ABOUT PDE-MODEL OF PORT CONVEYOR LINE WITH SPEED CONTROL OF CONVEYOR BELTS

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Currently, in the conditions of modernization of shiploads on port conveyor lines, it is especially important to load cargo on conveyor belts so that stress remains at minimum or at evenly distributed. It makes sense for loading products on conveyor belts and any cargo ship.

All ships actually are designed with limitations imposed upon their operability to ensure that the integrity is maintained. As the result, if these limitations will be exceeded it might result in over-stressing of the conveyor’s structure which may lead to catastrophic failure. So, based on above, there is a regulation of the speed of loading conveyor lines for transporting cargo to the ship to minimize situations that would lead to fatal errors due to uneven distribution of cargo.

With an enhancement of control systems for flow lines that operate with variable capacity the PDE-models currently are most demand [1]. Production systems with a variable output of the products include some production systems that use the conveyor type of the organization of the production (Fig. 1-3).

Fig. 1. Conveyor at the Port of Kembla in New South Wales

Fig. 2. Belt conveyors in Jiangsu Shagang Group

Fig. 3. Rubber belt conveyors in Baosteel Group

Considering the fact that on port production conveyors, the load is performed at varying speeds, this article will be considered in detail the model of a conveyor line with a regulable speed using partial differential equations.

The control of the speed of the belt of a single conveyor changes the statistical characteristics of the output. It leads to a change in the amount of input flow on subsequent conveyors, which affects their power consumption [2]. Uneven loading of cargo along the belt conveyor directly affects the transportation cost of the cargo and determines the dynamics of the system as a whole. So, it is required to plan normative volumes of the cargo mining while control systems of the conveyor are being designed. In fact, in real production, the flow of the cargo varies in time and these variations are very significant even during the daily period of functioning such systems.

The speed of the conveyor belt should correspond to the level that ensures the optimum work of the conveyor line.

Changing the speed of the conveyor belt is performed with a delay and it can be assumed the value of delay is proportional to the length of the conveyor and is inversely proportional to the speed of the belt. Special attention requires the problem of the transport dependence and operating costs on changing the distributing of the cargo load along the conveyor and the speed of the conveyor belt. By paying attention to all these facts, this article is devoted to the study of the distribution of the linear load of the cargo along the conveyor on the speed of the conveyor belt.

Currently for designing control systems for production lines is being used new class of models – PDE-model [3].

PDE-models consider the stochastic nature of the interaction of the technological equipment and the subject of labor during technological processing [4] as well as their distribution by technological positions. Just for example, the ideal production systems will be considered, which are characterized by the absence of loss of the subjects of the labor as a result of the production process (there are no defective products). The system of equations that determines the behavior of the parameters of the production line in a one-moment description has the form [3, p. 70]:

$$\frac{\partial[\chi]_0(t,S)}{\partial t}+\frac{\partial[\chi]_1(t,S)}{\partial S}=0\,, \tag{1}$$

$$[\chi]_1(t,S)=[\chi]_{1\omega}(t,S)\,,\ \ [\chi]_0(t_0,S)=\psi(S)\,, \tag{2}$$

where $[\chi]_0(t,S)$ is the density of the distribution of the subjects of the labor by technological positions; $[\chi]_{1\psi}(t,S)$ is the capacity of the processing of the subjects of the labor on a technological operation; $[\chi]_1(t,S)$ is the rate of processing of the subjects of the labor by technological positions at a time t.

The position of the subject of the labor in the technological route is characterized by the coordinate $S\in(0;S_d)$. When using the coordinates of the cost space, Sd corresponds the full self-cost of the product. The initial condition determines the number of the subjects of the labor at a time t on each technological operation. System of the equations (1)-(2) allows calculate the parameters of the production line.

As it was already mentioned above, the conveyor with a variable speed of the belt is used to reduce the costs of the transporting the cargo (in the mines, [2,5]), as well as to synchronize the output of the product with the existing demand (in industrial enterprise, [3]).

