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Comparison of passive and active reduction of vibrations of mechanical systems

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Analysis and modelling

ABSTRACT

Purpose: In the thesis there are presented basic methods of reverse task of active and passive mechanical systems realization. The principal aim of the research taken is to work out a method of structure and parameters searching i.e. structural and parametric synthesis of discrete model of mechanical system on the base of desired requirements. The requirements refer to dynamic features of the system, particularly their frequency spectrum.
Design/methodology/approach: In this work used unclassical method of polar graphs and their relationship with 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: Introduced in this paper approach adopted makes it possible to undertake actions aiming at the elimination of phenomena resulting in the unwanted operation of machinery or generation of hazardous situations in the machinery environment.
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, unclassical method of polar graphs and their relationship with 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 in question.
Keywords: Process systems design; Polar graphs; Structural numbers; Reduction of vibrations

1. Introduction

The introduction 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 and the impossibility to reduce the vibration of specific parts of machinery. 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 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 implementation of active measures of elimination of vibration enables the overcoming of limitations characteristic of passive methods such as low efficiency in the range of low frequency of input function and free vibration. The use of passive systems proves not satisfactory also in case of broad-band frequency. The low-frequency character of vibration may result in the failure of passive vibroisolation to ensure efficient reduction of vibration or may even lead to the increase of vibration and that is why in such cases, the active reduction of vibration often replaces the passive one. A characteristic feature of the active vibration reduction is the fact, that vibration is compensated by interaction from additional sources. Active vibroisolation systems are controlled by input function.

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 influenced by a previously developed programme. 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].

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 [4].

The problem of electric and electronic systems synthesis using unclassical method i.e. by means of graphs and structural numbers has been recognized very well. This method was used also for synthesis of passive vibrating mechanical systems. However there is no research about usage of unclassical method for the analysis and synthesis of active vibrating mechanical systems. In mechanical active systems there are analogies to electronic active 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. The model of the research

Discrete vibratory mechanical system is being considered, with dynamic and kinematical input function. The model considered (Fig. 1, Fig. 2) is created from the following elements:

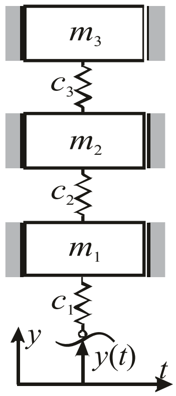

Fig. 1. The model of the system in question

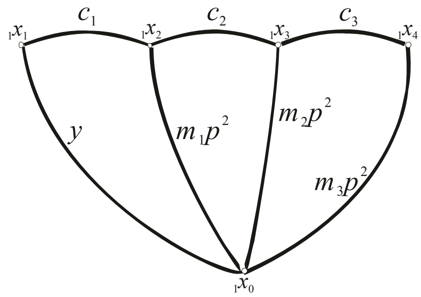

Fig. 2. Polar graph of the systems from Figure 1

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. In order to specify such elements, it is necessary to perform the synthesis or identification of a passive system and then, depending on a structure and parameters as well as input functions affecting the system, to determine the structure of a system containing active elements (Fig. 3).

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.

A general formula for amplitude value is as follows:

$$A_n = \frac{\left(\underset{z}{Sim}\left(\frac{\partial D(\omega)}{\partial[1]};\frac{\partial D(\omega)}{\partial[n]}\right)\left(F_1+F_{k1}+G_1\right)\right)+ +\left(\underset{z}{Sim}\left(\frac{\partial D(\omega)}{\partial[2]};\frac{\partial D(\omega)}{\partial[n]}\right)\left(F_2+F_{k2}+G_2\right)\right)+ +\ldots+\left(\left(\frac{\partial D(\omega)}{\partial[n]}\right)\left(F_w+F_{kl}+G_g\right)\right)}{D(\omega)} \tag{1}$$

where:

$D(\omega)$ - characteristic equation,

$\frac{\partial D(\omega)}{\partial[1]}$ - derivative of structural number the in relation to of edge [1],

$\underset{Z}{Sim}\left(\frac{\partial D(\omega)}{\partial[1]};\frac{\partial D(\omega)}{\partial[2]}\right)$ - function of simultaneousness of structural number,

$F_{k1}, F_{k2}, \ldots, F_{kl}$ - kinematic excitation,

$F_1, F_2, \ldots, F_w$ - dynamic excitation,

$G_1, G_2, \ldots, G_g$ - forces generated through active elements.

