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Synthesis of mechanical systems including passive or active elements reducing of vibrations

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Analysis and modelling

ABSTRACT

Purpose: In this work there is presented basic method of synthesis of active and passive mechanical systems realization. The principal aim of the research is to work out a method of structure and parameters searching i.e. structural and parametric synthesis of a discrete model of mechanical system on the base of desired requirements. The requirements refer to dynamic features of the system, particularly its frequency spectrum. The purpose of this paper is also comparison of reduction of vibrations in mechanical systems by use the passive and active elements.
Design/methodology/approach: In this work used unclassical method of polar graphs and their relationship with the algebra of structural numbers. This method enables analysis without limitations depending on kind and number of elements of complex mechanical system using electronic calculation technique.
Findings: Use of active elements into the elimination of vibration offers the possibility to overcome the limitations of the methods of passive elimination of vibration, such as, in particular, low efficiency in case of low-frequency vibration.
Practical implications: The results represented this work in form of polar graphs extend the tasks of synthesis to other spheres of science e.g. electric systems. The practical realization of the reverse task of dynamics introduced in this work can find uses in designing of machines with active and passive elements with the required frequency spectrum.
Originality/value: Thank to the approach, an unclassical method of polar graphs and their relationship with the algebra of structural numbers, can be conducted as early as during the designing of future functions of the system as well as during the construction of the system.
Keywords: Process systems design; Polar graphs; Structural numbers; Synthesis

1. Introduction

The occurrence of undesirable side effects in the operation of machinery may result from the factors, which may be related to a design and constructional process, manufacturing and manner of operating a machine. 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. Introducing the condition of vibration reduction into the set of constructional criteria substantially extends the scope of knowledge and qualifications required from designers and constructors [1].

There are many methods of preventing excessive vibration of machinery elements. The major division is that into passive and active measures of reducing vibration and active and passive forms of their execution. The term of passive measures of reducing vibration of machinery refers to such additional constructional elements of vibroisolation systems which do not constitute integral elements of a machine structure but are implemented additionally

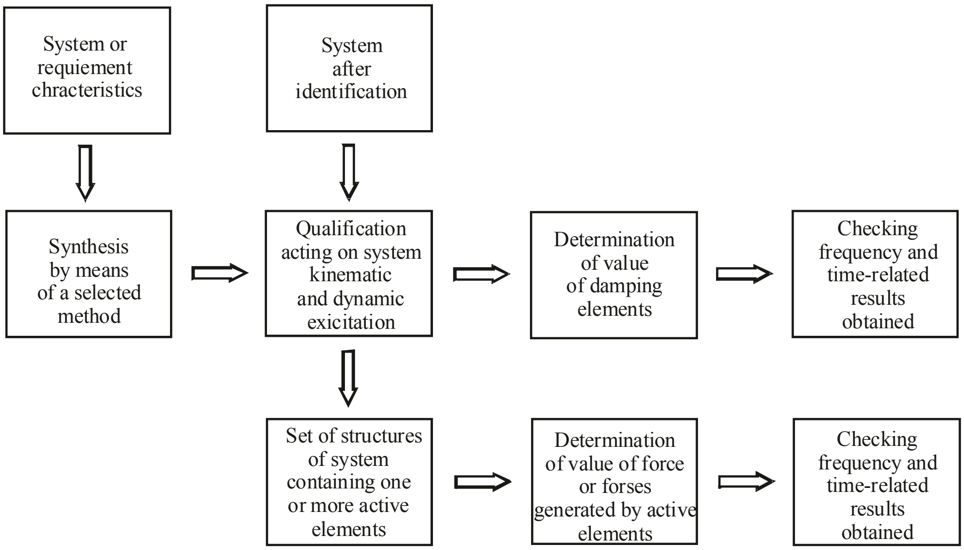


Fig. 1. Idea of synthesis of mechanical systems

by way of propagation of mechanical vibration signals such as mechanical filters of these signals. The term of active measures of reducing vibration usually pertains to all these subsystems, whose purpose is to reduce or eliminate reasons for formation of machinery vibration i.e. the subsystems interfering in the sources of generation of such vibration. Both passive and active measures of vibration reduction may take passive and active forms [1÷9].

