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VIBRATION DAMPING OF STRUCTURES USING DISSIPATIVE PROPERTIES OF THE COMPOSITE SYSTEM OF THE TYPE «ELASTIC - PLASTIC»

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ABSTRACT

The article is devoted to the task of damping of elastic systems by the use of the dynamic properties of the composite systems such as «elastic - plastic». The vector of generalized resistance force to traction of the composite system was obtained. The dynamic operation of the system was shown.

Keywords: composite systems, mechanical systems, plastic patches, vibrations, vibration damping, finite-element method.

INTRODUCTION

The main point of the dynamic vibration damping is that supplemental arrangements are attached to the object of vibrodamping in order to change its vibration state. More often the dynamic damping is to attach to the joint of a dynamic damper construction in which the reaction forces to the disturbing effect are formed and transferred to the protected object [1-8]. At this point the devices (dampers) are installed in which the mechanical energy of the vibrating structure is transformed into another types of energy that leads to vibration damping, or to the redistribution of energy from the protected object to the damper.

However, in some cases, greater effect can be achieved by means of structural operations that are performed for elements of the structures. Such activities include, for example, the aseismic pad device [9], elastic level [10], attachment of the reactive discrete mass to the beams [11], etc. This paper concentrates on the effect of the plastic resistance in composite system "elastic - plastic". Such systems may be particularly relevant at vibration damping of single-storey industrial frame buildings in seismic areas or for reducing the consequences of disturbing force of periodic nature on high-rise frame buildings.

We assume that the contoured or engineered steel pivot serves as the elastic base of the column and the plastic patches can be made of materials of high plasticity.

Nowadays the joining of dissimilar materials can be performed not by using the concentrated compounds in the form of riveting, threading, flanges but by means of welding or pasting. Along with providing the required combination of materials welding or pasting improves some directional properties of the bimetallic compounds. The use of bimetallic elements allows to create fundamentally new kinds of structures that were not used before, for example the columns, "steel - copper alloy", "steel – aluminum alloy" or "steel – zinc alloy".

The eutectic composite Ni−NbC can be considered as the alternative material of plastic patches. The matrix in this composition is the monocrystal of Nickel Ni and the reinforcing phase (fibre) is the whisker single crystal of columbium carbide NbC. The solid solution of carbide in Nickel has nearly ideal rigid plastic diagram.

Another example of a rigid plastic material can be specially selected carbon plastic or polymer that is attached to the elastic system by means of pasting. Last paragraph should outline the paper organization, with the contents of sections and conclusions.

The motion equations of composite systems

We consider a composite section of the bar (column) consisting of an elastic central part and plastic patches (Figure-1).

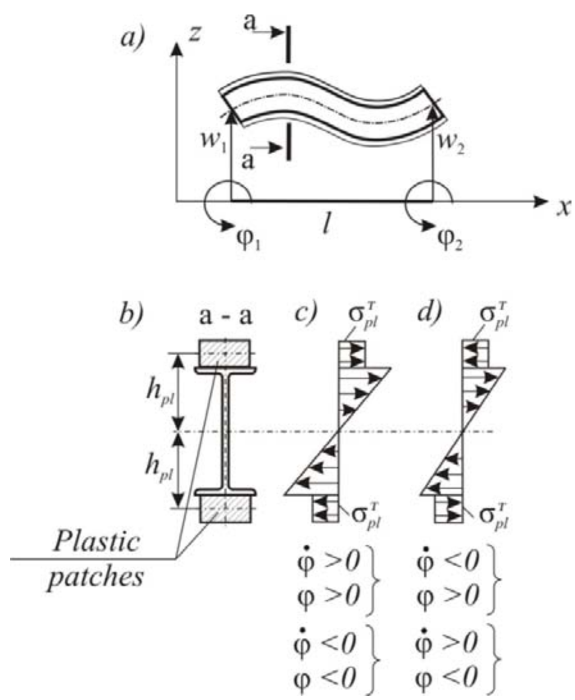

Figure-1. The composite section of the bar.

In rigid plastic patches while the oscillatory movement of such a bar there are the constant forces in value but variable in the direction of the resistance.

