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*Damping mass systems
diagnostic assessment of effects of vibration, active and
passive tuned mass damper, ATMD, PTMD*

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DAMPING MASS SYSTEMS IN THE BUILDING STRUCTURES

Technological progress and needs of civil engineering development in the area of dynamic excitations: seismic, para-seismic loads, cause searching methods and means of protection building objects against vibrations. Considerable attention has been paid to researches of effectiveness of structural damping devices. Selected issues of application of dynamic vibration dampers in the building structures are discussed in the paper

DYNAMICZNE TŁUMIKI MASOWE W OBIEKTACH BUDOWLANYCH

Postęp technologiczny i potrzeby związane z rozwojem budownictwa, wymuszenia dynamiczne: sejsmiczne, para-sejsmiczne powodują, iż konieczne jest poszukiwanie nowych metod i środków ochrony obiektów budowlanych przed drganiami. Szczególna uwaga powinna być zwrócona na badania skuteczności stosowanych urządzeń tłumiących. W artykule omówiono wybrane zagadnienia zastosowania dynamicznych tłumików drgań w obiektach budowlanych.

1. INTRODUCTION

Dynamical protection of structure has wide application in civil engineering [1,2,3]. In order to reduce level of vibrations the following methods are applied [1,4]:
removal of vibration source, balancing, aligning of device resting on the foundation, modification of technological process, sliding of devices producing vibrations in a distance from object sensitive to vibrations, increasing base stiffness, active, semi-active, passive, hybrid vibration isolation, application of passive, active, semi-active, hybrid dynamic dampers, use of passive, active, semi-active, hybrid bracing.
Besides, in practice vertical or sloping trenches filled with isolation materials are applied to protect structures against seismic or para-seismic excitation. Reducing of propagation of surface waves is possible by covering the base surface with dynamical vibrations dampers, as well
A well accepted strategy in utilizing dynamic control systems is based on the increase of

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structural damping. As a first idea damping devices can be installed. Then, they have the task to damp the relative motion between two structures, two parts of the same structure, or the structure and the ‘rigid’ vicinity. The damping effects may be obtained by friction, plastic deformation or viscose behavior inside the device.
The protection of the environment from vibrations is a priority requirement to be achieved [1].

2. SOLUTIONS OF SOME DYNAMIC VIBRATION DAMPERS

One of the directions of the designed solution is a dynamic vibration dampers in systems combining active and passive dampers (Fig. 1). Application of passive one-mass dampers has the restriction referring to tuning on one resonance frequency. Moreover, the addition of the one-mass damper gives rise to two resonance frequencies instead of one. Yang and Bies [5] showed that this defect can be eliminated by adding an active element in parallel.

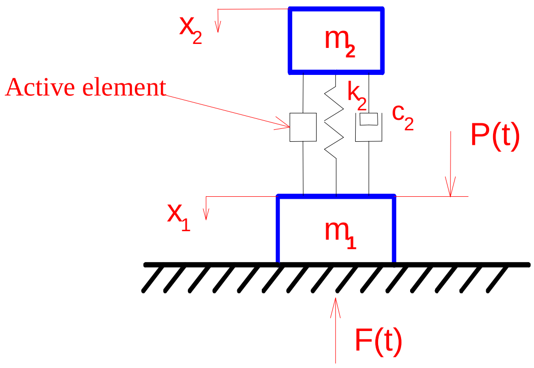

Fig. 1. Active element in the system with passive damper

Effect of the active element was analyzed by comparing the amplitude of vibration of the foundation of the mass m_1 under the dynamic load with an active element and then without it. Acceleration of the foundation mass was monitored by an accelerometer, then the measured signal was sent to the amplifying device, and to the active hydraulic damper. Depending on the phase the active damper can work as a spring element with a positive or negative value. It was assumed that the strength of the active damper is proportional to the absolute mass movements x_2 of the mass m_2.

Efficiency of damping layer depends on its deformation [6]. In practice, it is possible to use thick surface dampers with small parameters of strength. In this case lateral forces and deformations generated in the layer are important.

In order to increase the efficiency of damping properties, the elements of the layer with natural frequencies close to the resonant frequency of a protected structure can be used (Fig. 2).

