728. Mechanical and electrical elements in reduction of vibrations

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Abstract. The main aim of this work is the introduction of analysis and synthesis of systems including mechanical and electrical elements reducing vibrations. In results of synthesis were received structures and parameters of a discrete model meeting the defined requirements concerning the dynamic features of the system, in particular, the frequency spectrum. The approach adopted makes it possible to take actions aiming at the reduction of phenomena resulting in the unwanted operation of machinery or generation of hazardous situations in the machinery environment. Thanks to the approach, the above mentioned preventive activities can be conducted as early as during the designing of future functions of the system as well as during the construction of the system in question. In this work is also introduction of these two kinds of elements, mechanical and electrical, of reduction of vibrations.

Keywords: analysis and modeling, process systems design, synthesis, reduction of vibrations.

Introduction

Reducing the undesired vibrations is frequently discussed by scientists because of harmful effect it has on human organisms and machinery operation. Designers, manufacturers and users also have to face problems of preventing unwanted effects in the operation of newly designed machinery or adapting already manufactured and operating machines to meet requirements resulting from current knowledge of hazards caused by machinery [1, 2]. Reduction of the adverse effect of mechanical vibrations is the subject matter of numerous investigating studies. Minimization of undesired vibrations can be achieved by various methods, where the subdivision into passive, active and semiactive techniques is the most frequent approach [3÷5, 7]. The passive methods are not always effective, especially in the case of low-frequency vibrations, and for this reason they are being replaced by active ones. The aim is to perfect the synthesis seen as modification at the sub-assembly design level in relation to the required spectrum of vibration frequency of the system. Such definition of the problem requires application of the synthesis methods, in categories appropriate for the class of systems. The synthesis will have two stages. The first stage will include a synthesis of the passive system, and then a synthesis of the active system (dashed line) or system with damping (continuous line) (Fig. 1), [1, 2].

The model of the research

The arrangement under consideration is a cascade discrete vibration system. To create the above-mentioned system it is necessary to define requirements for the resonance and anti-resonance frequencies of the system (1):

$$\begin{cases} \omega_1, \ \omega_3, \ \ldots \omega_n - \text{resonant frequencies} \\ \omega_0, \ \omega_2, \ldots \omega_{n-1} - \text{anti-resonant frequencies} \end{cases} \tag{1}$$

n – odd number.

Synthesis consists in distributing the characteristic function (2) onto the continued fraction (3) [1, 2]:

$$U(s) = \frac{(s^2 + \omega_1^2)(s^2 + \omega_3^2)\cdots(s^2 + \omega_n^2)}{s(s^2 + \omega_2^2)\cdots(s^2 + \omega_{n-1}^2)} \qquad (2)$$

$$U(s) = \frac{c_1}{s} + \cfrac{1}{m_1 s + \cfrac{1}{\cfrac{s}{c_2} + \cfrac{1}{m_2 s + \cdots + \cfrac{1}{\cfrac{s}{c_k} + \cfrac{1}{m_k}}}}} \qquad (3)$$

