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Harmonic Balance Analysis of Bolted Structures in the Frequency Domain

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Joints play an important role in most mechanical applications and the prediction of the dynamical behavior of jointed structures is a challenging task in structural dynamics. Their inclusion leads to, for example, shifts of the resonance frequencies or the maximal response amplitude within a resonance due to damping effects. These effects are known as 'structural damping'. They are crucial for structures, where the internal 'material damping' either is quite low, as is the case for typical applications in mechanical engineering such as devices made of metal, and may even lead to instabilities in rotating machineries. The effects, which can be summed up to the abstract term of structural damping, can often be traced back to the appearance of dry friction between the contacting parts. The typical form of the equations of motion for a system containing a (friction type) nonlinearity contains not only the mass, damping and stiffness matrices as well as a vector of excitation forces, but additionally also a vector of inner forces which may depend nonlinearly on the time, on the displacement vector and its derivative with respect to time.
In this talk, the focus is on investigating the behavior of a jointed structure over a broad range of excitation frequencies within the frequency domain corresponding to the stationary behavior in the time domain. Due to the nonlinear forces, it is not possible to perform an analytical transformation of the system equations into the frequency domain directly. Instead, a possible approach to approximate the nonlinear term is the usage of the Harmonic Balance Method (HBM). In the framework of the HBM it is assumed that a harmonic excitation of the system leads to a harmonic response. A generalization or extension to periodic excitation and response functions is the Multiharmonic Balance Method (MHBM) which found its most popular application in the dynamic simulation of turbine bladings. In the framework of this article, the MHBM is realized using the Alternating Frequency Time Domain Method (AFT). The calculation procedure is applied to a friction oscillator containing a bolted lap joint, which is modeled via a Finite Element model with a corresponding three dimensional contact law.