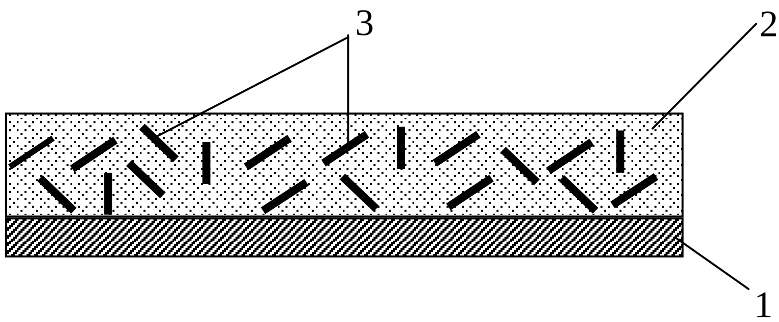

Fig. 2 .Damping layer with pin elements

Damping layer acts as follows. During vibration of the main structure 1, deformation of the damping layer 2 occurs and as the result - dissipation of energy and reduction of amplitudes of the protected structure. Elements 3 in the layer 2 vibrate in the transverse direction in relation to the main structure 1 and they act as vibration dampers.

Thereby they increase the dissipation energy and at the same time decline the amplitude of vibration of a protected structure. Elastic pins 3 cause the modification of the stiffness of the layer and increase the deformation of the layer 2. Location of elements 3 in several layers laid parallely to each other cause that they are working as multi-mass dynamic vibration dampers, extending the frequency range of damping.

Pendulum dampers are the solution with wide scope of efficiency. This type of damper was analyzed in [7,10]. Particular characteristics of such damper is the possibility of suspension dampers with several different lengths fixed at one point and a simple mechanism for implementation of the optimal tuning.

This solution of the pendulum damper is shown in Figure 3. The damper is composed of masses 1 axially mounted, connected to spring elements 2 with hangers 3, attached at one point on the protected structure 4 through the damping element 5. This model allows to implement two mechanisms of tuning. According to the first mode the vibrated structure make the vibration of mass 1. At frequencies close to the natural frequencies of the damper and protected structure, the movement of the structure is reduced owing to vibrations of mass 1 on hangers 3. In this mode the elastic bonds 2 play the important role.

In this case, parallel – series connection of the damper to the protected structure is made.

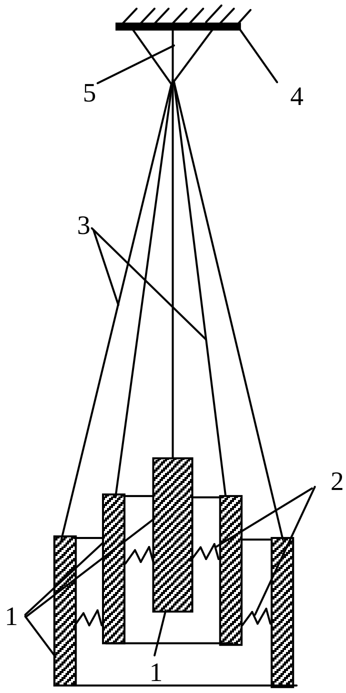

Fig. 3.Multi-mass pendulum damper

The second mode of tuning is performed if the bond 2 are omitted – the parallel connection of the dampers to the protected structure.

Presented multi-mass damper provides a simple mechanism for adjusting the natural frequency by changing the length of the suspension. It is also easy to obtain the tuned the frequency adjusting by changing the size of the masses. Additional change of the tuning parameters refers to adjusting of the spring parameters of the bonds 2 between mass 1. At the same time the damping elements can be used with bonds 2. In this case the damping hanger 5 is not applicated.

The possibility of suspension of several dampers in one point allows to assemble those dampers more rational on the protected structure.

The use of this type of damper for vibration of tall structures is particularly convenient.

In the case of several mode of frequency some dampers can be fixed on several heights of the protected structure.

Such damper perfectly meets the need to increase the damping in the case of wind and seismic loads.

Figure 4 shows another damper [9]. The damper consists of a base with a cylindrical cavity, the ring 2, the elastic elements 4 located between the element 2 and protected structure 3 and the pin 5.

Damper is equipped with masses, which interact by friction with the surface of a cylinder and spring bars. Damper works as follows.

Stiffness of the elastic element 4 is chosen so that the frequency of vibrations of the damper was close to natural frequencies of a protected structure 3.

In this case, vibrations of the ring 2 held in anti-phase with respect to the vibration of the object 3, which leads to a reduction of vibration of the protected element. As a result of mass movement the masses 6 vibrate, which as a result of friction transmit the energy.

