Ways of Improvement of Productiveness of Vibratory Tubular Conveyors

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Abstract – The principle of construction of two-mass lengthy tubular conveyors of coaxial type with electromagnetic oscillations exciter is considered. The dependence for determination of the conveyor productiveness is substantiated. The design diagrams of tubular multi-tube conveyors of two- and three-mass vibratory schemes are proposed and the efficiency of their implementation in order to increase the productiveness of bulk and lump products feeding due to the use of all tubular elements as transporting ones is substantiated.

Keywords – vibration, conveyor, tube, mass, armature, electromagnet, frequency, amplitude, speed of transportation, speed factor, productiveness.

I. Introduction

Vibratory tubular conveyors are the effective means of transporting bulk and lumpy products and piece parts. Using the separate machines (modules), the lengthy lines of required length (up to 50 m and more) may be constructed. The lengths of separate modules are 2…6 m. The most effective models are the models with two-mass oscillation scheme, coaxial placement of tubes of symmetrical structures and two-cycle electromagnetic oscillations exciter [1]. Their main advantage is the low power consumption and the absence of friction pairs. They are fed from AC power source using the frequency converters with the most expedient operating frequencies of 25 Hz, 16.7 Hz or 12.5 Hz. At these frequencies, it is possible to achieve greater lengths of transporting elements for one drive. During the operation of conveyors and lengthy transporting lines, there is practically no noise for these frequencies.

II. Models of tubular conveyors

One of the models of tubular conveyor is presented in Fig. 1. In the following conditions: the operating frequency of the conveyor oscillations of 25 Hz, the maximum horizontal amplitude of the oscillations of the conveyor tube of 5.0 mm, the maximum speed of the vibratory transportation of 600 mm/s, while transporting dry sand, the conveyor provides the maximum volumetric capacity of 14 m^3/h with an internal diameter of the tube of 116 mm, consuming up to 0.4 kW and providing the feeding of products at the distance of 3 m.

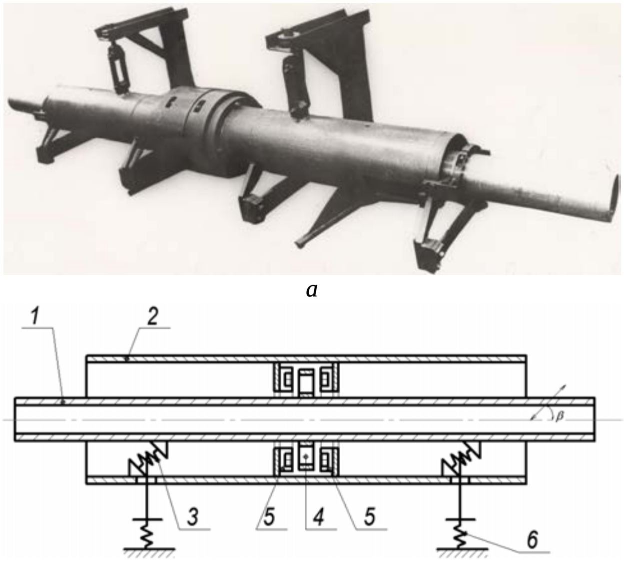

Fig. 1. Vibratory tubular conveyor: a – general view; b – structural diagram; 1 – working transporting tube; 2 – reactive non-transporting tube; 3 – elastic system; 4 – armature; 5 – electromagnet; 6 – vibrations isolators

Since the transporting element of these conveyors is only an internal tube, and the external tube performs the function of the reactive (balancing) mass in the two-mass oscillatory system [2], the productiveness of the conveyor depends on the internal diameter of the conveying tube, on the amplitude of its oscillations and on the operating frequency of the conveyor. It is known that the volumetric productiveness Q of a conveyor may be calculated by the dependence (1) [3]:

$$Q = 3600 \cdot v \cdot s \quad (\mathrm{m^3/h}), \tag{1}$$

where v is the speed of vibratory transportation (mm/s); s is the area of the cross-section of the product being transported ($\mathrm{mm^2}$).

The speed of transportation may be determined by the following formula [3]:

$$v = 2 \cdot \pi \cdot \upsilon \cdot A_{\Gamma} \cdot k_{Ш} \quad (\mathrm{mm/s}), \tag{2}$$

where υ is the operating frequency (Hz); A_{Γ} is horizontal component of the oscillations amplitude (mm); $k_{Ш}$ is the speed factor.

The optimal mode of vibratory transport will take place in the case, when the throwing motion of the products coincides with the oscillations of the transporting tube, i.e., when $k_{Ш} = 0.635$ [4]. During the vibratory transportation, loose products occupy approximately 50…60% of the internal cross-section of the transporting tube. If the product being transported occupies 60% of the tube internal cross-section, the productiveness of the conveyor may be determined by the formula (3):

$$Q = 1{,}1 \cdot 10^{-5} \cdot \upsilon \cdot A_{\Gamma} \cdot d^2 \cdot k_{Ш} \quad (\mathrm{m^3/h}), \tag{3}$$

where d is the transporting tube internal diameter (mm).