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These forces produce the constant in magnitude moment of tractive resistance. For a symmetric section and constant thickness of the patches, the value of this moment is equal to

$$m_{\text{pl}} = 2Ah_{\text{pl}}\sigma_{\text{pl}}^{T} \tag{1}$$

Here
A = sectional area of the patches;
h_{pl} = distance from the center of gravity of the section to the center of the patch;
σ_{pl}^{T} = yield load of the patches material

The operation of the internal forces required to bend or unbend the composite bar, is equal to:

$$\Pi = \int_{0}^{l}\left(0,5EIw'' \pm 2Ah_{\text{pl}}\sigma_{pl}^{T}\right)w'' \cdot dx \tag{2}$$

Here EI – the flexural stiffness of the elastic part of the section of the bar;
w'' = curvature of the bar axis.

Approximating the deflection of a cubic polynomial and using the properties of the deformation energy, we get to the matrix equation of flexural equilibrium as:

$$KU = P \mp F_{\text{pl}} \tag{3}$$

Here
K = stiffness matrix of bending of the elastic core bar;
F_{pl} = force vector of plastic strength of the patches under bending of the bar:

$$F_{pl} = \begin{bmatrix} 0 \\ \mp m_{pl} \\ 0 \\ \pm m_{pl} \end{bmatrix}; \tag{4}$$

$U = \begin{bmatrix} w_1 & \varphi_1 & w_2 & \varphi_2 \end{bmatrix}^T$ – the vector of focal displacements of the bar;

P = vector of external focal forces.

The sign the plastic damping forces of the patches changes. Here we will distinguish between bending and unbending of the bar. Under bending $\dot{\varphi} > 0$, $\varphi > 0$ and also at $\dot{\varphi} < 0$, $\varphi < 0$, the sign «minus», and under unbending $\dot{\varphi} < 0$, $\varphi > 0$ or at $\dot{\varphi} > 0$, $\varphi < 0$ - the sign «plus».

Passing to the mechanical system and the dynamic problem of the forced vibrations we will have the differential equation of relative motion of nodes as:

$$M\ddot{U}_t + KU_t = P_t - signF_{pl}(\dot{\varphi}), \tag{5}$$

Here M - the mass matrix of the mechanical system, and the signs of the vector components of the plastic strength force depend on the signs of the angular velocities of the rotations of the nodes. Thus, we obtained the matrix equation that is similar to the vibration motion equation of the elastic system under the action of dry friction forces. The simplest example of such a system is a spring pendulum, the load of which slides over the rough horizontal surface. The force of dry friction does not change in value, but it changes its direction when you alter the direction of the velocity. Thus, the vibratory movement is described by two equations of motion. These equations only differ in the sign of the friction force, which depends on the velocity direction of the load movement.

If at some point of time the disturbing actions stop, i.e.,

$$P_t = 0, \tag{6}$$

one will arrive at the following matrix equation of the damped harmonic oscillations:

$$M\ddot{U}_t + KU_t = -signF_{pl}(\dot{\varphi}). \tag{7}$$

The vector of amplitudes $\bar{a}$ decreases linearly in the course of time (Figure-2).

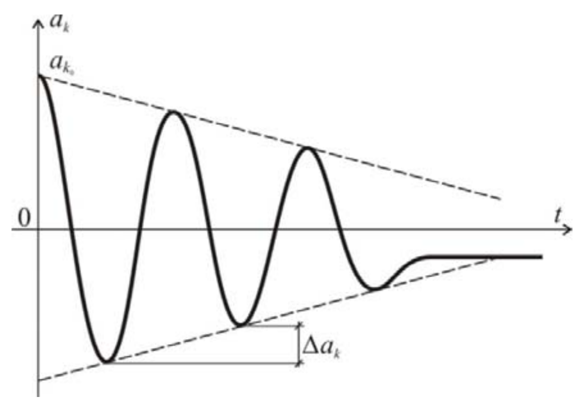

Figure-2. Decreasing of the amplitude vector.

Herewith the negative increment of the amplitude is equal to:

$$\Delta\bar{a} = 2K^{-1}F_{pl}. \tag{8}$$

Formulas (1), (4), (5) and (8) show that the operating efficiency of the plastic damping forces of the

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given elastic core depends on the area of the patches and the value of plastic stress of the patches material.