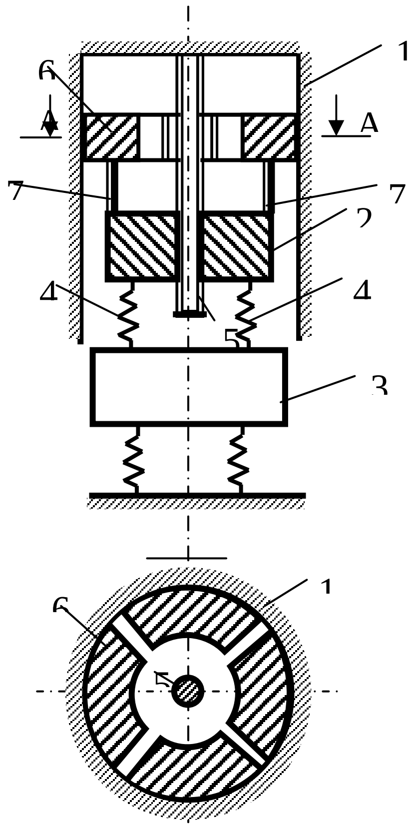

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Fig. 4.Multi-mass damper with mechanical friction

3. THEORETICAL INVESTIGATIONS

Numerical simulations of building structures under dynamical excitation with -mass systems have frequently been performed. In many cases a building model is taken and the additional mass is connected with the building. Then, different recorded dynamical excitation are run and the responses of the structure with and without tuned mass are compared.. It can be concluded from this procedure that the tuned mass improves the response behavior for most of the investigated cases.

In Figures 5 effect of the numerical modeling of the footing resting on the elastic half space with dynamic mass system is given as the example of modeling simulation of building structures with dynamic dampers.

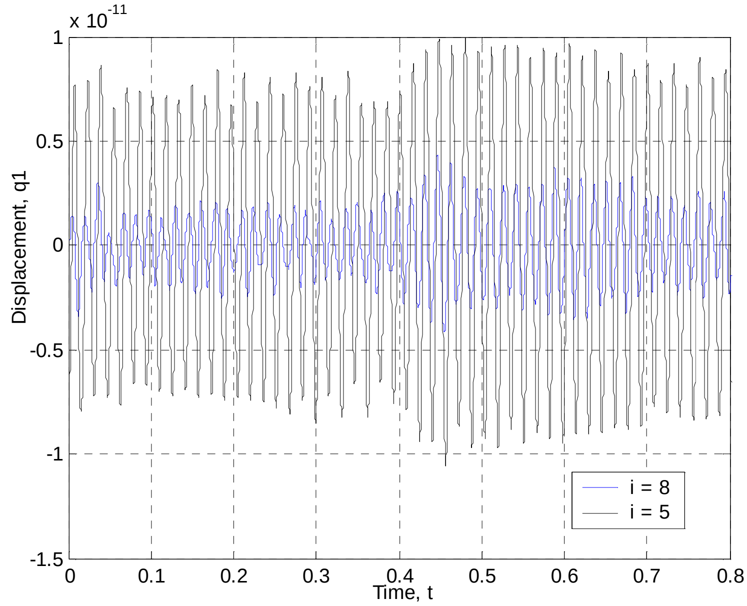

Fig. 5. Displacement of the protected structure

The influence of five- and eight-mass dynamical vibration damper characterized by parameters: m_i = 280 kg for five- and m_i = 175 kg for eight- mass damper, k_i=150 000 N/m, c_i=c=10 000 $Nm^{-1}s$ (fmd: i = 2..5; emd: i = 2..9) on the 4500 kg footing. One can see that eight-mass damper considerably decreases displacements of the foundation.

The performance of the structural response is improved by the dynamic dampers. The original response is given as a black curve and the induced peak responses are reduced by about 40 % by only activating the mass dampers(blue curve). It becomes obvious that the mass has a significant influence already at an early phase of the ground motion. The dynamic damper causes an increase of damping for the structure and this can also be seen in the displacement-time history.

4. CONCLUSIONS

On basis of the presented examples supported by author's analysis one can formulate the following conclusions.

Properly designed tuned-mass control systems can achieve as follows:

- *effectiveness of mass dampers arises with the increase of number of masses,*

increase of damping coefficient causes the reducing of dislocations of foundation in the analyzed range, increase of damper mass causes cutting of peaks

- they reduce dynamically induced responses in terms of displacements, accelerations, internal stresses and strains as well as subsoil demands.
- they increase the structural safety.
- they improve the serviceability of structures. Damage and corresponding repair cost in case of dynamic events are reduced significantly.
- regarding the overall procedure and required material for the installation of a tuned mass system this strategy can be classified as 'cost effective'.

The technical problems e.g. the effect of possible collisions of damper with other structural elements should be taken into consideration at the design stage. However, they do not eliminate the possibility of application of dampers to reduce vibrations.

5. REFERENCES

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