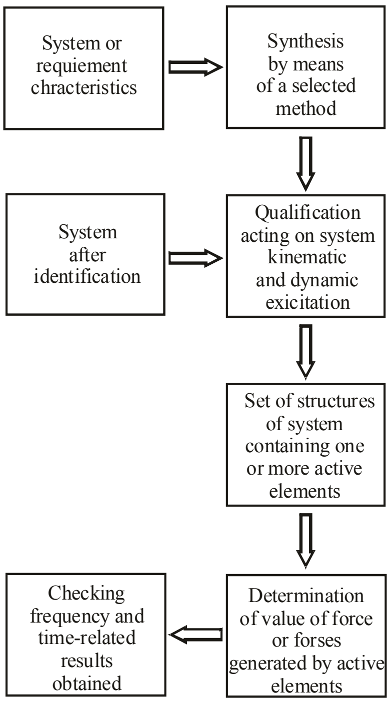

Fig. 3. Idea of synthesis of active mechanical systems

In order to solve the problem of reducing the vibration of system it is possible to implement passive elements. In order to specify such elements, it is necessary to perform the synthesis or identification of system and then, depending on a structure and parameters as well as input functions affecting the system, to determine the structure of a system containing passive elements (Fig.4).

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

$$b_i = \lambda c_i \tag{2}$$

where:

b_i - damping elements

λ - modulus of proportionality

c_i - elastic elements

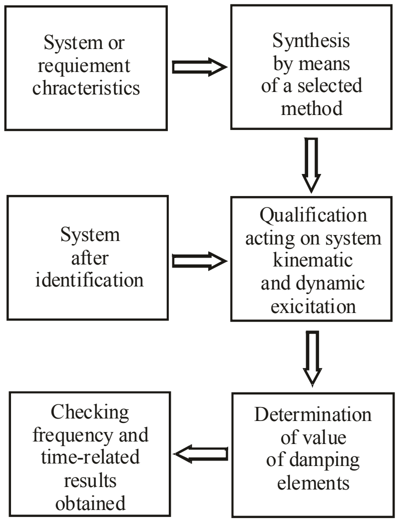

Fig. 4. Idea of synthesis of mechanical systems with damping elements

Systems with active and passive elements reducing vibrations they be introduced on Figure 5:

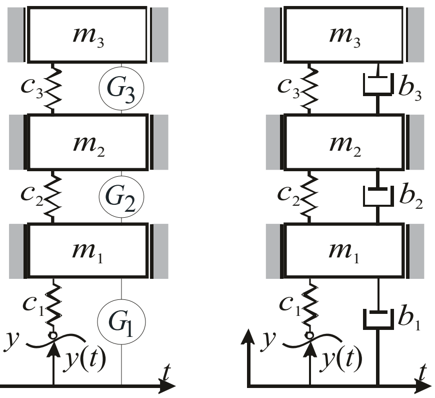

Fig. 5. The models of the system with active and passive elements

3. Conclusions

In this work, the method of polar graphs and their relationships with structural numbers were used in order to derive equations determining the values of amplitudes of forces generated by active elements. The use of such a method enables the automation of calculation during the determination of dynamic characteristics of a system and the algorithmisation of calculations.

Introduced in this work approach adopted makes it possible to undertake actions aiming at the elimination of phenomena resulting in the unwanted operation of machinery or generation of hazardous situations in the machinery environment. Thank to the approach, the aforementioned 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.

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