The methods of active reduction of vibration are divided into controlling or adjusting processes of mechanical vibration. The controlling of the motion of an object refers to a situation when a command signal is supplied to the system from the outside and this signal does not depend on the current condition of the object but is previously designed. The other method consists in the adjustment of an object motion and in such a case a command signal depends on the current condition of the object and it is necessary to implement additional elements such as output sensors, a control unit and executive devices [8].

Used in this work unclassic method of polar graphs and their relationship with structural numbers determines the new conception of problem of reduction of mechanical vibrations. The problem of electric and electronic systems synthesis using unclassical method has been recognized very well. In mechanical systems there are analogies to electronic systems. One should however remember that we cannot uncritically assign the results gained in analysis and synthesis of electronic systems to analysis and synthesis of mechanical systems [10÷15].

2. Synthesis of mechanical systems

In order to solve the problem of reducing the vibration of mechanical system, it is necessary to perform the synthesis or identification of a system. Depending, on a structure and parameters as well as input functions affecting the system, to determine the structure of a system containing active or passive elements (Fig. 1).

Properties of mechanical systems was it been possible to use dynamic characteristics in form of dynamic slowness and mobility [1,3], about following figures:

$$U(s) = H\frac{d_l s^l + d_{l-1}s^{l-2} + \ldots + d_1 s}{c_k s^k + c_{k-1}s^{k-2} + \ldots + c_0} \tag{1}$$

$$V(s) = H\frac{c_k s^k + c_{k-1}s^{k-2} + \ldots + c_0}{d_l s^l + d_{l-1}s^{l-2} + \ldots + d_1 s} \tag{2}$$

The synthesis of mechanical systems to be applied be able through distribution of characteristic function into partial fraction or continued fraction expansion.

2.1. Synthesis of mechanical system by means of continued fraction expansion method

The required frequency spectrum:

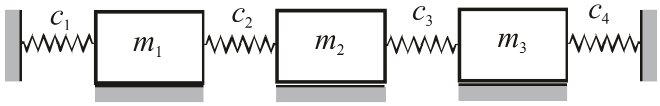
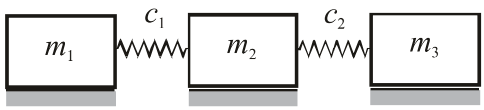
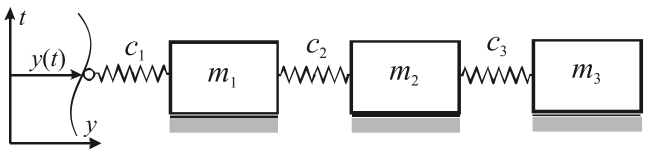
$$\begin{cases} \omega_1 = 6\frac{rad}{s}, & \omega_3 = 19\frac{rad}{s}, & \omega_5 = 31\frac{rad}{s}, \\ \omega_0 = 0\frac{rad}{s}, & \omega_2 = 13\frac{rad}{s}, & \omega_4 = 25\frac{rad}{s}. \end{cases}$$

The structures of systems after accomplishment the synthesis was introduced in Table 1.

2.2. Qualification acting on system dynamic excitation

System number 1 (from Table 1) was selected to more far considerations. This system was weighted dynamic excitation (Fig.2). Polar graph of the system was introduced in Figure 3.

Table 1.
The structures of systems after accomplishment the synthesis

No	FUNCTION	STRUCTURE
1	$U(s)=s+\cfrac{1}{\cfrac{s}{564}+\cfrac{1}{2s+\cfrac{1}{\cfrac{s}{500}+\cfrac{1}{2.08s}+\cfrac{1}{\cfrac{s}{213}}}}}$	
2	$U(s)=\cfrac{80}{s}+s+\cfrac{1}{\cfrac{s}{484}+\cfrac{1}{1.474s+\cfrac{1}{\cfrac{s}{250}+\cfrac{1}{1.01s}+\cfrac{1}{\cfrac{s}{50}}}}}$	
3	$U(s)=s+\cfrac{1}{\cfrac{s}{528}+\cfrac{1}{1.56s+\cfrac{1}{\cfrac{s}{227}+\cfrac{1}{1.72s}}}}$	
4	$V(s)=\cfrac{564}{s}+\cfrac{1}{s+\cfrac{s}{333}+\cfrac{1}{1.08s+\cfrac{1}{\cfrac{s}{250}+\cfrac{1}{2.68s}}}}$	

