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Nazarenko I.,
Slipetskyi V.

DEVELOPMENT OF THE ORGANIZATIONAL PRINCIPLES OF FORMATION OF THE OPTIMAL DIAGRAM AND PARAMETERS OF VIBRATION SYSTEM

Розглянуто загальні питання розробки оптимальної принципової схеми вібраційної системи й визначення параметрів цієї схеми, що забезпечують екстремум критерію оптимальності. Об'єктом дослідження є технічні машини і технологічні середовища, які розглядаються як система, що підкорена єдиному вібраційному процесу. Технічними машинами прийняті в роботі вібраційні машини для реалізації процесів ущільнення. Технологічними середовищами прийняті двофазні дисперсні середовища, що використовуються для ущільнення. Такими середовищами прийняті бетонні суміші та ґрунти. Зниження енергетичних витрат, високий рівень і швидкість передачі енергії на виконання технологічного процесу є головними чинниками в створенні оптимальних схем вібросистем. Одним з найбільш проблемних місць у вирішенні такого підходу є відсутність загальноприйнятої моделі взаємодії робочих органів машин із оброблювальним середовищем. Існуючі дослідження базувалися на роздільному визначенні параметрів машин і середовищ. Такі методи характеризуються значними витратами енергії та довгою тривалістю протікання технологічного процесу. Запропонований підхід на основі гармонізації сил машин і середовищ, що виникають у вібраційному процесі, дозволив значно знизити витрати енергії. У роботі також отримано новий синергетичний ефект системи. Це пов'язано з тим, що у запропонованого методу створення оптимальної схеми є ряд особливостей. Так, в ході дослідження використовувалися режими поєднання пружно-інерційних сил підсистем в єдиній системі. Визначено зокрема реалізація субрезонансних та суперрезонансних режимів. Завдяки цьому забезпечується можливість довести до максимуму ефективність вібросистем не тільки в нових конструктивних рішеннях, але й в цілеспрямованому використанні внутрішніх властивостей об'єднаної системи. У порівнянні з аналогічними відомими вібраційними машинами забезпечується зменшення витрат енергії на 50 %. Запропонована методика розробки організаційних принципів формування оптимальної схеми та параметрів використані при проектуванні вібраційних систем для вібраційних та вібраційно-ударних режимів ущільнення будівельних сумішей.

Ключові слова: *організаційні принципи, оптимальна схема, вібраційна система, критерії оптимальності, параметри схеми, субрезонансні і суперрезонансні режими.*

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1. Introduction

The choice of the optimal circuit diagram of the vibration system and the determination of the parameters of this circuit are the tasks of synthesis of the optimal power vibration systems. And the choice of a scheme is a task of structural synthesis, the choice of parameters of a given constructive scheme is a task of dynamic synthesis. Both in content and in the methodology for solving these problems are significantly different, and if the dynamic synthesis of a given structural scheme of a vibration system can be carried out for almost any such scheme, the structural synthesis of optimal power vibration systems is not sufficiently developed. The adopted approach to the selection of the circuit diagram of the power vibration system is based on the analysis of known power vibration systems.

The process of improving technical systems is continuous. The effectiveness of this process is determined by how much the problem of developing methods for determining the optimal structures of technical systems at the design stage is solved [1]. The study of the general problems of creating resonant vibration apparatuses is the subject of work [2]. The structure itself (that is, the totality and interconnection of certain elements) to some extent determines the reliability and durability of the system. The widespread adoption of such vibrational techniques is constrained by a number of existing reasons [3]. So, the adequacy of the calculation model to the real process for a long time is based on simplified approaches to taking into account the mutual influence of working bodies and processing media. Studies [4] are performed taking into account the stress-strain state of the metal structures of the machine for technological purposes, but do not take into account the dynamic effects on their condition. Under modeling conditions, when the nature of the behavior of the system is accepted harmonious, in real vibrational systems, the emergence of lower and higher harmonics is possible [5]. The nature of their manifestations is different. In any case, this is the effect of nonlinearity effects. In a certain way, these can be subresonance and superresonance regimes. Phenomena in complex nonlinear systems, as noted by the authors of [6], are a promising direction and require additional research. In [7], the method of active vibration control is applied to nonlinear systems. The advantage of such an integral method is that there is no need to know the parameters of the system, such as mass, dissipation and stiffness coefficients, which are usually obtained by finite element methods. To measure the dynamic process of the system's motion, the acceleration method is used [8]. However, there are other alternative solutions. So, in [9], options for remote measurement of vibrations using laser and optical instruments are considered. The use of vibration sensor based on optical fiber is proposed in [10].