The experimental investigations of a number of models of two-mass tubular conveyors shows that the maximum amplitudes of oscillations of such machines operating at a frequency of 25 Hz reach $A_{\Gamma\max}$ = 6…7 mm. Tubes diameters for the main range of conveyors are within d = 100…200 mm, which is limited by the own frequencies of the transporting tubes and their lengths [1]. It has been experimentally determined that $k_{Ш}$ is larger than k_{III} = 0.635 and reaches k_{III} = 0.8…0.85 at maximum amplitudes of oscillations. After analysing a number of models of conveyors while carrying out the investigation of their real constructions, we conclude that, it is necessary to modernize their structural diagrams in order to ensure the significant improvement of the productiveness of such machines. The most significant improvement of the productiveness will be in models, in which all oscillating masses made of elongated transporting tubes will be transporting ones and their number will be two or more.

The most common ones are two- and three-mass design diagrams of vibratory conveyors. Multi-mass diagrams (with four or more masses) are not widespread because developers are always facing a dilemma: the conveyor should be as simple as possible while designing, manufacturing, installing, operating, and ensuring a prescribed productiveness.

In this publication, we will take into account only two- and three-mass structural diagrams. Fig. 2 shows the structures of tubular transporting elements of modernized devices. Elastic restrictions allow oscillation of the transporting elements along their axis with the vibration angle ensured by the flat elastic elements. The diagrams of Fig. 2, *a* and *b*, have two oscillating masses m_1 and m_2 which are placed parallel to each other. The centres of the oscillating masses O_1 and O_2 are not concentric, but due to the significant moment of inertia of the transporting tubes and the multi-block elastic planar system, parasitic oscillations around the reduced centre of mass *O* will not occur in the longitudinal plane. The diagrams of Fig. 2, *c* and *d*, consist of four tubes forming two oscillating masses which mass centres are reduced to point *O*. This structure completely balances the oscillating masses and prevents parasitic oscillations. The diagrams of Fig. 2, *e* and *f*, consist of three oscillating masses with three (Fig. 3, *e*) and six (Fig. 3, *f*) transporting tubes. Systems with a larger number of masses and transporting tubes, may be constructed similarly to those presented in Fig. 2 using the method of combining of multi-mass systems.

Conclusions

The proposed structural designs ensures a significant improvement of productiveness, since each tubular element is simultaneously a transporting one. The possibilities that will be laid in the structural and dynamic diagrams of such conveyors will be used almost at 100%. Experimental studies of some of the proposed models have shown that the filling of tubes while transporting products may reach 95%...100% unlike the models presented in Fig. 1. Therefore, this will significantly increase the productiveness of the conveyor. At the same time, due to the uniform loading of the oscillating masses, which will have approximately the same values, the field of oscillations along the length of the tubular lengthy elements will be uniform [1]. This will ensure the uniformity of the vibratory transportation. The effect of loading on the operation of the devices will be negligible if one carries out the designing according to the theory of self-stabilization of oscillations described in [2]. In addition, since the angles of vibrations of such conveyors are within the range of β = 10º…30º and the main component of the amplitude of oscillations is horizontal one, the loading effect in the modes with throwing will also be negligible. The further research in this field may be reduced to the development of models of conveyors with lengths of transporting elements of L = 3…8 m and of lengthy lines constructed of these modules.

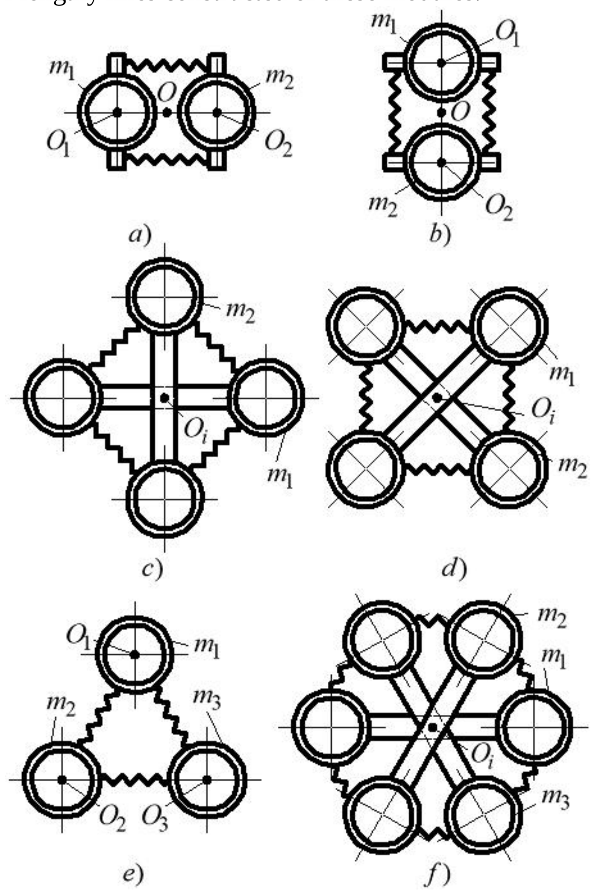

Fig. 2. The design diagrams of tubes of modernized tubular conveyors: a, b – two-mass two-tube ones with non-concentric mass centres; c, d – two-mass four-tube ones with concentric mass centres; e – three-mass three-tube one with non-concentric mass centres; f – three-mass six-tube one with concentric mass centres

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