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Non-homogenous localized Kelvin-Voigt model for estimation of dynamical behaviour of structures with bolted joints

Anuj Sharma[1]*, Wolfgang Mueller-Hirsch[1], Sven Herold[2] and Tobias Melz[2]

[1] AE/EVR-DE, Robert Bosch GmbH, Robert-Bosch-Strasse 2, Schwieberdingen, 71701 Germany,
anuj.sharma2@de.bosch.com*, wolfgang.mueller-hirsch@de.bosch.com

[2] Division Smart Structures, Fraunhofer Institute for Structural Durability and System Reliability LBF, Bartning Strasse 47, 64289 Darmstadt, Germany,
sven.herold@lbf.fraunhofer.de, tobias.melz@lbf.fraunhofer.de

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Structures with contact interfaces show a nonlinear behaviour with predominance of local energy dissipation in comparison to inherent material damping losses. This paper implements an equivalent local discrete spring-damper system at contact interface based on generalized Hertz and Mindlin contact models for definition of contact stiffness, with the motivation of capturing the major nonlinear effects of predominant structural modes. In contrast to many time domain methods, the present model is implemented in frequency domain to enable advantages of easy modelling and reduced computational time for various practical applications.

A double layered beam with four bolted joints is used as base model for test and validation of the contact model. A pressure dependent joint model is illustrated in this paper to obtain the equivalent contact stiffness in normal and tangential directions. For excitations provoking tangential relative motion, the region of micro slip existing between the stick and sliding region is idealized for maximum damping. Different sets of distribution curves of damping in accordance to predominance in micro slip regions are implemented using discrete hysteretetic damping elements in contact interface. The structure's dynamic behaviour is quantitatively studied for a variation of bolt pretension (variation in contact pressure).

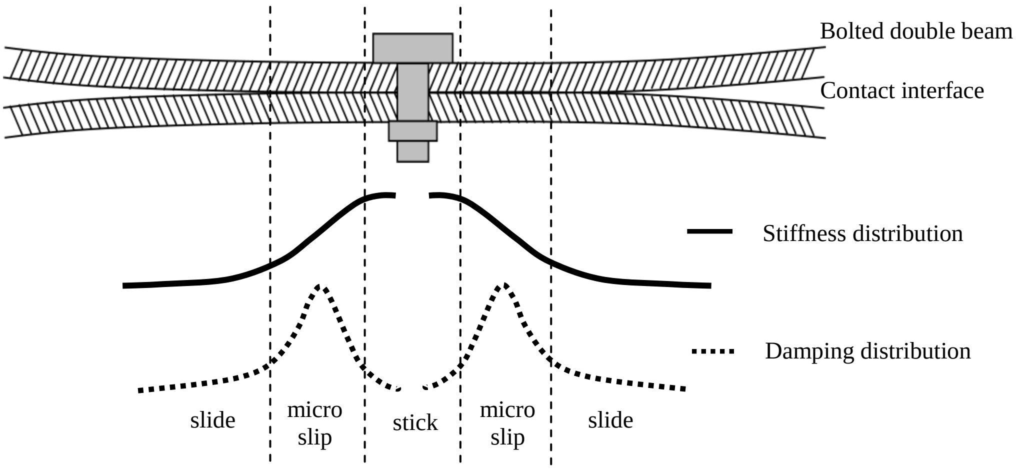
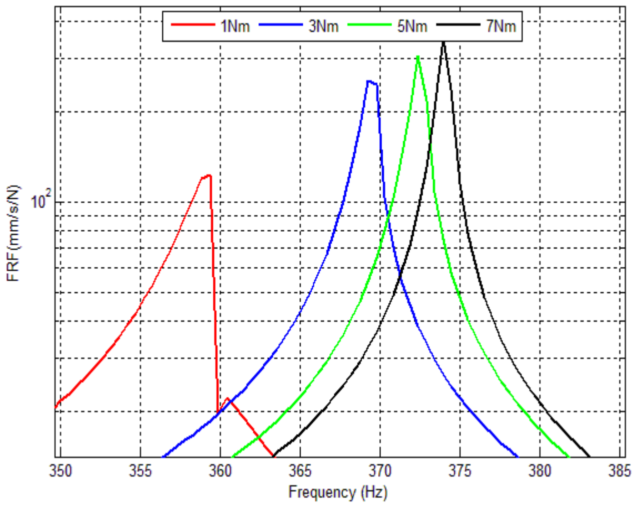


Figure.1: Division of regions in contact interface with equivalent contact stiffness and predicted damping distribution.

A quantitative model verification and parameter study of base model has been done with a set of experiments. A hammer impulse excitation experiment is used to ensure equal excitation amplitude for all measurement points. Initial observations have shown a good match for both eigenfrequency and modal damping between simulation and experiment.



Experiment (Hz)	Simulation (Hz)	Error (%)
369.8	372.5	0.73
404.6	403.9	0.173
899	884	1.66
1103.9	1103.2	0.06
1720	1721	0.05
1783	1835.7	2.95
2080	2130	2.4
2140	2138.8	0.05
2985	3028.7	1.46
3950	3987	0.93
5270	5381	2.1

Figure.2: (a) Effect of bolt pretension on first eigenfrequency of double-layered beam with 4 bolted joints. (b) Table showing eigenfrequency match between experiment (EMA) and simulation at the example of 3Nm bolt torque moment.

It can be concluded for the present contact model, that the model shows good convergence with experimental investigations and thus can be used for lightly damped nonlinear systems at very efficient computational times.

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