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Determination of eigenfrequencies in three dimensional finite element models in comparison with experimental results: A bolted joint problem

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A good joint model should be as simple as possible and still capture all the important physical properties of the actual joint [1]. Evaluating the achievable accuracy of a simulation involving linear models to approximate a structures real dynamic behavior is a core aspect of the present content. This work presents some of the available methods to implement a bolts behavior in large 3d Finite Element Models. A short review of the theoretical background to identify contact conditions and their uncertainties is given [2, 3, 4]. For eigenfrequency extraction the most critical parameter is the most accurate approximation possible of member stiffness, its distribution, and joint stiffness. In the end, a complete model stiffness is created, see [5]. The model stiffness is influenced by uncertainties such as the joints material, surface and contact properties, geometry, clamping force, pressure distribution, and the specific joint configuration. Especially the member stiffness is related to the pressure in the contact zone [6, 7]. Therefore, the pressure distribution in bolted joints interfaces is scrutinized, tangential and normal interface stiffnesses are set into relation to bolt pre-load, and the effect of varying tightening torques and surface properties is studied. The numerically estimated pressure distribution and amplitude are experimentally validated for the joint interface. The systems eigenfrequencies are then computed with the finite element method in Abaqus and compared to the experimental results from a laser Doppler vibrometer setup, to the results from a comprehensive model and to those from analytical beam theories. The geometry used for the numerical and physical testing of the models is a double beam structure bolted together with seven equally spaced M10x16 tapped bolts. The bolts in the physical model are torqued with 30 Nm for the comparison with simulation results. All finite element models presented in this work use the same basic assembly. The pros and cons of developed screw analogous finite element models, universal design issues, and the sensitivity of joint parameters will be described and discussed. The authors are confident that, with the lessons learned in this early stage of testing and the ongoing efforts to create a tailored analytical model, a simplified modeling strategy based on Connector Elements in Abaqus / CAE could be a potent method for modeling bolted joint connections in large finite element models for modal analysis in the near future. As the results show, tangential stiffness is essential for accurate prediction of a system's dynamic behavior, especially for torsional modes. Only a normal joint member stiffness can be computed analytically because rough surfaces are not sufficiently represented with analytical methods and only perfectly flat and smooth surfaces can be taken into account. The significance of this work is to clarify the potentials of available methods and the requirement for more research in this field.

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