Damping in Structures Assembled by Bolted Joints

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Introduction

Vibration properties of most assembled mechanical systems depend on frictional damping in joints. The nonlinear transfer behavior of the frictional interfaces often provides the dominant damping mechanism in a built-up structure and plays an important role in the vibratory response of the structure. This article gives a short overview of three different approaches to damping modeling based on the contact distribution in joints. It gives an overview of modeling issues and as well as advantages and disadvantages of proposed methods.

Point-Wise Joints

For improving the performance of systems, many studies have been carried out to predict, measure, and/or enhance the energy dissipation of friction. Here, the techniques for describing the nonlinear transfer behavior of bolted joint connections are introduced. If the joint dimension is small, compared to the shortest wavelength of structural deformation, point-wise joint models are sufficient. They include classical Coulomb and practical engineering models. Constitutive and phenomenological friction models describing the nonlinear transfer behavior of joints are discussed. The models deal with the inherent nonlinearity of contact forces (e. g. Hertzian, Mindlin contact), and the nonlinear relationship between friction and relative velocity in the friction interface. The research activities in this area are a combination of theoretical, numerical, and experimental investigations. Various solution techniques, commonly applied to friction-damped systems, are presented and discussed. Recent applications are outlined with regard to the use of joints as semi-active damping devices for vibration control. Several application areas for friction damped systems due to mechanical joints are presented [1, 2].

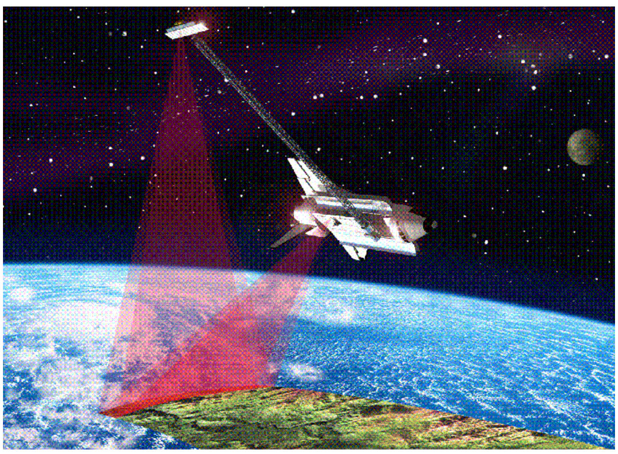

Figure 1: Application example: SRTM (Shuttle Radar Topography Mission) mast with friction joints represented by point contact.

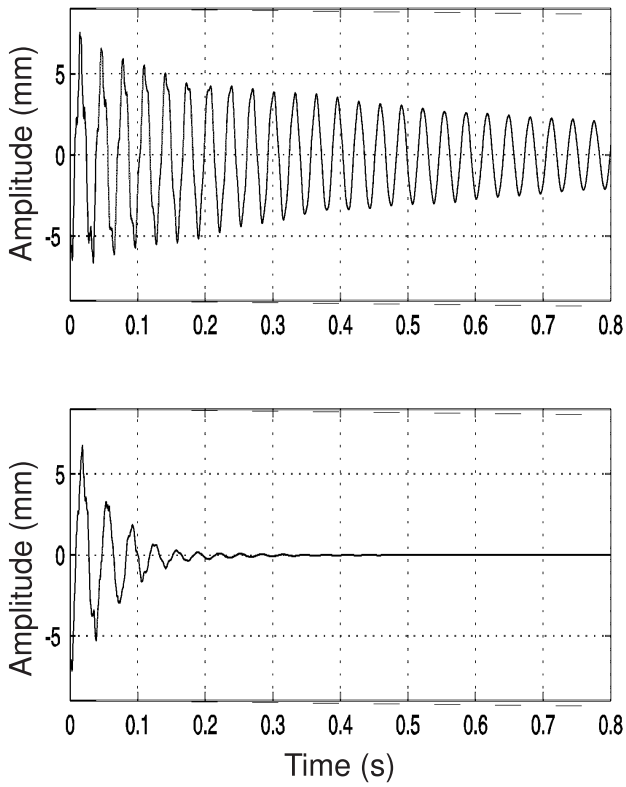

Figure 2: Displacement of the mast tip; top: free vibration; bottom: controlled vibration.

