Definition energy consumption for overclocking powered by mass with sinusoidal acceleration and synthesis drive mechanism

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Abstract

Introduction. Theoretical developments concerning the determination of the energy costs of the transition process dispersal devices driven mass food production based on the driving factors and factors of resistance.

Materials and methods. The mathematical description of these processes was carried out using Newton's laws, the principle of d'Alembert, general theorems of dynamics and power relations, as well as the independence of the forces .

Results and discussion. It is proved that the benefits of growth dynamic forces over the forces of resistance leads to a reduction in the time course of the transition process, but energy costs at the same time remain stabilized at the level of the kinetic energy of the mass.

Conclusions. Mathematical models have shown that the capacity of developing drivers with reduced time transients, increasing as the dynamic load of the system. This should be considered when designing and engineering calculations occasions devices for food industry.

Introduction

Concerning to food technology, mechanical power of action and interaction between the various components are widespread. They concerning to the processes that characterize the operation input reception commodity flows, transportation, processing, storage, overhaul, maintenance of internal flows, formation of gas and liquid flows, ensuring their interaction with the commodity flow, thermodynamic achieve this transformation of air or gases, special purpose and etc. Implementation of specified actions mean to have necessity to overcome the resistance factors, requiring introduction to the driving factors. Value of the driving factors (forces or moments of forces) and resistance factors determine the nature of the process that accompanies their performance. Inequality of main factors and resistance factors means that their effect on individual lot will be accompanied by transients, result in the emergence of forces of inertia and (or) the moments of inertia forces [1].

This chapter includes following tasks:

- the choice of methods of estimation of parameters of mechanical systems;
- determination of energy expenditure in systems transporting cargo conveyors;
- determination of the energy costs of moving goods in the transition process;

Materials and methods

The mathematical description of these processes is using in Newton's laws and in the principle of D'Alembert. Using the latter allows it go from strength factors acting on a body or system of bodies (w) to describe their kinematics.

In subsequent studies, expected use of general theorems of dynamics and power relations, as well as the independence of the forces.

Results and discussion

Creating technological machines always linked to performance requirements set operations and also to minimize the energy, materials and economic costs of their operation. The most common in modern equipment operations include moving and handling specific cargoes or complexes of them (group of packages) that occur on the job of their surface areas of overcoming the friction forces [2, 3].

Giving some cargoes velocity and kinetic energy in the process of dispersal should to perform work against the forces of inertia.

These components of energy expenditure are required, but it is possible to significantly limit the total number of them through the full use of the kinetic energy of the body, accumulated during the dispersal of the latter [7]. Since established theoretical background processes of acceleration and coasting cargo is not in doubt, it is logical to make the transition to the problem of machine maintenance. Implementation of various laws of motion of the working bodies used in these operations can be carried out by various mechanical, pneumatic hydromechanical or electromechanical means.

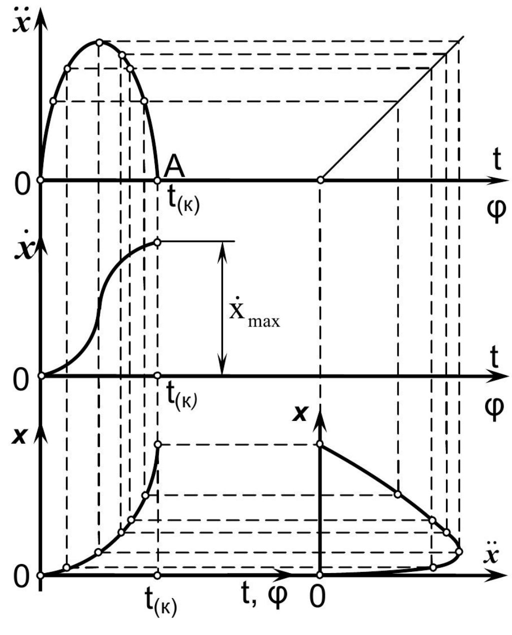

Fig. 1. Kinematic diagram displacement, velocity and acceleration of the pusher and chart x = x($\ddot{x}$)

Widespread use is a cam mechanism through which the cam profiles implemented various laws of motion outgoing links (pushers).

Let pusher and with it a load on the section 0 - A has a sinusoidal law of motion $\ddot{x} = \ddot{x}_{\max} \sin(\omega t)$ (Fig. 1).

