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Experimental based tuning of active 3-DoF planar absorber

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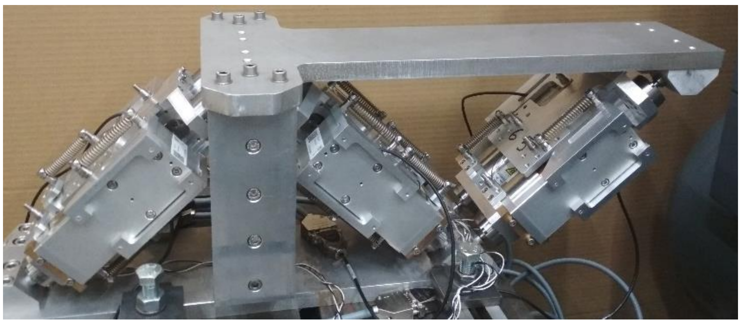
Vibration suppression takes place in many applications and enviroments. In various cases, for example in robotics and industrial enviroment [3], it might be convenient to use absorbers [1] to suppress vibrations of the main structure. Based on application, mass-spring absorber is attached to main structure in point of interest, tuned and actively driven if needed. In order to be able to actively tune and control absorber, some sort of sensors needs to be implemented in the main structure or in the absorber itself, such as accelerometers, encoders, geophones, etc. Depending on absorbers count and the nature of vibrations, various algorithms can be used to drive absorber's actuators, such as PID regulation, H-inf, LQR [4], Delayed resonator [2], etc. Nevertheless, besides mass and stiffness of the absorber, due to many kinds of bearings, usually some sort of damping takes place in the absorber. Lots of real cases of beraing damping are far from linear and thus burdens control algorithms. In this paper we are experimentally tuning real active absorber to be as much undamped (ideal) as possible, so it can be further controlled by superior algorithm.

3-DoF assembly (Fig. 1b) is configured such that active elements lies in mutually perpendicular axes, and enables full planar motion (translation in both directions and rotation). Each active element (based on assembly MGV52 – Fig. 1a) consists of preloaded springs, linear ball bearing, voice-coil actuator and built-in linear encoder. dSpace computer is then used to read sensors and control voice-coil actuators through motor driver (Fig. 2a).

First of all, rough identification must take place in order to get basics characteristics, such as precise mass, stiffness of elements and drive coefficients. Since this identification is based on measurement data from the control pc, ceratin delay of the loop between output and input of the pc (Fig. 2a) is also included among these characteristics. After that it is possible to more closely identify the damping function.

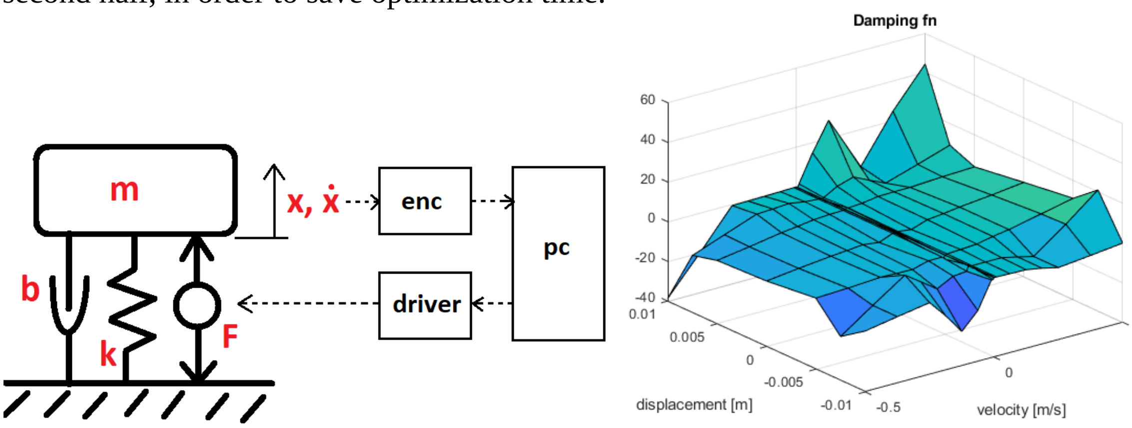
a) active element with linear bearing



b) 3-DoF planar mass-spring configuration

Fig. 1. Absorber design based on MGV52 assembly

Since every planar motion of the whole assembly can be transformed into set of linear motions of every active element, prev to the 3-DoF tuning, tuning of the single element has been performed to get potentionally convinient initial values. Combination of various non-linear functions with tunable coefficients has proven insufficient for the damping identification as well as 1-D look-up table, because results implied the function to be not only the function of velocity, but of the displacement as well – since voice-coil has been chosen as an active absorber's actuator for various advantageous reasons, there are more damping sources apart from bearings. Firstly, its closed-end design with one millimeter wide gap does not allow air to flow effortlessly in and out. Secondly, and more relevantely, electrical characteristic of magnet-coil coupling greatly depends on the mutual position. Therefore, parametrical 1-D look-up table must be at least 2-dimensional. Fig. 2b shows one of more precise idendifications of damping as a function of both, displacement and velocity one of the active elements. It consists of more or less conventional coulomb-viscous area in low speeds and strokes, as well as of great fluctuations (with some sense of symetry) in areas of high strokes. This parametrical plane, when put into positive feedback, is then able to reduce relative damping of the absorber and retain its stability at the same time. When assembled into the final 3-DoF planar configuration, another optimization process takes place in order to adapt initial parameters to increased mass (and therefore forces in bearings). This process is centralized in first half and broken apart in the second half, in order to save optimization time.



a) Control scheme

b) Damping function included in algorithm

Fig. 2. Absorber control algorithm

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References

[1] Kraus, K., Šika, Z., Beneš, P., Krivošej, J., Vyhlídal, T., Mechatronic robot arm with active vibration absorbers, Journal of Vibration and Control 26 (13-14) (2020) 1145-1156.

[2] Olgac, N., Elmali, H., Hosek, M., Renzulli, M., Active vibration control of distributed systems using delayed resonator with acceleration feedback, Journal of dyn. systems, measurement, and control 119 (3) (1997) 380-389.

[3] Olsson, T., Haage, M., Kihlman, H., et al., Cost-efficient drilling using industrial robots with high-bandwidth force feedback, Robotics and Computer-Integrating Manufacturing 26 (1) (2010) 24-38.

[4] Šika, Z., Kraus, K., Beneš, P., Vyhlídal, T., Valášek, M., Active multidimensional vibration absorbers for light robots, Proceedings of the 5th Joint International Conference on Multibody System Dynamics, Lisbon, 2018, pp. 1-12.