Inverse Lyapunov method based semi-active control transferring energy between vibrational modes

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ABSTRACT

The present study deals with a semi-active control strategy transferring the mechanical energy between structural vibration modes. The analysed structure is equipped with lockable joints, which allow the transmission of bending moments between neighbouring structural members. Depending on the control signal, the joints can be dynamically locked to transmit the bending moments or released to work as truss hinges. Such a control strategy has been successfully developed earlier for attenuation of vibrations by energy transfer to modes with higher material damping [1].

The motivation for the research is a broad field of potential applications, including energy-harvesting from mechanical vibration and structural safety. The proposed semi-active control can be used to transfer vibrational energy to a selected mode which cooperates well with given energy-harvesters, which are usually designed to work with only one frequency or mode shape. Besides, the approach can be used to transfer the energy to modes which do not interfere with the operation of the structure or are not dangerous. Semi-active control has many advantages compared with active control, including lower actuator price. As no high-performance power source is required, the presented strategy is relatively easy to be applied, in comparison with the active methods, and it can be applied in large structures [2] including decentralized control.

The entire idea of the proposed semi-active control strategy is derived from the simple requirement: the increase of mechanical energy of the target vibrational mode is to be maximized. From the character of semi-active control, it follows that for free vibrations the energy of the maximized mode will increase only at the expense of other modes, which causes the energy transfer. Furthermore, a mathematical description of the energy transfer between all vibrational modes as well as the respective measurement technique are proposed. The derivation of the model is based on coupling of modal equations by coefficients that depend on the control signals, mode shapes and the placement of the lockable joints.

As a demonstrative example a three-bar frame structure has been used. Two different kinds of finite element models of this structure have been analysed: crude (with one finite element per beam only) and refined (with four elements per beam). The first model is very simple and clearly introduces the semi-active control strategy. The second one allows the participation of undesirably excited higher modes and their influence on the modal energy transfer. It is shown that using the proposed methodology the modal energy transfer is possible, but part of the energy is lost due to inevitable natural material damping of higher modes.

REFERENCES

[1] B. Popławski, G. Mikułowski, A. Mróz and Ł. Jankowski, "Decentralized semi-active damping of free structural vibrations by means of structural joints with an on/off ability to transmit moments", *Mechanical Systems and Signal Processing*, Vol. **100**, pp. 926–939, (2018).

[2] L.Y. Lu, "Semi-active modal control for seismic structures with variable friction dampers", *Engineering Structures*, Vol. **26**, pp. 437–454, (2004).