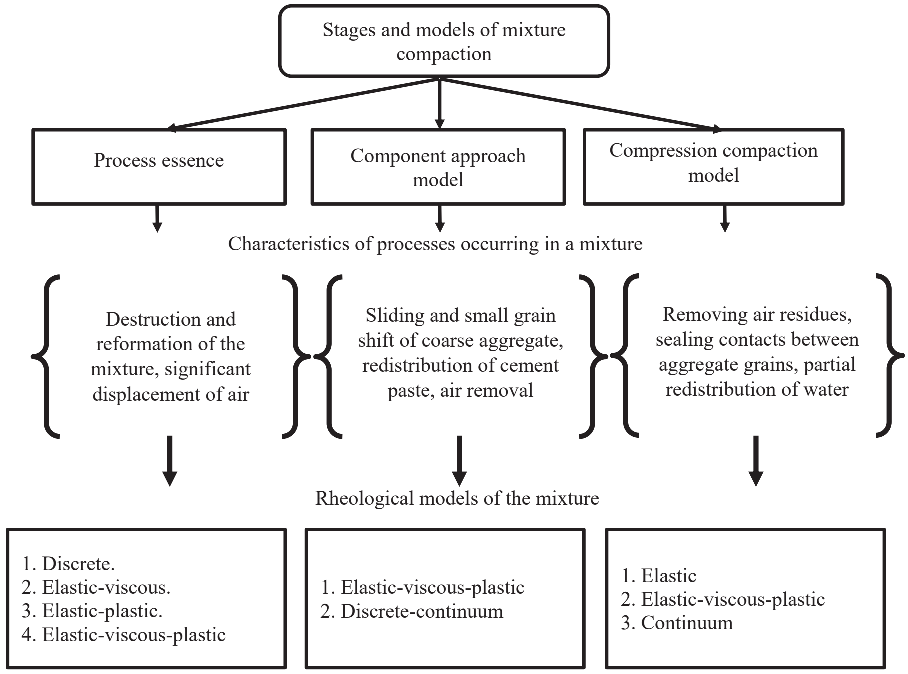

Fig. 1. Stages and models of the processes of compaction of mixtures

In [11], when studying the processes of processing technological media, the effects of the interaction of the working body and the medium are taken into account. Thus, obtaining the final method for creating optimal vibration systems is the initial condition for the adequacy of the calculation model to the real technological process.

Thus, the urgent problem is the development of basic organizational principles for the formation of the optimal scheme and parameters of the vibration system. From the point of view of the possibility of solving the problem of structural synthesis, theoretical and experimental analysis of systems allows to identify ways to improve the modes and parameters. This conclusion is the prerequisite for this research.

The object of research is technical machines and technological media, which are considered as a system subordinated to a single vibration process. By technical machines, vibration machines adopt in the work for the implementation of compaction processes are adopted. Technological media adopt two-phase dispersed media used for compaction. Concrete mixes and soils are accepted by such media. Reducing energy costs, a high level and speed of energy transfer to the process, are the main factors in creating optimal schemes of vibration systems.

The aim of research is development of the basic organizational principles for the formation of the optimal scheme and parameters of the vibration system.

2. Methods of research

The analysis of literature and the results of previous studies [1, 3] makes it possible to develop a structural diagram of the stages of the processes of compaction of mixtures (Fig. 1).

The rheological models are presented that reflect the principle of compaction processes at the entire stage of compaction of mixtures and allow to suggest the values of the main parameters during the implementation of various modes.