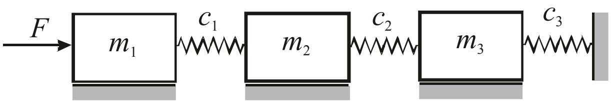


Fig. 2. Idea of synthesis of mechanical systems

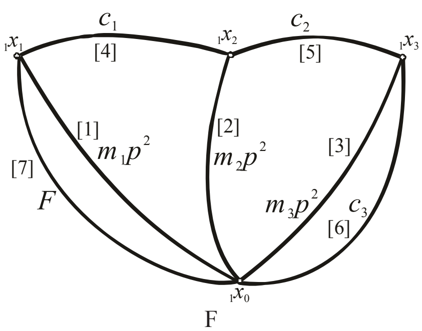


Fig. 3. Polar graph of the system with dynamic excitation

2.3. Determination of value of damping elements

In order to solve the problem of reducing the vibration of system it is possible to implement passive elements.

A general formula for value of damping [15], when damping is proportional to elastic element, is as follows:

$$b_i = \lambda c_i \tag{3}$$

where:

b_i - damping elements

λ - modulus of proportionality $\left(0<\lambda<\dfrac{2}{\omega_n}\right)$

ω_n - the largest value of frequency

c_i - elastic elements

$\lambda = 0.01$

$b_1 = 5.64\dfrac{Ns}{m}$; $b_2 = 4.32\dfrac{Ns}{m}$; $b_3 = 2.29\dfrac{Ns}{m}$

Systems with passive elements reducing vibrations they be introduced in figure 4 (polar graph in fig.5):

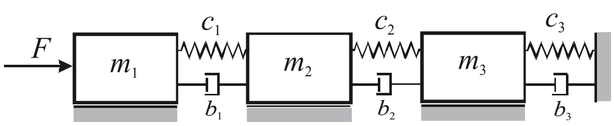


Fig. 4. The models of the system with passive elements

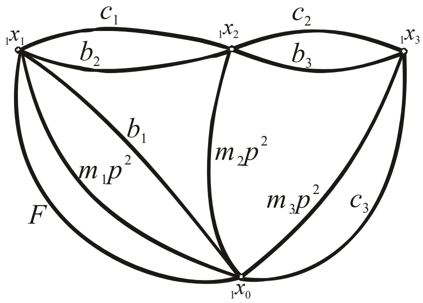


Fig. 5. Polar graph of the systems from fig. 4

2.4. Determination of value of forces generated by active elements

In order to solve the problem of reducing the vibration of selected parts of a system it is necessary to implement active elements by „locating" them in optionally selected places of the system.

Applying the theory of polar graphs and their relation to structural numbers [10], it is possible to determine the values of amplitudes of forces generated by active elements.

Systems with active elements reducing vibrations they be introduced in figure 6 (polar graph in fig.7):

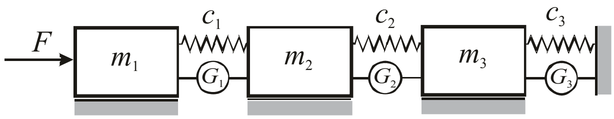


Fig. 6. The models of the system with active elements

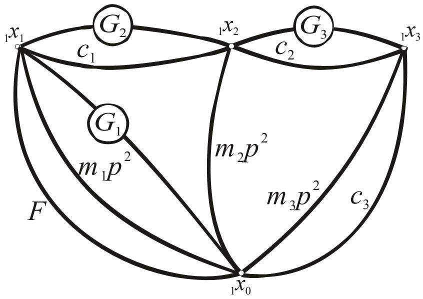


Fig. 7. Polar graph of the systems (fig.6)

3. Conclusions

In this paper there are presented the basic methods of mechanical systems synthesis. The synthesis realization aims to achieving the optimum mechanical system meeting the basic and additional assumptions.

The received mathematic model as a result of synthesis allows to select mechanical system parameters for it to possess required dynamic features. The problem showed in such a way requires usage of synthesis methods, defined in categories adequate to the active and passive systems class being considered.

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