The numerical solution of the problem

Consider the numerical solution of the problem of forced vibrations of the composite three-tier column with the core made of steel I-beam No. 30, the plastic patches with $\sigma_{pl}^{T} = 1{,}2 \cdot 10^{8}$ Па of 14 mm thick and the width of 14 cm. At the upper end of each tier of the column the mass is fixed. The mass matrix has the form $M = diag\left[m_1\ I_1\ m_2\ I_2\ m_3\ I_3\right]$. The column base (Figure-3) oscillates according to the law:

$$\ddot{\Delta} = -0.3\sin(2t) - 3\sin(3t).$$

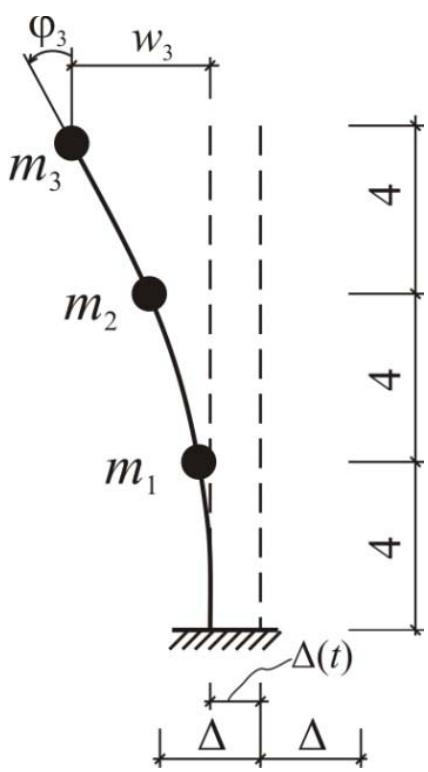


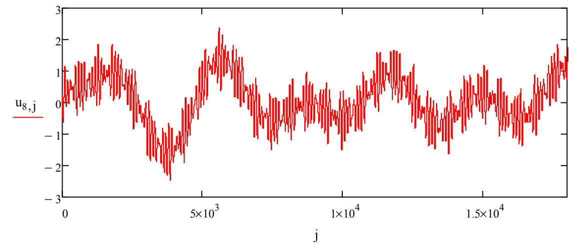
Figure-3. Composite column.

This problem was solved in two ways:

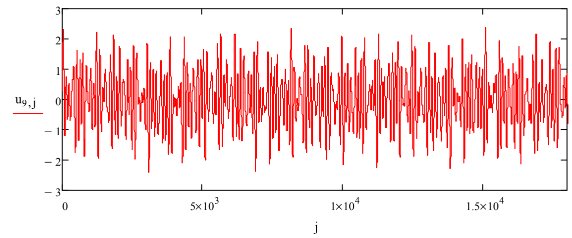
a) the vibrations of an elastic core of the column (Figure-4);

b) the vibrations of the composite column (Figure-5).

The comparison of the oscillation graphs of these two solutions shows high efficiency of the damping properties of plastic patches.

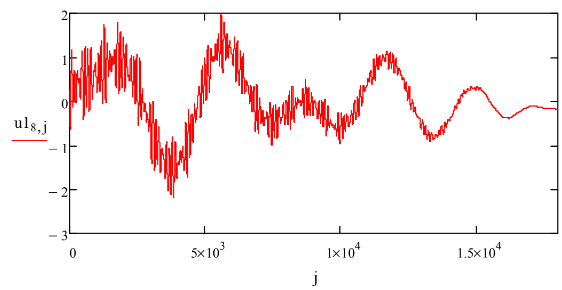


a)

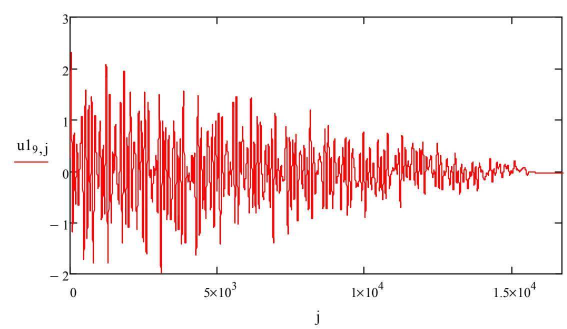


b)

Figure-4. The relative vibrations of the elastic core: a) linear displacements w_3, b) angular displacements φ_3.



a)



b)

Figure-5. The relative vibrations of composite columns: a) linear displacements w_3; b) angular displacements φ_3.

The idea of plastic deceleration, as a way of damping, can be used while reducing the vibration level of plates and casings. As a plastic layers the reinforced polymeric materials can be used here.

CONCLUSIONS

hus, in this article the problem of oscillation damping of elastic systems is solved by using the dynamic properties of the composite systems such as «the elastic core - the plastic patches». The vector of generalized resistance force to traction of the composite system was obtained. The effective dynamic operation of the composite under damping of the mechanical system was shown. This approach can also to be helpful in solving the calculation problems of finite-element method of the ideally elastic-plastic systems.

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