Tunable Elastic Metamaterial based on Piezoelectric Transducer

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Nowadays, a large effort is devoted to shield propagation of vibrations to locations where they can cause problems or damage. There exist plenty of damping strategies based typically on passive elements. Nevertheless, such solutions are not suitable in some situations, e.g. due to weight or spatial limitations. In such situations, active damping may present an interesting alternative.

In our research, we focus on semi-active damping of vibrations using piezoelectric actuators, in an approach known as active elasticity control (AEC): elastic properties of a piezoelectric actuator are altered by connecting its electrodes to an active shunt circuit. Adjustment of the electric impedance of the shunt circuit allows to control the elastic properties of the actuator in a relatively large range from hard to soft and even drive the actuator to the regime of negative elasticity. Such an actuator, placed to the vibration-propagation path, can lead to significant attenuation of vibrations [1].

Nevertheless, the proper adjustment of the shunt-circuit electric impedance is a delicate issue. This is mainly because the shunted piezoelectric stack is operated as close to the edge of the stability as possible. At the same time the actuator itself changes its electric properties considerably e.g. due to temperature changes of the surrounding environment or due to the dissipation of heat in the piezoelectric material upon active driving. For an efficient control of the electric-shunt properties it is vital to be able to determine electric properties of the piezoelectric stack in runtime.

We report here a method for determination of the electric impedance of the piezoelectric actuator in relation to the electric impedance of the shunting circuit, which is a critical quantity for controlling the operation regime of the actuator. The procedure is based purely on measurement of the mechanical transfer function of the system, which is possible to be determined on a running system. It is shown that the derived impedance is comparable with direct measurement using impedance analyzer, which is nevertheless not applicable in runtime [2]. For accurate setting of the shunt impedance we use synthetic impedance device designed for this purpose [3]. The presented method is foreseen to facilitate application of correction to the shunting circuit and bring the AEC-based devices closer to applications.

[1] T. Sluka and P. Mokrý, "Feedback control of piezoelectric actuator elastic properties in a vibration isolation system", Ferroelectrics vol. 351, p. 51 2007.

[2] P. Marton, J. Nečásek, J. Václavík, and P. Mokrý, "Tuning of an elastic metamaterial: Direct observation and analysis", submitted to Smart Materials and Structures, 2016.

[3] J. Nečásek, J. Václavík, and P. Marton, "Digital synthetic impedance for application in vibration damping", Review of Scientific Instruments, vol. 87, p. 024704, 2016.