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Active multidimensional vibration absorbers for light structures

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There has been high effort to increase production efficiency of production machines and robots last decades, including the usage of new types of kinematics [3], special control algorithms for non-traditional usage of machines [1], etc. The accurate motion control of the end-effector can be achieved through accurate measurement of the end-effector position and including such an information into the main control algorithm using base or additional actuators, but not all cases are suitable for such a design due to lack of space, bad work environment or many obstacles in the workspace. The counterpart of external end-point accurate measurement is the strategy of controlled vibration suppression [2], which can be realized through damping, vibro-isolation, vibro-compensation or vibro-absorption principles. Further differentiation distinguishes between active and semi-active approaches. Vibration suppression applications span from aircraft wings through towers and telescopes to cable bridges stabilization.

Well known passive vibration absorbing using mass connected to the primary structures works well in single DoF cases or even in multi DoF structures using more single DoF absorbers, but the frequency band is quite narrow and non-tunable while in operation. Using active or semiactive elements, better results in frequency band and response can be achieved. In this paper, single-mass multi-DoF active absorber is considered in order to reduce weight and spatial demands, so that added single body can reduce vibrations in many directions concurrently.

The concept of multi-level mechanisms consisting of main structure and additional single-mass multi-DoF absorber brings potential to improve dynamical properties of diverse lightweight robots with large workspace, since relatively small and light additional mass can be attached. This solution, along with well calibrated robot, presents an alternative idea of robot's end-point accuracy around its equilibrium, with less demanding and more robust local sensing, e.g. by accelerometers or geophones.

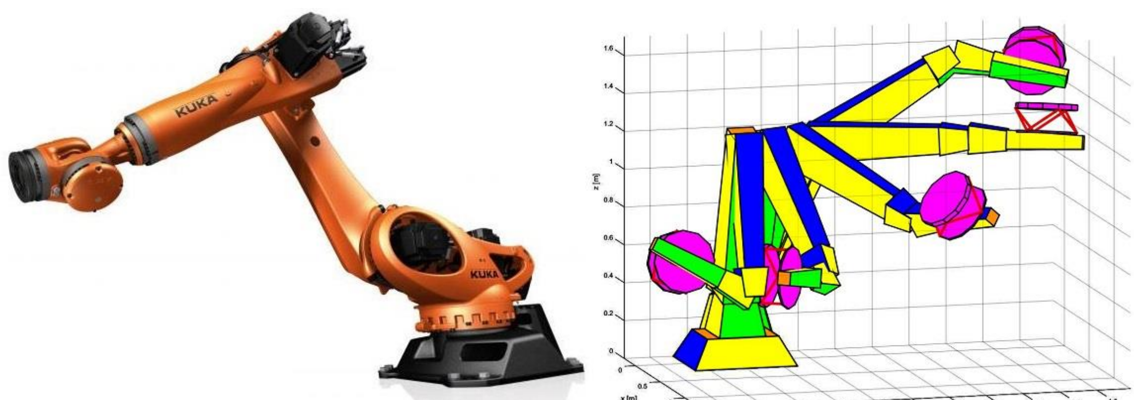

Fig. 1. Industiral light robot (left); simulation model of the robot with absorber in 5 different positions (right)

Fig. 1 (left) shows an example of 6-DoF light industrial robot, which can operate in large workspaces and concurrently suffers from end-point dynamical accuracy due to low stiffness. Fig. 1 (right) shows simulation mathematical model of such a light robot in five diverse positions through workspace already with vibration absorber attached. The absorber design is based on cubic structure, so that 6 active elements are formed along 6 edges of virtual cube, providing symmetrical neutrality of the additional mechanical structure.

Active elements of the absorbers consist of spring and voice-coil actuator. Dynamical properties of the absorber were optimized such that the vibrations in all directions and in all of the five robot's positions are as small as possible. Both, the robot and the absorber, are equipped with accelerometers providing feedback information.

Feedback control of mechanical parallel structure leads most likely to some type of centralized control algorithm, such as PID regulators, H-inf, LQR or Delayed resonator [4]. In this paper, LQR approach is considered as initial control design. There is a need of creating of multiple sets of ABCD matrices of local linearized state space models of the multi-level structure. Time-dependant ABCD matrices generations remains an opened question.

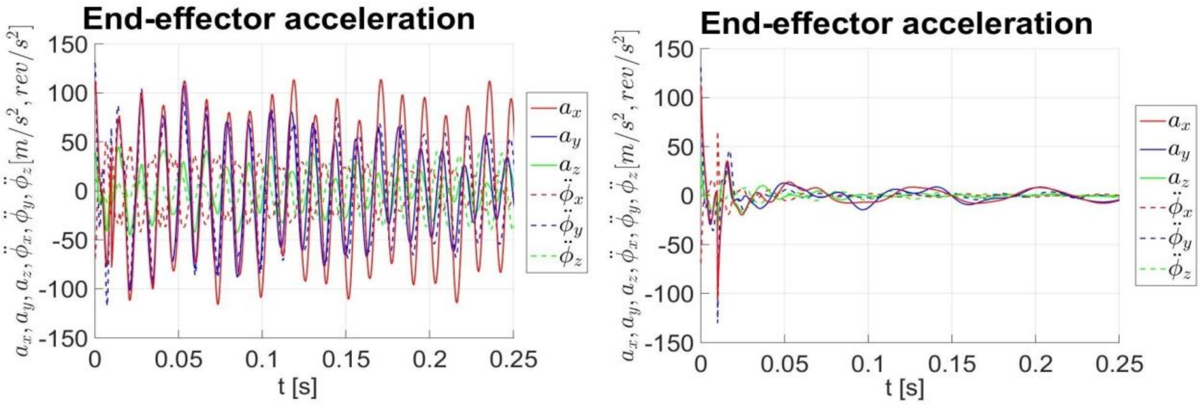

Fig. 2. End-effector acceleration in all directions without (left) and with (right) attached active absorber

Fig. 2 shows acceleration of the end-effector of the robot without (left) and with (right) attached active absorber based on LQR control. Absorbers are not designed to reach accurate positions, but to damp vibrations around equilibrium of the robot. The research of whole problematics is still in the process, so, many questions remain opened. For example, what sensors and what location of them to choose, how to adapt ABCD matrices through workspace, etc.

Acknowledgements

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