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ДЕЯКІ РЕЗУЛЬТАТИ РОЗВ'ЯЗАННЯ УЗАГАЛЬНЕНОЇ МІЖГАЛУЗЕВОЇ ПРИКЛАДНОЇ МЕХАНІЧНОЇ ЗАДАЧІ ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ОБРОБКИ ЗЕРНИСТИХ МАТЕРІАЛІВ В БАРАБАННИХ МАШИНАХ НА ОСНОВІ ВСТАНОВЛЕНОГО ЕФЕКТУ САМОЗБУДЖЕННЯ АВТОКОЛИВАНЬ

Анотація. Представлено окремі результати, отримані при спробі розв'язання задачі зниження енергоємності обробки зернистих матеріалів в барабанних машинах. Застосування встановленого гідродинамічного ефекту автоколивань зернистого заповнення камери обертового барабана при м'якому та жорсткому самозбудженні демонструють різку інтенсифікацію та зниження енергоємності процесів шляхом посилення дилатансії та активізації пасивної частини заповнення. Це відкриває шлях до створення нового покоління енергоефективних процесів машин барабанного типу.

Ключові слова: машини барабанного типу, зернистий матеріал, обертовий барабан, внутрішньокамерне заповнення, автоколивання, м'яке та жорстке самозбудження

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SOME RESULTS OF SOLVING A GENERALIZED CROSS-INDUSTRY APPLIED MECHANICAL PROBLEM OF INCREASING THE EFFICIENCY OF PROCESSING GRANULAR MATERIALS IN DRUM MACHINES BASED ON THE ESTABLISHED EFFECT OF AUTO-OSCILLATIONS SELF-EXCITATION

Abstract. Some results obtained in an attempt to solve the problem of reducing the energy consumption of processing granular materials in drum machines are presented. The use of the established hydrodynamic effect of auto-oscillations of the granular filling of the rotating drum chamber with soft and hard self-excitation demonstrates a sharp intensification and reduction of the energy consumption of processes by increasing dilatancy and activating the passive part of the filling. This opens the way to the creation of a new generation of energy-efficient processes of drum-type machines.

Keywords: drum-type machines, granular material, rotating drum, internal chamber filling, auto-oscillation, soft and hard self-excitation

Drum-type machines remain the main equipment for high-volume processing of granular materials. The International Patent Classification distinguishes 9 classes corresponding to 9 main types of drum machines: B01J 2/12 – granulators, B01J 8/10 and B01J 19/28 – reactors, B01F 29/60 – mixers, B02C17/00 – mills, B03B 5/56 – washing machines, B07B 1/22 – screens, B24B 31/02 – tumbling machines, F26B 11/04 – dryers, F27B 7/00 – heat treatment machines.

The problem with drum machines is the high energy intensity of the working process. This is caused by the low intensity of the relative movement of the processed granular material in the chamber of the rotating drum. A significant portion of the granular filling of the chamber is passive, does not undergo shear deformation and does not participate in the working process.

The generalized cross-industry applied mechanical problem was solved on the basis of a new established physical phenomenon. The hydrodynamic effect of self-excitation of auto-oscillations of the granular filling of the rotating drum chamber was revealed. Auto-oscillations are excited due to the loss of stability of the rotating drum vibration system on the verge of establishing a dynamic balance between the action of gravitational and centrifugal force fields on the granular filling. This is accompanied by a mutual transition of the flow regimes of the liquefied granular filling in the chamber – the circulation and wall layer.

The first direct video recording of the auto-oscillating mode of movement of the granular filling of a rotating drum [1] was made in 1966 in a technical video film of the IWF film studio (Göttingen, Germany) (Fig. 1).

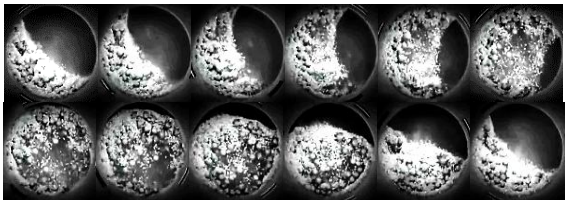


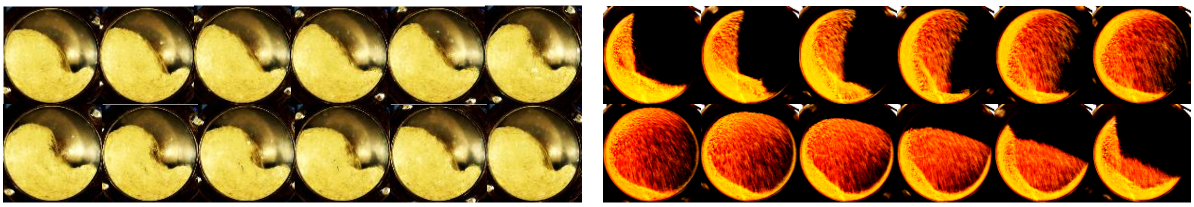
Fig. 1. Sequence of pictures of one period of auto-oscillations of granular filling of the chamber of a laboratory drum mill (according to [1])

Subsequently, the conditions for the stability of the motion of the drum machine unit were established [2], the mechanism for implementing the auto-oscillating mode of the filling flow was revealed [3], and a model of the conditions and factors for the oscillatory stability of the motion of a two-fraction granular filling was constructed [4]. The influence of the degree of filling of the chamber and the content of the crushed material in the filling on the technological and energy efficiency of the auto-oscillating grinding process in a drum mill was experimentally evaluated [5-8].

It turned out that self-excitation of auto-oscillations allows you to switch from a passive mode of implementation of the process of processing granular material to an active intermittent dynamic process based on self-regulation due to feedback without the need for external periodic action. This allows you to sharply intensify and accelerate the process. Auto-oscillations lead to periodic pulsating motion and activate the passive part of the filling and significantly increase the intensity of interaction of particles of the medium with the working body and the medium.

At the first stage of solving the problem, innovative processes for processing granular materials were created when the drum rotation speed reaches the bifurcation value [9-17]. The processes are implemented using a device that contains a drum and a drive with a rotation speed regulator, an elastic element and a recorder of the element's oscillation amplitude. To determine the bifurcation value of the speed, the initial arbitrary drum rotation speed is changed with simultaneous measurement of the amplitude of oscillations of the elastic element until the maximum value of the measurement results is reached.

Recent studies have revealed two qualitatively different modes of self-excitation of fill oscillations – soft (Fig. 2a) and hard (Fig. 2b), which significantly affect the implementation of technological processes.



a b

Fig. 2. The obtained pictures of one period of auto-oscillations:
a – with soft self-excitation, b – with hard self-excitation

In the soft mode, there is a smooth self-excitation of auto-oscillations of the filling of a quasi-harmonic form with a limited amplitude (Fig. 2a). This mode is characterized by monostability, reduced bifurcation values of the drum rotation speed and the dilatancy of the filling in the chamber, and an increased number of pulsations per one drum rotation.

In the rigid mode, there is a jump-like self-excitation of discontinuous relaxation auto-oscillations of filling anharmonic form with a significant amplitude (Fig. 2b). Such a regime is characterized by bistability, increased amplitude, reduced quality factor, and increased degree of relaxation of auto-oscillations.

At the second stage of solving the problem, innovative auto-oscillating processes of granulation, washing, classification and mixing were created in the soft self-excitation mode [17-21] and the processes of heat treatment, grinding, drying, reaction and tumbling in the hard self-excitation mode [22-25].

At the third stage of solving the problem, which is currently under implementation, innovative methods will be created to control the processes of processing granular materials when conducting self-excitation of auto-oscillations in soft and hard modes.

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