For harmonic vibrations with a frequency of $\omega = 300–600$ s^{-1}, the optimal amplitude:

$$X_{OPT} = \frac{(4-6)g}{\omega^2}, \quad (1)$$

where g – the acceleration of gravity (g=9.8 m/s^2).

For a frequency of 314 s^{-1}, the optimal vibration amplitude is determined by the lower and upper acceleration, that is, X_{OPT}=0.4–0.6 mm; for higher frequencies with an upper acceleration limit (for ω=420 s^{-1} X_{OPT}=0.35 mm, for ω=628 s^{-1} X_{OPT}=0.15 mm).

For vibration shock modes with a frequency of $\omega = 105–157$ s^{-1}, the optimal amplitude of vibrations (half-range vibrations) is determined by the dependence:

$$X_{OPT} = \frac{(2-2.25)g}{\omega^2}. \quad (2)$$

The task of forming optimal vibration systems is considered as a task, which involves the sequential solution of the following subtasks:

1. The search for such controls in power vibration systems, when specified in the formulation of the general problem in its conditions, provides an extremum of the optimality criterion.
2. The choice of structures in which optimal controls are found can be implemented (structural synthesis).
3. Determination of optimal dynamic parameters of selected structures of power vibration systems (dynamic synthesis).

3. Research results and discussion

The studies and the consistent solution of these subtasks allow to formulate the following principles for the formation of the optimal scheme of a vibrating machine for compaction of the mixture:

1. The optimal, time-varying frequency of the vibration processing of the medium.

2. Change in the amplitude of vibrations in the process of vibration processing of the medium.

3. The condition by which a smaller distance of the points of the medium in the vibrating organ is provided.

4. The provision to change the friction and adhesion forces only in the pronounced direction of the active force.

5. The optimal conditions under which the maximum energy is transferred from the working body to the processed medium.

6. The system provides the most approximate transmission of the movement of the working body to the largest number of particles of the processed medium.

7. Optimization parameters and system mode to take into account the features of the stages of the process of compaction of the mixture.

Thus, a vibration system that satisfies the above principles is controllable and optimal in time for acting on the processing medium.

The task of forming the optimal circuit is interpreted as designing and creating a vibration system that satisfies the principles listed above. Of these, the principle of time variation in the frequency and amplitude of the vibrations is especially important. The design of a device for changing parameters is reduced to continuous or discrete changes in temporary optimization of the workflow.

The obtained results follow that:

1. The stages of the process of compaction of mixtures consist in the renegotiation of the components of the mixture (transition from chaotic to stable conclusion of the components), their compaction (compact layout of the components of the mixture) and compression to compaction (air removal).

2. The accelerated and efficient process flow requires at the first stage significant amplitudes of vibrations (0.8...1.2 mm) with a frequency (100...150 s^{-1}). And at the next stages of ensuring the amplitudes of the vibrations (0.4...0.45 mm) with a frequency (250...314 s^{-1}).

3. The basic principles of the formation of the optimal circuit are determined, the essence of which is the harmonization of the modes of motion of the vibrating machine and the medium.

4. Conclusions

As a result of the studies, the basic principles of creating the optimal scheme of the vibration system, which is based on the targeted use of the internal dynamic properties of machines and media, are established. Moreover, such a system in research and determination of optimal parameters is considered as being subjugated by a single vibrational process.

The method proposed in the work for determining the basic principles of the formation of the optimal scheme of the vibration system can be effectively used for the implementation of other technological processes in various industries where vibration technologies are used.

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Nazarenko Ivan, *Doctor of Technical Sciences, Professor, Head of Department of Machinery and Equipment of Technological Processes, Kyiv National University of Construction and Architecture, Ukraine, e-mail: i_nazar@i.ua, ORCID: http://orcid.org/0000-0002-1888-3687*

Slipetskyi Volodymyr, *Deputy Director, Department of Procurement and Contract Policy, Corporation «DSK – ZHITLOBUD», Kyiv, Ukraine, e-mail: slipetskiyv@gmail.com, ORCID: http://orcid.org/0000-0002-9539-6022*