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Dynamically isotropic planar mechanism of vibration absorber

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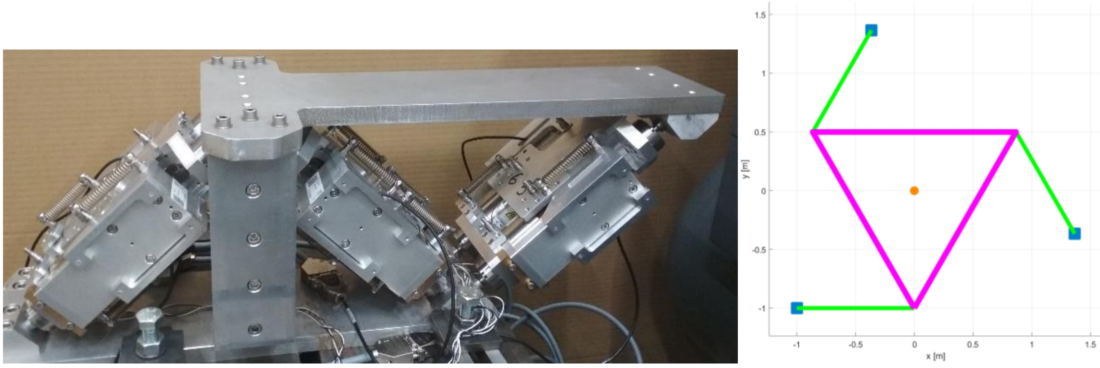
This paper deals with dynamical isotropy of absorbers, that are designed in single-mass and multi-DoF configuration. Such tuning property has been researched for both planar and spatial cases. Vibration suppression takes place in many applications and environments. In various cases, for example in robotics and industrial environment, it might be more convenient to use absorbers [1] to suppress vibrations of the main structure over other methods for technical or practical reasons. Based on application, mass-spring absorber is attached to main structure in point of interest, tuned and actively driven if needed. 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 [3], etc. Usually, some sort of damping takes place in the absorber structure and lots of real cases of bearing damping are far from linear. That burdens control algorithms and some way of active control might be needed to make such an absorber as ideal as possible [2]. Besides all above, for full vibration suppression in the given coordinates of desired system, considering all possible projections, the unifrequency (aka dynamical isotropy) property is a crucial feature [5].

In principle, dynamical isotropy is based on tuning of all the absorber's eigenfrequencies to single value, when using single-mass and multi-DoF configuration. That is crucial for full vibration suppression in all coordinates. There are solutions for simplified models, where only the absorber's mass is considered. The problem is that any flexible-damping-actuating structure (or legs), supporting and controlling the absorber's mass itself, has its own mass, which affects entire absorber's system. For all absorber designs, this ratio of supporting mass to the absorber's mass is non-trivial and can be very significant in some cases. Especially when using electromagnetic actuators, which usually includes heavy magnets. Therefore, it is necessary to tune and design the absorber as a whole, to be implemented in real world, which can bring some limitations.

In planar design, 3-DoF absorber's mass is joined to the system with three supporting flexible legs. Each leg consists of spring, actuator and linear bearing, and is joined using rolling bearings on each end. That gives us two more bodies per leg and each body has its own mass, moment of inertia and position of the centre of mass. Considering perpendicular design of the absorber (see Fig. 1a) and all the dynamical parameters and constraints mentioned above (in addition to dynamical parameters of the absorber's mass itself), we obtain complex problem of dynamical isotropy tuning. Although there is a solution for simplified model [5] at analytical level, equations for this new parallel seven-body system are fairly complex. Therefore, whole problem has been transformed into optimization task.

Built optimization software works with independent dynamical equations of the seven-body system and with multiple parameters mentioned above. Due to high number of such parameters, a series of subsequent optimization jobs with various subsets have been performed at first, along with linear constraints of parameters across legs if needed. Our results had not show any non-trivial solution of such absorber in perpendicular configuration. The only result of dynamical isotropy for such case happens only when some of the leg masses tend to zero.



a) Perpendicular design of 3-DoF absorber b) Symmetrical design of 3-DoF absorber

Fig. 1. Planar absorber kinematical configurations

Although there is convenience of the perpendicular absorber design in terms of ease of attachment to the main structure, it is not suitable candidate for dynamical isotropy tuning when implemented to real world structure. For such purpose, a symmetrical triangular symmetrical structure is considered (see Fig. 1b), although its attachment points require building of supporting structure all around the absorber's mass.

Symmetrical structure is instantly more suitable for dynamical isotropy by the fact that it already ensures both transitional eigenfrequencies of the absorber to be equal. It is conditioned by the equal dynamical and kinematical parameters of all legs and by the symmetricity of the absorber's mass and dimensions.

In order to lock scale of the absorber during optimization, mass of the absorber and its size are fixed. All other legs parameters can be tuned, such as length, angle, masses, moment of inertia, stiffness, position of CoF, as well as moment of inertia of the absorber (mass distribution). Not only we now use equal parameters across all legs, but, due to the symmetricity, not all of them must be tuned in order to achieve unifrequency. One of the main contributor to eigenfrequency is the angle of the legs, which, depending on the constellation, can equalize rotational and translational eigenfrequency of the absorber.

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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] Kraus, K., Šika, Z., Krivošej, J., Experimental based tuning of active 3-DoF planar absorber, Proceedings of computational mechanics, University of West Bohemia, Plzeň, 2022, p. 54-55.

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

[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, Lisabon, 2018, pp. 1-12.

[5] Šika, Z., Vyhlídal, T., Neusser, Z., Two-dimensional delayed resonator for entire vibration absorption, Journal of Sound and Vibration 500 (2021) 116010.