THE PROTOTYPE, MATHEMATICAL MODELLING AND OPTIMIZATION OF ADAPTIVE TUNED PARTICLE IMPACT DAMPER

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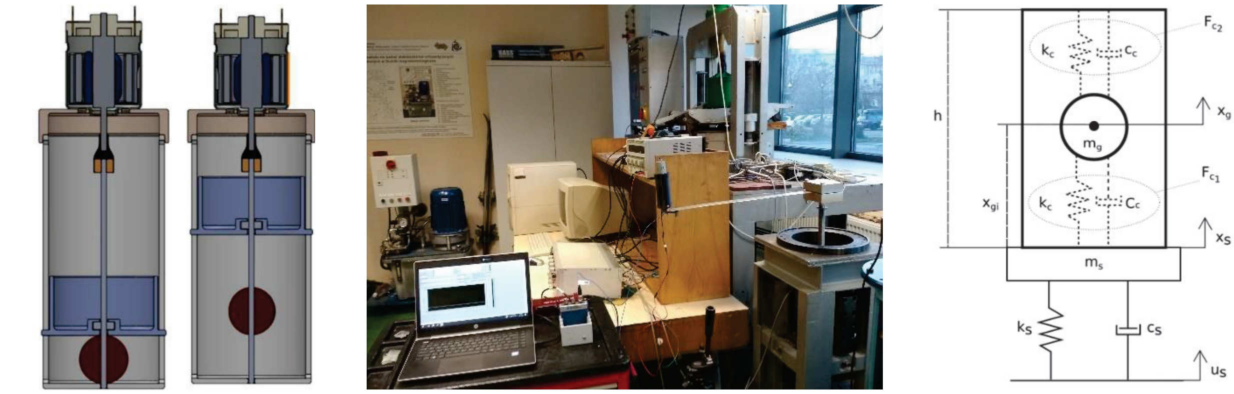
1. Introduction

The contribution presents a short description of the novel controllable device called Adaptive Tuned Particle Impact Damper (ATPID). Such device allows to effectively reduce mechanical vibrations of the beam element under various types of excitations. The whole construction can be considered as an extension of the classical Particles Impact Damper (PID) [1, 2, 3], in which container height can be changed (in real time) by the movement of the ceiling controlled by a simple electromechanical system. The ATPID operation is determined by particle flight time and particle-container contact duration [4], which depend on actual container height. Therefore, control of the damper height is crucial from the vibration mitigation point of view.

2. ATPID construction and modelling

The conducted research consists of experimental and numerical part. The experimental part concerns construction and prototype of the proposed ATPID damper (Fig. 1a). The specially designed test stand (Fig. 1b) allows to study response of the beam vibration under harmonic excitation of a wide frequency range.



a) b) c)

Fig. 1 a) ATPID model, **b)** Experimental test stand, **c)** Scheme of the ATPID construction

The numerical part of research is devoted to mathematical modelling, sensitivity analysis and optimization of the ATPID damper. The scheme of the ATPID construction (Fig. 1c) is used to derive governing equations, which take the form:

$$m_s\ddot{x}_s + F_{ext} - F_{ATPID}(x_s, x_g, \dot{x}_s, \dot{x}_g, h, \dot{h}) + Q_s = 0 \quad (1)$$

$$m_g\ddot{x}_g + F_{ATPID}(x_s, x_g, \dot{x}_s, \dot{x}_g, h, \dot{h}) + Q_g = 0 \quad (2)$$

where: m_s - mass of the base system, m_g - mass of the grain, F_{ext} - harmonic excitation, F_{ATPID} - the total force forces generated by the ATPID, x_s - displacement of base system, x_g - displacement o the grain, h - height of the damper, Q_s and Q_g - gravity forces acting on the system and grain, respectively. The total force generated by the ATPID damper F_{ATPID} depends on forces exerted during impacts of the grain against cylinders walls (Eq. 3). Both these forces are modelled using soft contact theory [5 and 6] and nonlinear viscoelastic model of impact (Eqs. 4 and 5):

$$F_{ATPID}(x_s, x_g, \dot{x}_s, \dot{x}_g, h, \dot{h}) = -F_{c_1}(x_s, x_g, \dot{x}_s, \dot{x}_g) + F_{c_2}(x_s, x_g, \dot{x}_s, \dot{x}_g, h, \dot{h}) \quad (3)$$