Area Contact Joints

Zero-Thickness Elements

Contact interfaces of joints in built-up structures can be modeled by zero-thickness Finite Elements which incorporate nonlinear tangential and normal contact models. A new model incorporates the Hertz and Mindlin contact of a single spherical asperity generalized by a statistical approach for rough surfaces according to Greenwood [4]. An application example is shown in Figures 3 and 4. This approach is able to simulate the behavior of structures with non-homogeneous contact distribution, even in joints susceptible to uplift. The method suffers from long calculation times, limiting the application of the approach to smaller Finite Element models.

Figure 3: Electronic control unit with non-homogeneous contact pressure distribution in joints.

Thin-Layer Elements

Assembled metallic structures with dry bolted joints can be modeled by thin layer Finite Elements in order to avoid a contact approach. The interface energy dissipation is found experimentally from a generic isolated joint test bench. The thin layer elements contain stiffness and damping parameters obtained from hysteresis measurements. The linearized approach provides a reliable prediction of modal damping ratios even in the design phase of assembled structures [3]. However, constant hysteretic damping estimation can be carried out only in frequency domain, since in time domain it leads to non-casual behavior [5]. Also, joined surfaces should always remain in contact, since this would cause non-linear behavior and would compromise the linear approximation of this approach. An example of the application where this method can be implemented with positive results is shown in Figure 5.

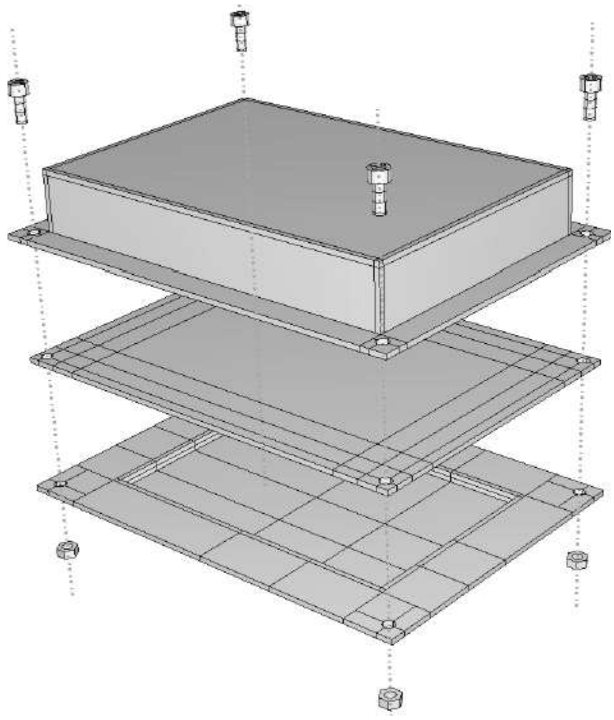

Figure 4: Simplified geometry of an electronic control unit; the contact area is represented by zero-thickness elements.

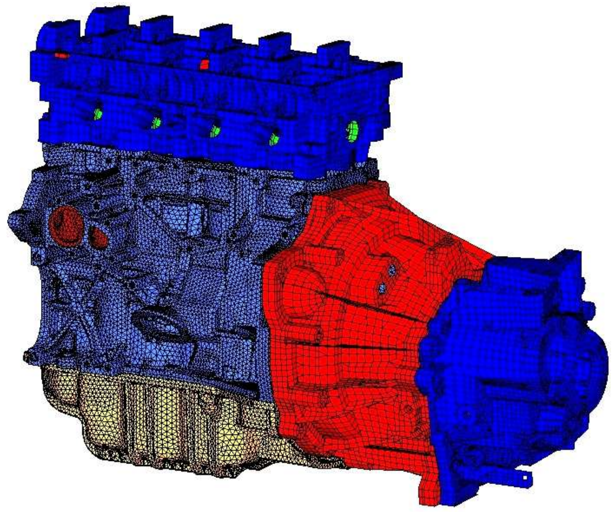

Figure 5: Application example: FE model of an engine with gearbox where the damping is incorporated by thin layer elements.

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