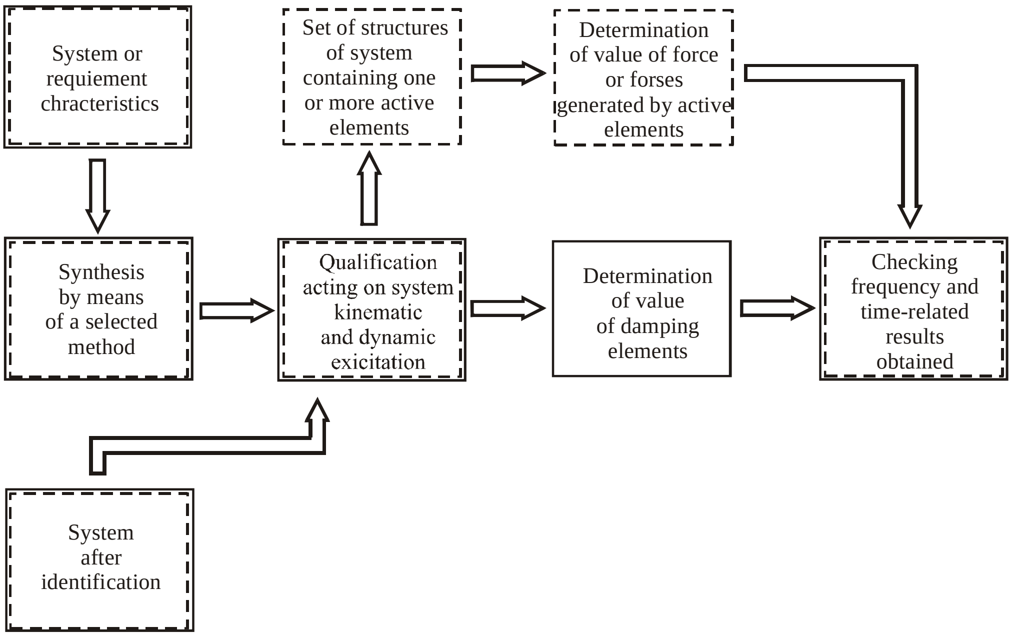

Fig. 1. Idea of synthesis of mechanical systems with passive or active elements reducing vibrations

The next step requires the identification of external effect influence on the system. In this case it was established that the system is influenced by dynamic excitations on inertial elements (Fig. 2).

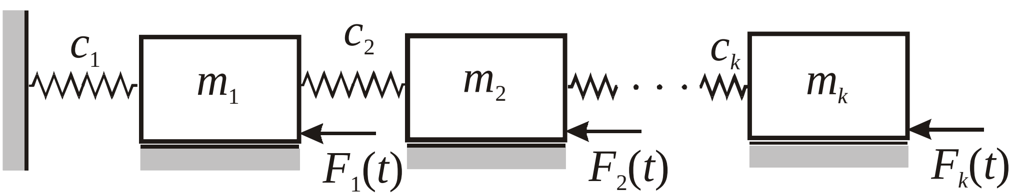

Fig. 2. Model of the system after synthesis with dynamic excitations

The symbols on the Fig. 2 denote:
$m_1, m_2, \ldots, m_k$ - inertial elements,
$c_1, c_2, \ldots, c_k$ - elastic elements,
$F_1(t), F_2(t), \ldots, F_k(t)$ - dynamic excitations.

Passive elements in reduction of vibration

According to the flow chart that is shown in Fig. 1, decrease of vibrations can be achieved by application of either passive or active elements.

The passive elements can be implemented, for instance, as viscous dampers. To find out the value of viscous dampers one can use the following relationships (4, 6). The first equation is used for damping elements that are proportional to the inertial elements, the second one is applicable to elastic elements [1]. The model of system where passive elements are implemented as dampers proportional to the inertial elements is shown in Fig. 3 and the model with passive elements proportional to the elastic elements is shown in Fig. 4.

$$b_i = 2h \cdot m_i \tag{4}$$

where:
b_i – value of the damping element,
m_i – value of the inertial element calculated as a result of the synthesis process,
h = idem – constant of proportionality.

The value for the h constant is selected from the range (5):

$$0 < h < |\omega_{\min}| \tag{5}$$

where:
$\omega_{\min}$ – lowest value of the resonance frequency different from zero.

