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Planar and spatial active resonator absorbers for robotics

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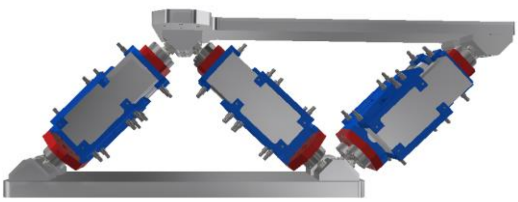
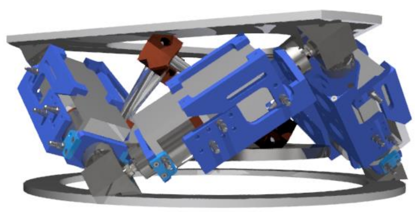
Vibrations have negative effect in many engineering applications. In robotics, there are types of machines such as serial robots or cable manipulators, that are typically able to cover large workspace, which usually implies high mass/stiffness ratio. Such robots are not capable of high accuracy while performing operations with high dynamic of the end-effector tool or external excitations. During last decades, there has been an intensive development of serial robots in order to increase their production efficiency, including their non-traditional usage e.g. for drilling [1].

The open problem is what can be achieved through the accurate measurement of the absolute end-effector motion and its subsequent use to compensate for control loop errors between robot drives and the end-effector. Such measurement, considering large workspace in complex industrial environment, is typically very problematic. Second problem is, that the drives of robots typically are not capable to operate in frequency range of vibrations induced by disturbances. Consequently, some other robust concept of vibration suppression is desirable. The usage of dynamic absorbers with active elements is one of the promising ways [2], [3]. The important reason for usage of active resonator absorbers is the strong change of eigenfrequencies and eigenmodes of serial robots operating in large workspaces. In order to perform active vibration suppression effectively, it is important to begin with absorber (Fig. 1) optimized properly passively with respect to dynamic properties of the robot mechanical structure. The reasonable way is to tune absorber mechanically close to the average value of the robot lowest eigenfrequency. During the robot end-effector motion along the trajectory (Fig. 2 a)), however, not only the first eigenfrequency value (Fig. 2 b)) changes, but also the geometric shape of the corresponding first eigenmode. From this fact came the idea to tune the resonator passively and subsequently also actively along trajectory as uni-frequency. Concerning planar absorber (Fig. 1 a)) the goal is to tune all three absorber's working eigenfrequencies to one value. The analogous goal for the spatial absorber (Fig. 1 b)) would be to tune all its six eigenfrequencies to one value. However, this goal is unattainable for passive mechanical tuning of structure from Fig. 1 b), maximum 5 of its eigenfrequencies can be the same. The control law algorithm for vibration absorption of moving flexible robot has been firstly developed for planar robot (Fig. 2 a)) equipped by planar 3DOF uni-frequency absorber (Fig. 1 a)). The aim is to prepare the control law as simple as possible.



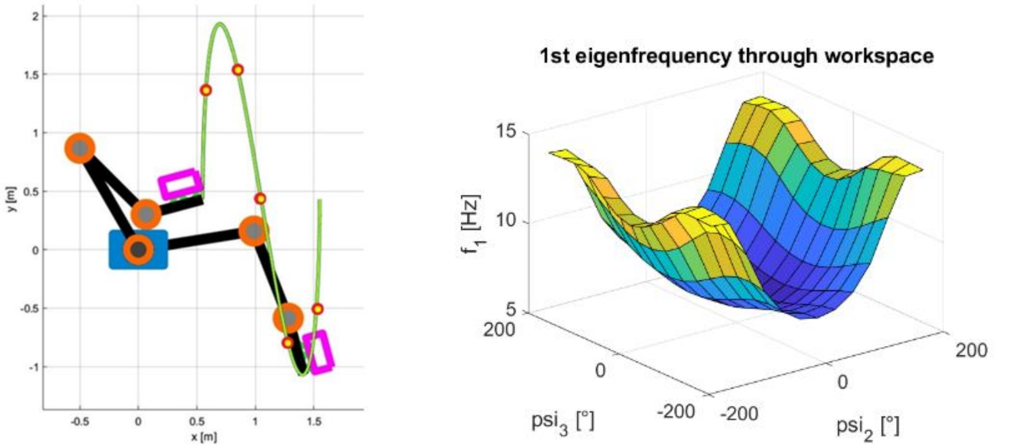
a) planar 3 DOF version



b) spatial 6 DOF version

Fig. 1. Experimental demonstrators of active absorbers with mutually perpendicular voice-coil actuators

The basic concept of the control law is to evaluate the active voice-coils forces in order to change absorber tuning according to the first eigenfrequency in given position of robot (Fig. 2 b)). The active force in each voice-coil has two components, component modifying the efficient stiffness and component evaluated from the delayed acceleration. The example of effect of this control along some trajectory is shown in Fig. 3. The efficiency of this simple law with respect to other concepts (e.g. LQR with observer) is continuously evaluated.



a) trajectory with points of impulse disturbance b) map of first eigenfrequency in workspace

Fig. 2. Model of flexible planar robot with planar absorbers

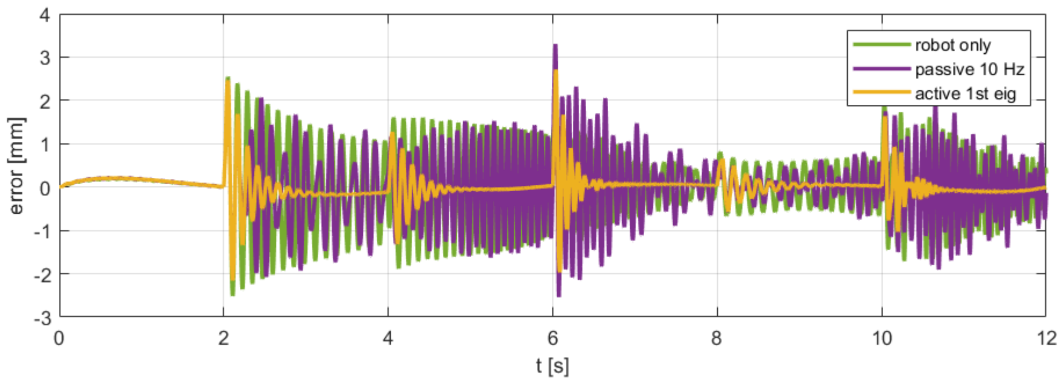


Fig. 3. Vibrational response of end-effector to force impulses on trajectory

Acknowledgements

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