-free boundary condition in eliciting nonlinear behaviors of the system through a wide range of studies. This current work focuses on the linear and nonlinear effects of the beam's dynamical responses under a fixed-free boundary condition. A parametric finite element study for the bolt properties is conducted to determine the corresponding effects on the system's natural frequencies and mode shapes. Next, finite element studies are carried out using the Abaqus solver in 3D Experience to provide an expected range of natural frequencies to assist in nonlinear experimental testing. Finally, a modified Brake-Reuß beam is designed and manufactured to investigate the effects of the bolts and joints on the linear and nonlinear characteristics of the system.

Introduction

Bolted joint connections are commonly used for connecting components due to their ease of disassembly and simple design. However, bolted joints may exhibit both microslip and macroslip due to an applied force, which introduces nonlinearity into the system [1]. This nonlinearity is difficult to accurately describe and research is still progressing to develop more refined empirical models for characterizing these connections. This is an essential field of research because many structural systems use bolted connections, where the need to predict the linear and nonlinear behaviors of these joints is vital for reliability and safety. The Brake-Reuß beam is a common benchmark structure used throughout the literature for empirical modeling of and experiments involving a bolted joint connection [2-4]. The goal of this work is to simulate and test a modified version of this beam (shown in Figure 1(a)) to study the linear and nonlinear effects of a fixed-free boundary condition and the resulting joint asymmetry.



(a) (b)

Figure 1: (a) CAD model of a modified Brake-Reuß beam; (b) numerical verification with previous results for the free-free beam [3].

Results and Discussion

Finite element modeling is performed to first validate previous numerical and experimental results of the Brake-Reuß beam. Figure 1(b) shows the first three out of plane bending modes which are verified with [3] for the free-free beam. Next, a parametric study of bolts, joints, and interface properties using finite element simulations will be illustrated to investigate the impacts that the shank diameter, Young's modulus, and Poisson's ratio of the bolts have on the natural frequencies and mode shapes of the modified Brake-Reuß beam. Experiments will be conducted to further characterize the linear and nonlinear effects associated with the bolted lap joint in the modified fixed-free beam when different levels of input accelerations are considered.

References

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