Then the initial conditions

$$t_{(i)} = 0; \quad x_{(i)} = 0; \quad \dot{x}_{(i)} = 0; \quad \ddot{x}_{(i)} = 0 \tag{1}$$

we obtain

$$\dot{x} = \frac{\ddot{x}_{\max}}{\omega}\left(1 - \cos(\omega t)\right), \tag{2}$$

$$x = \frac{\ddot{x}_{\max}}{\omega} t - \frac{\ddot{x}_{\max}}{\omega^2} \sin(\omega t) \tag{3}$$

It is known that the energy costs associated with acceleration dynamic mass elementary displacement are determined dependence

$$dE = m\ddot{x}(x)dx \tag{4}$$

In our case, and the acceleration $\ddot{x}$ and displacement x are functions of time, except as a graphical parameter t (Fig. 1) we can get the chart $\ddot{x} = \ddot{x}(x)$. The area, which is bounded by the curve and the axis 0h determines wanted integral $\int_0^x \ddot{x}(x)dx$. At the same time accumulated at the end time $t_{(e)}$ defined as the kinetic energy

$$W_{kin} = \frac{m\left(\dot{x}_{(e)}\right)^2}{2} = \frac{m\left(\dot{x}_{\max}\right)^2}{2} \tag{5}$$

However, there is a possibility of an analytical evaluation of the kinetic energy via the displacement and acceleration. To get it out of the formula $\ddot{x} = \ddot{x}_{\max} \sin\left(\omega\ t\right)$, we determine

$$t = \frac{\arcsin \dfrac{\ddot{x}}{\ddot{x}_{\max}}}{\omega} \tag{6}$$

Then substituting (6) into equation (3) we obtain

$$x = \frac{\ddot{x}_{\max}}{\omega^2} \arcsin \frac{\ddot{x}}{\ddot{x}_{\max}} - \frac{\ddot{x}}{\omega^2} \sin\ \arcsin \frac{\ddot{x}}{\ddot{x}_{\max}} \tag{7}$$

As a result, look up and transformations we obtain the dependence for the determination of energy to overcome the forces of inertia

$$E = \frac{mx_{\max}^2}{2\omega^2} - \frac{mx_{\max}^2}{\omega^2}\cos(\omega t) + \frac{mx_{\max}^2}{2\omega^2}\cos^2(\omega t) \tag{8}$$

However, the kinetic energy of the body has determine as a function of time according to the formula

$$W_{kin} = \left(\frac{\ddot{x}_{\max}}{\omega}\right)^2 \left(1 - \cos^2(\omega t)\right)\frac{m}{2} \tag{9}$$

For further analysis we choose a finite displacement

$$t_{(e)} = \pi / \omega \tag{10}$$

and the resulting kinetic energy

$$W_{kin(e)} = \left(\frac{\ddot{x}_{\max}}{\omega}\right)^2 \left(1 - \cos\pi\right)\frac{m}{2} = m\left(\frac{\ddot{x}_{\max}}{\omega}\right)^2 \tag{11}$$

Moving cargo at $t = t_{(e)}$

$$x_{(e)} = \frac{\ddot{x}_{\max}}{\omega}\cdot\frac{\pi}{\omega} - \frac{\ddot{x}_{\max}}{\omega^2}\sin\pi = \frac{\ddot{x}_{\max}\pi}{\omega^2} \tag{12}$$

Energy costs associated with overcoming the friction forces at this stage

$$E_{F_m} = fmgx = fmg\frac{\ddot{x}_{\max}\pi}{\omega^2}. \tag{13}$$

Then the total energy at this stage

$$E_t = W_{kin(e)} + E_{F_m} = m\left(\frac{\ddot{x}_{\max}}{\omega}\right)^2 + fmg\frac{\ddot{x}_{\max}\pi}{\omega^2} \tag{14}$$

To minimize energy consumption at the stage of dispersal, then we note the need for further clarification of end conditions. Obviously, it is more reasonable to use the accumulated kinetic energy of the second phase, which is characterized as a stage freewheel. The initial level of the kinetic energy of the body at the second stage $W_{kin(i)}^{II}$ the final value of the first stage

$$W_{kin(i)}^{II} = W_{kin(e)}^{I} = m\left(\frac{\ddot{x}_{\max}}{\omega}\right)^2$$

Assuming that the kinetic energy is spent on performance against the forces of friction, we can write

$$m\left(\frac{\ddot{x}_{\max}}{\omega}\right)^2 = fmg\,x_{(\kappa)}^{II} \tag{15}$$

from

$$x_{(e)}^{II} = \frac{\ddot{x}_{\max}^2}{f\,\omega^2 g} \tag{16}$$

Then two general steps will be moving

$$x_g = \frac{\pi \ddot{x}_{\max}}{\omega^2} + \frac{\ddot{x}_{\max}^2}{f\,\omega^2 g} \tag{17}$$

From the last formula it shows that the parameters that can affect the outcome include the maximum value of acceleration $\ddot{x}_{\max}$ and angular velocity of the cam mechanism. The same values x_g can achieve different pairs of values $\ddot{x}_{\max}$ and ω. But let us return to the question of the choice of parameters in which energy minimization is achieved on the movement of goods and perform the differentiation dependence (14) for $\ddot{x}_{\max}$. Then

$$\frac{dE_g}{d\ddot{x}_{\max}} = \frac{2m}{\omega^2}\ddot{x}_{\max} + \frac{\pi\,fmg}{\omega^2} \tag{18}$$