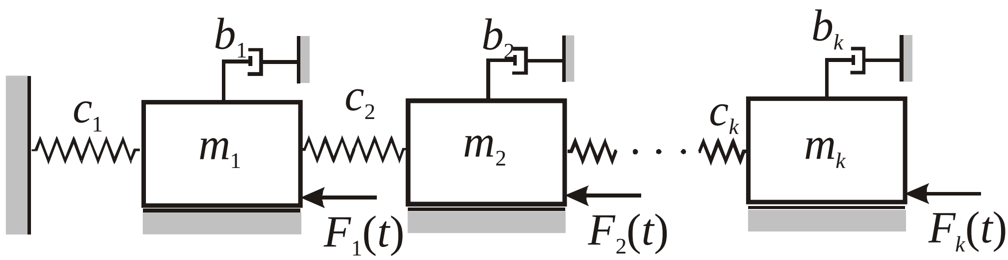

Fig. 3. The model for a discrete mechanical system with passive elements proportional to inertial elements

$$b_i = \lambda\, c_i \tag{6}$$

where:
c_i – value of elastic element calculated as a result of the synthesis process,
λ = idem – constant of proportionality.

The value for the constant of proportionality λ should be selected from the range (7):

$$0 < \lambda < \frac{2}{\omega_n} \qquad (7)$$

where:

ω_n – highest value of the resonance frequency different from zero.

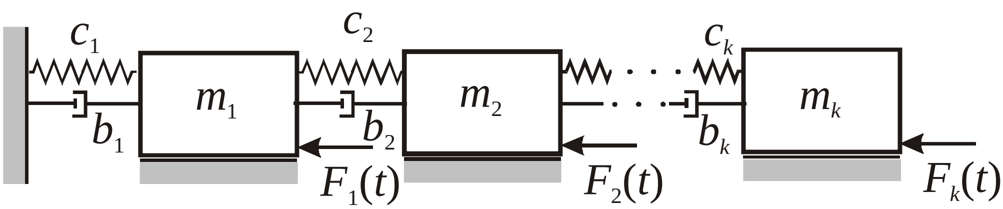

Fig. 4. The model for a discrete mechanical system with passive elements proportional to elastic elements

Active elements in reduction of vibration

Application of dampers for decrease of vibrations makes it possible to reduce displacements of inertial elements but complete elimination of such displacements is not always possible.

To reduce displacements of individual inertial elements of the system caused by the effect of dynamic and /or kinematic excitations one can apply active elements that are represented by forces acting from the outside (Fig. 5). Resolving of the equation system written in the matrix form (8) leads to calculation of values for individual active elements that act onto specific inertial elements:

$$G = D \cdot A - F \qquad (8)$$

where:

G – matrix of excitations generated by active elements,
D – matrix of dynamic stiffness,
A – matrix of amplitudes (approaching zero),
F – matrix of dynamic and/or excitations.

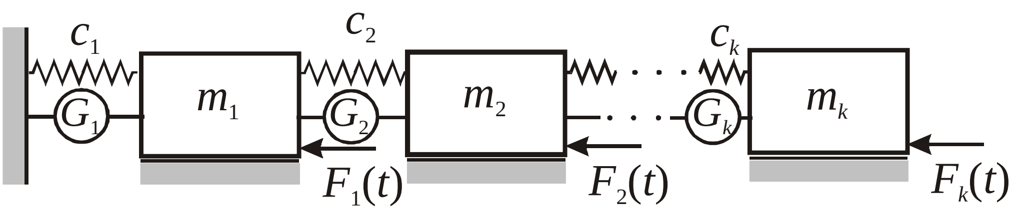

Fig. 5. The model of a discrete mechanical system with active elements

Another important issue is the way in which the active excitations are implemented. The one possible way to implement such excitation is application of solely mechanical elements in the form of kinematic excitations (Fig. 6) or electrical elements (Fig. 7).

In case of using kinematic excitations, the only elements that may change their values are displacements y_i whilst the elastic elements c_i remain unaltered.

To determine values for elastic elements and their displacements one has to benefit from the relationship (9):

$$y_i = \frac{K_i}{c_{ii}} \tag{9}$$

where:
K_i – values of kinematic excitations, equivalent to the values of G_i,
y_i – displacement that occurs in the specific kinematic equation,
c_{ii} – values of the elastic elements that occurs in the specific kinematic equation.

Figure 6 presents a model of the system that incorporates kinematic excitations.

