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Reverse task of passive and active mechanical systems

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Analysis and modelling

ABSTRACT

Purpose: The main purpose of this work is to present the algorithm of a converse problem of dynamics of mechanical systems containing passive and active elements. Solving the problem results in obtaining structures and parameters of a discrete model meeting the defined requirements concerning the dynamic features of the system, in particular, the frequency spectrum. Another objective of this work is to compare the reduction of vibration by means of passive or active elements or while using passive and active elements at the same time.
Design/methodology/approach: The work involves the application of a non-classical method of polar graphs and their relation to structural algebra. The use of such a method enables the analysis of mechanical systems irrespective of the type and number of the elements of such a system.
Findings: The application of active elements to eliminate vibration enables overcoming limitations which occur if passive elements are used. One of the most important limitations is low efficiency in case of low-frequency vibration and inability to reduce vibration of selected parts of the system.
Research limitations/implications: The scope of discussion is reverse task of passive and active mechanical systems, but for this type of systems, such approach is sufficient.
Practical implications: 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. Using method and obtained results can be value for designers of mechanical systems.
Keywords: Process systems design; Polar graphs; Structural numbers; Reduction of vibrations

1. Introduction

While designing a machine it is necessary to take into consideration various factors which may affect its operation. Proper modelling enables appropriate optimisation of machine construction as early as at the design stage. At the beginning of design stage it is possible to obtain system parameters and structure meeting previously adopted requirements in relation to dynamic properties. It is also possible to design a system eliminating unwanted phenomena for already existing system.

Designing active systems consists in searching for values of elements meeting specified requirements. If a given system does not meet the requirements, it needs further analysis and modification. Such an approach can be called a method of successive trials and produces desirable results in the design of simple systems. In case of complex systems, such an approach has proved very time-consuming and unreliable as far as obtaining desirable effects is concerned. For that reason it is necessary to apply non-classical design methods such as an inverse operation called ”synthesis”. This method consists in searching for a system structure with such values of elements which meet required frequency characteristics [1-6].

2. Reverse task of mechanical systems

In order to solve problem of reduction of vibrations in first step it is necessary to perform the passive synthesis or identification of system. In next step one should determine the structure of a system containing active or passive elements [2-6].

The synthesis of mechanical systems to be applied be able through distribution of characteristic function into partial fraction, continued fraction expansion or mixed method [2, 7-12, 15-17].

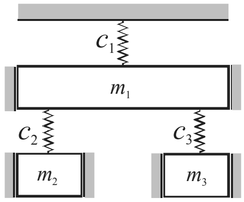
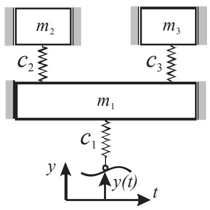
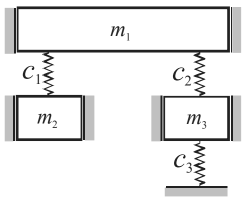
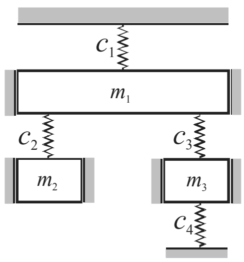
The required frequency spectrum:

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

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

System number 1 (from table 1) was selected to more far considerations. This system was weighted dynamic excitation (fig.1). Polar graph of the system was introduced in figure 2.

