COMPUTATIONAL MECHANICS 2018
34th conference with international participation
Srní
October 31 - November 2, 2018

Mechatronic modal hammer

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Many types of engineering structures exhibit nonlinear behavior under real operating conditions, e.g. brake sequel and undesirable engine mounting oscillations. In the aerospace industry, nonlinear motions may have serious implications for fatigue life ([4]). Even modal properties of advanced materials (plastics, glass or carbon fiber composites etc.) exhibit non-linear characteristic ([5]). In addition, current components are often lightweight, with thin walls and complicated internal structure.

Experimental modal analyses is well known and widely used tool for FEM model verification, calibration and recently quality assurance as well. The range of measured problems increased. Components with some level of non-linearity are measured. The quality control requires rapid measurement set-up. Accurate determination not only eigen-frequencies and eigen-modes, but also modal damping is essential ([2], [3]). Source of excitation force is essential part of the measurement chain. Influence of the measurement set-up of the measured item needs to be minimized. This disqualify modal shakers. They have to be connected (by screws or glue) to the item and it adds artificial damping and measurement uncertainty. Bending torques and added stiffness substantially modify the modes. Classical modal hammers do not influence properties of measured item. However, their usage requires skilled worker, it is exhausting, thus unreliable and impact force varies extremely between measurements.

Spatial vibration modes needs to be investigated accurately. So huge number of measured points (at least twice per highest mode wavelength) is necessary to mitigate spatial aliasing or mode shape misinterpretation. The scanning vibrometer allows automatic measurement of all measured points. But stable, robust, automatic excitation without influencing measured item used to be a problem.

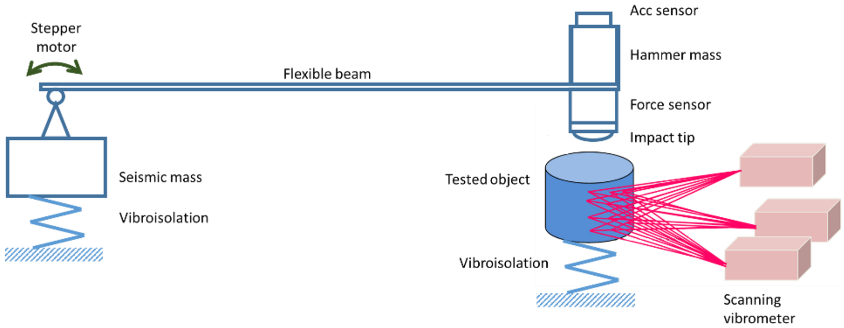

Fig. 1. Hammer structure

The paper introduces automatic modal hammer, which ensures high repeatability of impacts, clean impacts without double hits and controlled impact force level. Mechatronic design (Fig. 1) is based on highly flexible beam holding impact tool with force sensor. This enables clear single impact as the drive can reverse motion. The residual vibrations of the beam are suppreesed by input shaping control ([1]) of the backward hammer motion. On-line tuning and feedback control based on hammer accelerometer to compensate unknown coefficient of restitution.

Fig. 2a shows functional prototype of the mechatronic modal hammer working together with 3D laser Doppler vibrometer Polytec. The setup enabled 17 hours of continuous experimental modal analyses measurement with impact excitation. Fig. 2b demonstrates spatial mode, which could hardly be measured accurately with modal shakers.

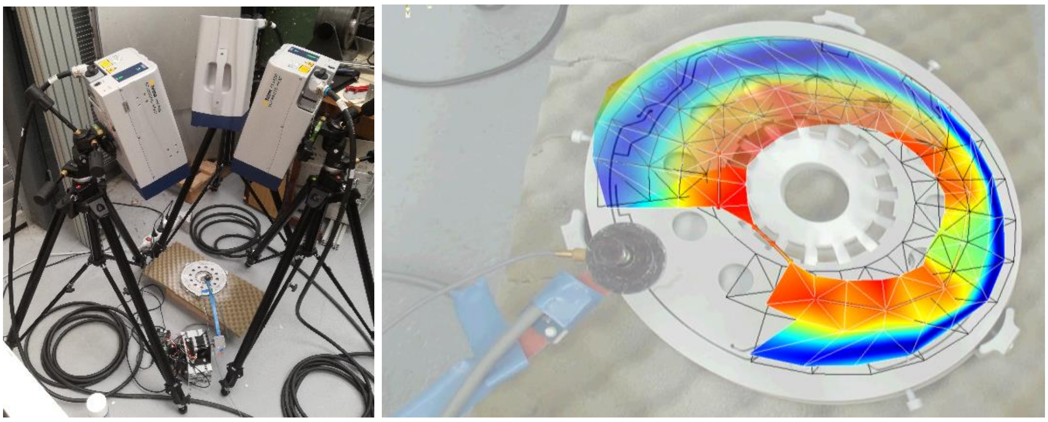

Fig. 2. Mechatronic modal hammer working with 3D laser doppler vibrometer (a), spatial eigen mode at frequency 685,16Hz excited by mechatronic modal hammer (b)

The mechatronic modal hammer was designed and manufactured. Basic structure is relatively simple. However, suitable choice of mechanical parameters and smart control (feedback and feedforward) enables the device to achieve high parameter stability of impact excitation. The repeatability of the excitation force pulse is thus very high and long time measurement of experimental modal analyses is reliable and accurate. Furthermore, the mechatronic modal hammer is significantly cheaper then shaker. Mechatronic hammer installation is also very easy. This increases measurement quality, because several positions of excitation can be quickly tested to avoid modal nodes.

Acknowledgements

This research has been realized using the support of EU Regional Development Fund in OP R&D for Innovations (OP VaVpI) and The Ministry of Education, Youth and Sports, Czech Republic, project # CZ.1.05/2.1.00/03.0125 Acquisition of Technology for Vehicle Center of Sustainable Mobility and The Ministry of Education, Youth and Sports program NPU I (LO), project # LO1311 Development of Vehicle Centre of Sustainable Mobility. This support is gratefully acknowledged.

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