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Spatial active absorber for non-collocated vibration suppression

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Vibration plays an important role in many engineering applications and often needs to be eliminated. These problems occur with robots, machine tools, with turbine rotors for different applications, in precise instruments such as electron microscopes, deep space telescopes, particle detectors, etc. A novel methodology for vibration absorption of mechanical structures is proposed utilizing tuneable active absorbers as key elements. The absorber(s) are considered to be located in a certain distance from the point on the structure, where vibrations are to be suppressed. This original concept, referred to as the "non-collocated vibration absorption" has a high potential towards applications, where the absorber cannot be placed in the conventional "collocated" manner due to various technological constraints.

The idea of passive vibration absorber connected to the primary mechanical structure to suppress its vibrations is known and patented many decades. The active versions of vibration absorption concept however significantly improve its efficiency. There is a lot of ways of control algorithm design. One specific alternative is a Delayed Resonator (DR) approach [1], which has recently been generalized for simple unidirectional flexible mechanical structures also to non-collocated absorption of vibrations [2].

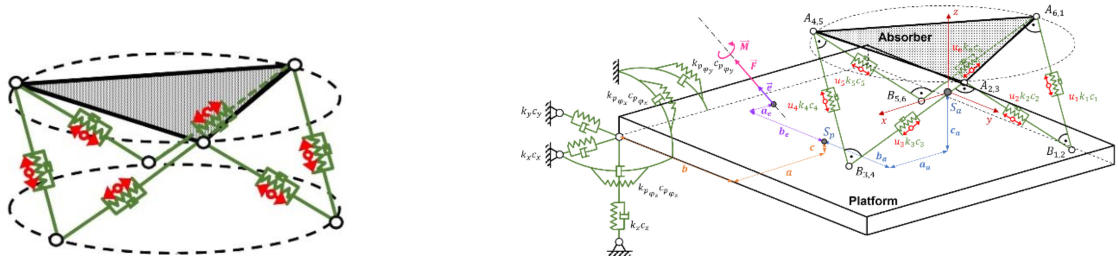
Realization of non-collocated absorption for a general spatial structures is neither straightforward nor simple. Reduced modal description with consideration of the static residues [3] for neglected higher eigenfrequencies/eigenmodes seems to be suitable form of model. The original state space model is described by matrices in form (1), part of the states corresponding to low frequencies "1" is preserved, whereas part "2" is reduced and replaced by residues. Using modal state variables, the whole state matrix is simplified (2), and residues affect only the feedthrough matrix (3). The matrix $\boldsymbol{A}_{22}$ is tridiagonal and consequently inversion $\boldsymbol{A}_{22}^{-1}$ is also tridiagonal [3]

$$SS_{orig} = \begin{bmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} & \mathbf{B}_1 \\ \mathbf{A}_{21} & \mathbf{A}_{22} & \mathbf{B}_2 \\ \mathbf{C}_1 & \mathbf{C}_2 & \mathbf{D} \end{bmatrix}, \tag{1}$$

$$\mathbf{A} = \begin{bmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} \\ \mathbf{A}_{21} & \mathbf{A}_{22} \end{bmatrix} = diag(\mathbf{A}_{mi}), \mathbf{A}_{mi} = \begin{bmatrix} 0 & \Omega_i \\ -\Omega_i & -2b_{di}\Omega_i \end{bmatrix}, \tag{2}$$

$$SS_{\mathrm{mod}\,spa} = \begin{bmatrix} \mathbf{A}_{11} & \mathbf{B}_1 \\ \mathbf{C}_1 & \mathbf{D} - \mathbf{C}_2\mathbf{A}_{22}^{-1}\mathbf{B}_2 \end{bmatrix}. \tag{3}$$

As the significant extension of previous 2D-DR research [4], [5] the aim of the current investigation is 6 DOF spatial absorber on the flexible spatial multi-DOF structure. The absorber is proposed as compact three-dimensional active device with six identical eigenfrequencies, which could be based e.g. on Stewart platform equipped with springs and voice-coil actuators in each leg (Fig. 1a). The cubic architecture is close to the uni-frequency ideal. Subsequently, applying delayed position feedbacks from voice-coil length encoder sensors, the 3D-6 DOF absorber is turned to the ideal absorber at the given frequency similarly to planar case in [4] and [5]. Basic configuration, with elastically mounted rigid 6 DOF primary platform (Fig. 1b), is farther extended to the above mentioned general flexible spatial multi-DOF primary structure. The example of spatial uni-frequency absorber functionality in *x*, *y*, *z* directions on multi-DOF flexible structure is shown in Fig. 2.



a) absorber mechanical scheme b) absorber mounted on primary platform

Fig. 1. Spatial 6 DOF active absorber

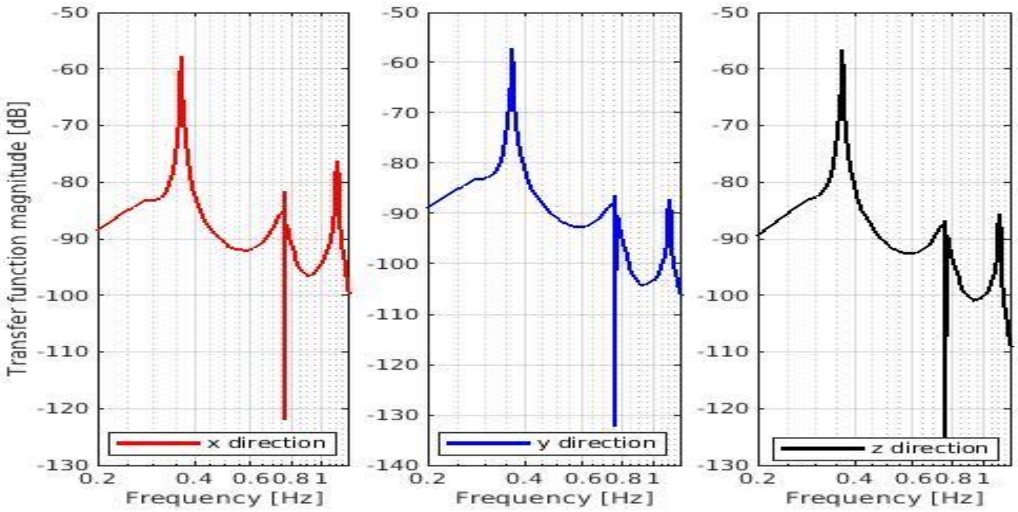


Fig. 2. Example of absorber functionality in *x*, *y*, *z* directions on flexible structure

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