The characteristic feature of the modelling of the conveyor line for an industrial enterprise is that the subjects of the labor move along the conveyor with the same speed. The system of equations describing the motion of the cargo along the conveyor line has the form:

$$\frac{\partial[\chi]_0(t,S)}{\partial t}+\frac{\partial[\chi]_1(t,S)}{\partial S}=\delta(S)\lambda(t)\,,\qquad \int_{-\infty}^{\infty}\delta(s)dS=1\,, \tag{3}$$

$$[\chi]_1(t,S) = [\chi]_0(t,S)a(t)\,,\ [\chi]_0(t_0,S) = H(S)\psi(S)\,,\ H(S) = \begin{cases} 0, if\ (S<0); \\ 1, if\ (S \geq 0). \end{cases} \tag{4}$$

The coordinate $S = S_d$ corresponds to the degree of readiness of the subject of the labor, that is, the state to which the subject of the labor must correspond when leaving the conveyor line according to the production and technological documentation. Parameters $[\chi]_0(t,S)$ and $[\chi]_1(t,S)$ (4) have related each other by a coefficient $a = a(t)$ that determines the speed of the conveyor belt. So, it is assumed that the speed of the belt during the day has the next form:

$$a(t) = a_0 - a_1 \cos\left(2\pi \frac{t}{T_S}\right) \qquad a_0, a_1 \geq 0\,,\ \ a_0 - a_1 \geq 0\,, \tag{5}$$

where a_0 is an average conveyor speed during the duration T_S; a_1 is the amplitude of the change of the speed during the duration T_S. In this case the speed of the conveyor is considered at the start of the day, and is $a(t)\big|_{t=nT_S} = a_0 - a_1$, increases with the time and reaches the maximum value in the middle of the day $a(t)\Big|_{t=\left(n+\frac{1}{2}\right)T_S} = a_0 + a_1$, then decreases to its start value $a(t)\big|_{t=(n+1)T_S} = a_0 - a_1$. In the equation right side specifies the source of the supply of the cargo on the first technological operation with the coordinate S = 0.

The state of flow parameters of the conveyor line will be described using dimensionless variables and parameters

$$\tau = {}^{t}\!/_{T_d}\,,\ \ \xi = {}^{S}\!/_{S_d}\,, \tag{6}$$

$$\theta_0(\tau,\xi) = \frac{[\chi]_0(t,S)}{\ell}\,, \qquad \ell = \max\left\{\psi(S), \int_{t_0}^{t} \lambda(\eta)d\eta\right\}. \tag{7}$$

The balance equation (3) and (4) is written down in the dimensionless form:

$$\frac{\partial\theta_0(\tau,\xi)}{\partial t} + g(\tau)\frac{\partial\theta_0(\tau,\xi)}{\partial\xi} = \delta(\xi)\gamma(\tau)\,, \tag{8}$$

$$\theta_0(\tau_0,\xi) = H(\xi)\psi(\xi)\,. \tag{9}$$

One of the most essential characteristics of the production system is duration of the production cycle. The duration of the production cycle is equal to the time interval for which the object of labor passes the path from the first technological position to the last. Calculation of the duration of the production cycle for enterprises with a flow-method of organizing production is given in [4]. The value the duration of the production cycle for a conveyor-type production line can be defined as follows:

$$\tau_d = \int_0^1 \frac{d\xi}{g(\tau)}\,, \tag{10}$$

Cargo that arrived on the conveyor line at the time τ_0, leave the conveyor line at time τ with a delay $\tau_d = \tau - \tau_0$. This delay is equal to the duration of the production cycle. The delay depends on the time at which the cargo enters the conveyor, it is not constant value.

Conclusions and prospects for further development. The results of the research are background for the development and improvement of production control systems with conveyor type. As it is demonstrated the distribution of cargo along the conveyor belt depends on the speed of the conveyor belt.

Apart from this, the using of PDE-models has a number of disadvantages, such as the construction of a closed system of equations of the production process. So, further prospect of discussed issue is the construction of control system for production line with conveyor type with variable speed of the belt's movement.

Transshipment of products is being dirty and old-fashioned, so a number of Groups try to use innovation methodologies to avoid these effects. In particular, BEUMER Group supplied and installed a Pipe Conveyor that transports products with speed 2,300 t/h from the warehouse to the ship and this conveyor ensure dust-free transportation of concentrates (Fig. 4).

Fig. 4. The BEUMER pipe conveyor

Fig. 5. Damaged conveyor belt

It's another prospect for development that together with regulation of transferring of the cargo in ship loading system allows avoid cases when conveyor belts are damaged (Fig. 5) due to overload at certain points with certain speeds, resulting in production delays and significant emissions and pollution of the environment as well.

References

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