Equating to zero right-hand side of this formula, we obtain the acceleration $\ddot{x}_{\max}$, which corresponds to the extreme function $E_g = E_{\max}\left(\ddot{x}_{\max}\right)$:

$$\ddot{x}_{\max} = \pi\,fg/2 \tag{19}$$

Using the relation (19) , we write the expressions for finite displacements on the stages and the angular velocity , wondering quantity $x_{(\kappa)}^{I}$:

$$x_{(e)}^{I} = \frac{\ddot{x}_{\max}\pi}{\omega^2} = \frac{\pi^2 fg}{2\omega^2}; \quad x_{(e)}^{II} = \frac{\ddot{x}_{\max}^2}{f\,\omega^2 g} = \frac{\pi\,fg}{4\omega^2} \tag{20}$$

$$\omega = \sqrt{\frac{\pi^2 fg}{2x_{(\kappa)}^{I}}} \tag{21}$$

If we take $x_{(e)}^{I} = 0{,}1$ m ; f = 0,3; g = 9,81 m/s^2, the

$$\omega = \sqrt{\frac{3{,}14^2 \cdot 0{,}3 \cdot 9{,}81}{2 \cdot 0{,}1}} = 12{,}045\ \text{s}^{-1}, \tag{22}$$

corresponding to the frequency of rotation of the cam $n = \frac{30\omega}{\pi} = \frac{30 \cdot 12{,}045}{3{,}14} = 115$ rev/min.

The table shows the correlation between parameters $x^{I}_{(e)}$, ω and n with f = 0,3, g = 9,81 m/s^2 and m = 10 kg. Determination of the angular velocity and acceleration $\ddot{x}_{\max}$ of the cam plunger movement are important components in the synthesis of cam mechanism. The next step should be to determine the values of the phase angles. If the selected value corresponds to the laws of motion and of the working of the cam, which is used to disperse the load. As the value $t^{I}_{(\kappa)}$ concerning $\ddot{x} = 0$, so the corner $\phi^{I}_{(\kappa)} = \omega t^{I}_{(\kappa)} = \pi$.

Table

Relationship between the geometric, energetic and kinematic parameters of "cam gear -load"

$x^{I}_{(e)}$, *m*	0,10	0,15	0,20	0,25	0,30	0,35
ω, *s*$^{-1}$	12,045	9,835	8,517	7,62	6,95	6,44
n, *rev/min*	115	94	81,4	72,8	66,4	61,5
$x^{II}_{(e)}$, *m*	0,2	0,3	0,4	0,5	0,6	0,7
E_g, *J*	4,4	6,62	8,79	11,03	13,24	15,44

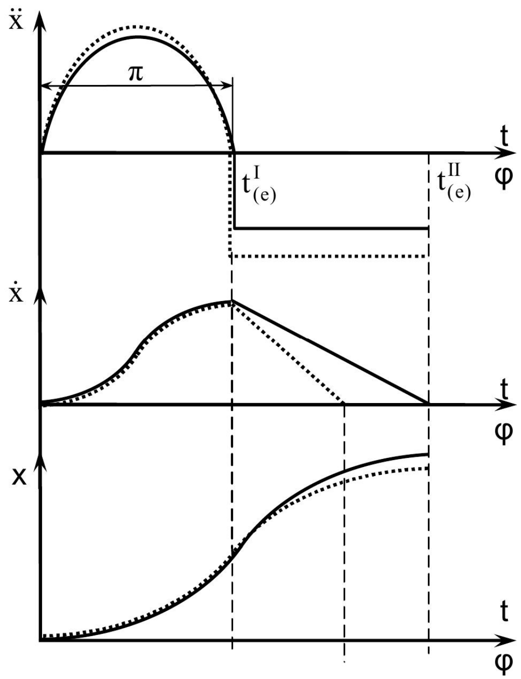

Fig. 2. Kinematic diagram of moving the pusher (·········), cargo (——)

The area from $\varphi^{I}_{(e)}$ to $\varphi^{II}_{(e)}$ important values to plug pusher acceleration was less than the negative acceleration module load (Fig. 2). At the corner of the phase reverse movement of the cam its laws of motion do not affect the goods, but because of their choice should be guided by the provisions of generally accepted theory of mechanisms and machines.

Conclusions

Growth of the benefits of dynamic forces over the forces of resistance leads to a reduction in the time course of the transition process, but energy costs at the same time remain stabilized at the level of the kinetic energy of the mass of the system. Nevertheless, capacity of developing dynamic with a reduction in the time transients, increasing as the dynamic forces of the system elements.

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