(4) $$F_{c_1}(x_s, x_g, \dot{x}_s, \dot{x}_g) = k_c \xi_{c_1}{}^{3/2} + c_c \dot{\xi}_{c_1} \xi_{c_1}{}^{1/4}$$

(5) $$F_{c_2}(x_s, x_g, \dot{x}_s, \dot{x}_g, h, \dot{h}) = k_c \xi_{c_2}{}^{3/2} + c_c \dot{\xi}_{c_2} \xi_{c_2}{}^{1/4}$$

In the mathematical model the moveable ceiling is implemented by using time-dependent function of the damper height $h(t)$ defined by Eq. 6. Such parameter is described by initial minimal value of the height h_{min} (diameter of the grain), the controllable range Δh and control function $\psi(t)$:

(6) $$h(t) = h_{min} + \Delta h \psi(t)$$

The proposed ATPID model is validated against experimental results. Moreover, the model allows to disclose the principles of the ATPID operation, investigate the influence of the selected parameters on the damping ability and to conduct optimization process of ATPID parameters.

The change of damping effectiveness of the proposed device is revealed by displacements of the beam under resonant excitation, corresponding to five different controllable ranges of the damper heights (Fig. 2). The obtained results show the increase of damping ability with an increase of the maximal absorber height. In particular, in considered case, the vibration reduction of up to 90 % can be observed for the height $h(t) = 0.212\ m$. The larger container heights result in rumble effect, which decreases vibration mitigation ability.

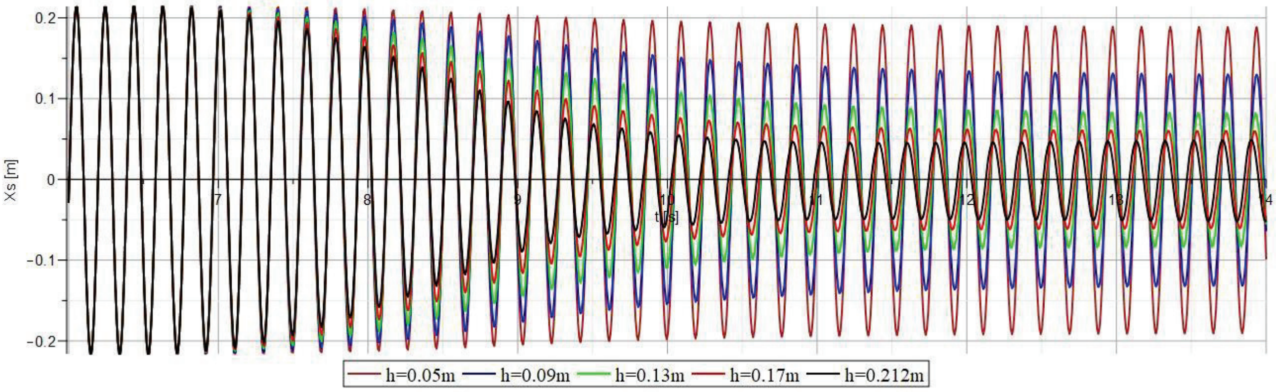


Fig. 2 Beam displacements for various maximal container heights

3. Conclusions

The proposed ATPID damper with controllable container height provides high damping effectiveness for a wide range of harmonic excitations of various frequencies and amplitudes. Therefore, it can be considered as promising solution mitigation of vibrations of various engineering structures. The further research in this field will be dedicated to development of various control algorithms and application of the ATPID damper in multi-degree of freedom systems.

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References

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