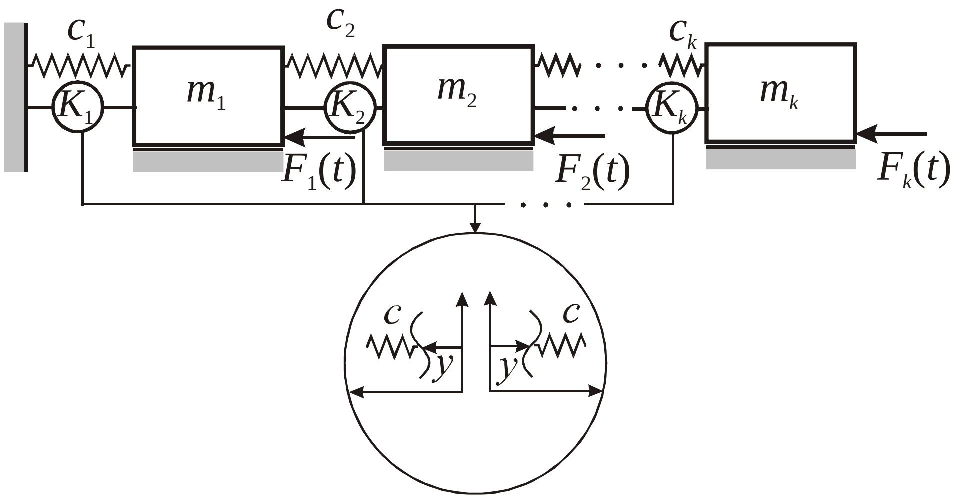

Fig. 6. A model of the system with kinematic excitations

There are also other solutions for active components, such as electric or electromechanical appliances. The force acting on a conductor kept in a magnetic field is given by (10) [6]:

$$F = BIL \tag{10}$$

where:
F = force acting on the conductor,
B = magnetic flux density,
I = current in the conductor,
L = length of the conductor.

Figure 7 presents a model of the system with electric elements as excitations generated by active elements.

Conclusions

This paper describes design examples of systems with active vibration-reducing elements. The system structure and parameters were obtained using the method of decomposing characteristic function into continued fractions.

One of the important issues considered in this paper is how to create the active elements. This paper covers active subassemblies in the form of mechanical elements subjected to kinematic excitation and electric elements.

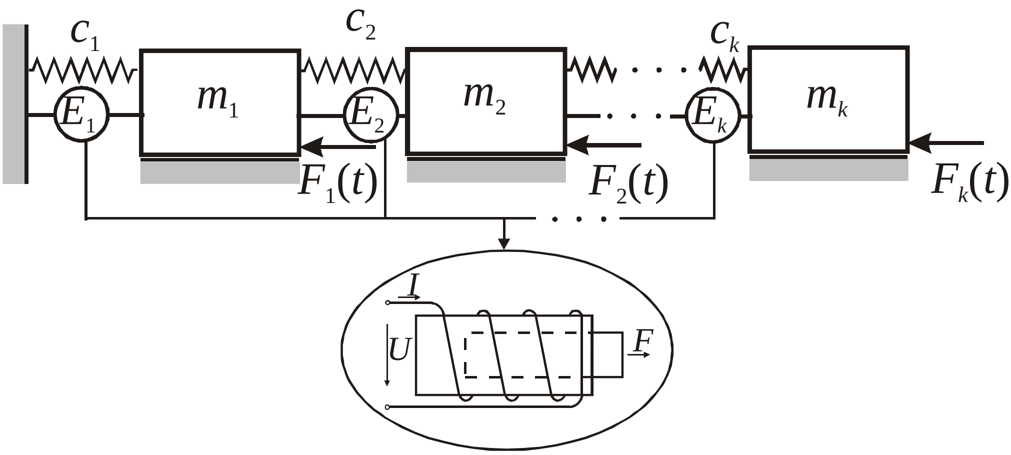

Fig. 7. A model of the system with electric elements

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