Table 1.
The structures of systems after accomplishment the synthesis

No	FUNCTION	STRUCTURE
1	$U(s)\dfrac{1}{H} = \dfrac{118{,}24}{s} + s + \dfrac{1}{\dfrac{s}{262{,}44} + \dfrac{1}{1{,}6s}} + \dfrac{1}{\dfrac{s}{183{,}3} + \dfrac{1}{0{,}3s}}$	
2	$V(s)\dfrac{1}{H} = \dfrac{s}{564} + \dfrac{1}{1s + \dfrac{1}{\dfrac{s}{113{,}75} + \dfrac{1}{0{,}25s}} + \dfrac{1}{\dfrac{s}{168{,}03} + \dfrac{1}{3{,}53s}}}$	
3	$U(s)\dfrac{1}{H} = s + \dfrac{1}{\dfrac{s}{262{,}43} + \dfrac{1}{1{,}55s}} + \dfrac{1}{\dfrac{s}{301{,}54} + \dfrac{1}{0{,}79s} + \dfrac{1}{\dfrac{s}{194{,}5}}}$	
4	$U(s)\dfrac{1}{H} = \dfrac{100}{s} + s + \dfrac{1}{\dfrac{s}{262{,}43} + \dfrac{1}{1{,}55s}} + \dfrac{1}{\dfrac{s}{183{,}322} + \dfrac{1}{0{,}293s} + \dfrac{1}{\dfrac{s}{18{,}24}}}$	

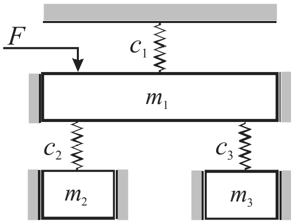


Fig. 1. Model of system with dynamic excitation

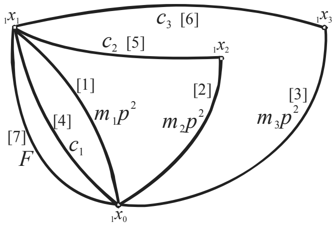


Fig. 2. Polar graph of the system with dynamic excitation

2.1. System including 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

$\lambda = 0.02\ s$

$b_1 = 2.36 \dfrac{Ns}{m}$; $b_2 = 5.25 \dfrac{Ns}{m}$; $b_3 = 3.66 \dfrac{Ns}{m}$

Systems with passive elements reducing vibrations they be introduced in figure 3 (polar graph in fig.4):

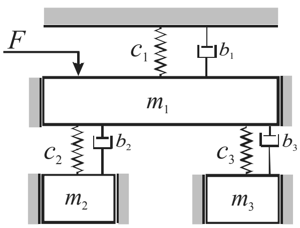


Fig. 3. The models of the system with passive elements

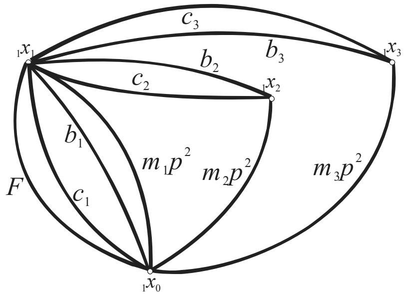


Fig. 4. Polar graph of the systems from fig. 3

2.2. System including active elements

Using active elements enables the reduction of vibrations of selected parts of a system. Implementation the theory of polar graphs and their relation to structural numbers [2, 10-14, 18-20], 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 5 (polar graph in fig.6):

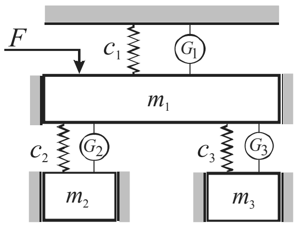


Fig. 5. The models of the system with active elements

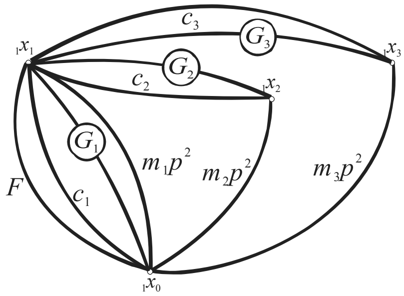


Fig. 6. Polar graph of the systems (fig.5)

3. Conclusions

The task presented in the work is regarded as an issue related to design of dynamic methods inverse to an analysis operation. The solution-oriented activity is intended to find a sequence of phenomenological models of a designed system characterised by a specific amplitude-frequency form of transition function. The next stage requires the processing of results of synthesis from the field of phenomenological models to the field of practically achievable and useful technical objects. This, in turn, makes it possible to obtain structures of active and passive systems meetings assumed dynamic properties. The obtained discrete system structures enable the selection of concept of system from the created set of possible solutions.

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