THE INVESTIGATION OF THE PROCESS OF A SCREW CONVEYER SAFETY DEVICE ACTUATION

ДОСЛІДЖЕННЯ ПРОЦЕСУ СПРАЦЮВАННЯ ЗАПОБІЖНОГО ПРИСТРОЮ ГВИНТОВОГО КОНБЕЄРА

Abstract: The article presents the design of a safety device with slipping and axial shifting regimes, which are separated in time and are used in order to recondition the working capacity of a conveyor. Also, power analysis of the operation of a safety mechanism is conducted, which gives the opportunity to estimate the change in the moment of rotation of a driven half-clutch and a screw T depending on the change in the angle of the relative turning of half-clutches ρ. Based on the results of the static experimental investigation of the safety device, it was determined that the given static analytical dependences can be used in the engineering design of different standard sizes of a safety device.

Key words: screw conveyor, the safety device, half clutch, torque, groove.

INTRODUCTION

Screw conveyers are widely used for moving loose and lump materials in different production processes. However, when transporting some materials, a screw working body may jam, which can be caused by the clearance between the surface of screw rotation and the inner surface of a directing case.

In order to recondition the working capacity of a conveyor it is necessary to shift the jammed edge of a conveyor in the axial direction from the place of contacting with the material and, after the removal of the surcharge, the elements of the drive must provide the initial state of the working body for transporting the materials to the unloading area.

The principle of reversing a jammed body, which is carried out with the help of planetary safety devices, which secure the reverse rotation of a conveyor from a nonessential angle of turn to a couple of complete revolutions with further reconditioning of its initial state, is known.

Moreover, it is possible to shift the jammed working body of a screw with the help of ball safety clutches with edgewise making of holes both at clutch release and at clutch engagement [1, 2, 3, 4, 5, 6, 7, 8].

Having analyzed the available investigations, it can be deduced that the main disadvantages of the existing safety devices, which ensure the reversing of overloaded working bodies, are their constructive and technical complexity, material holding capacity and unreliability in use. Also, they have considerable overall size and when working, there can be great dynamical load due to the significant inertia power of the slave holes of a drive and a working body with the automatic reconditioning of its initial state.

MATERIAL AND METHOD

In order to improve the effectiveness of the functioning of conveyers in the extreme conditions of their operation, the circuit of a safety device is propounded (Fig. 1. a), which ensures the axial shift of a screw in the direction opposite to the direction of the moment of rotation of a driven half-clutch with the help of planetary safety devices, which enforces the reversing of overloaded working bodies.

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material transportation at the automatic reconditioning of its working mode.

When the working body of a screw conveyor is jammed, the driven half-coupling of the device stops and the driving one continues rotation. As a result, the main unlinking of half-clutches takes place, in other words, balls come out of holes with the value of $\delta_1$. Then, the balls move along the inclined working grooves with $\beta$ slope angle on the head plane of a driving half-clutch and thus, smooth and “soft” axial shift of a screw working body with the value of $\delta_2$ takes place, which essentially decreases the dynamic overloading of the drive of a screw conveyor. Due to the rotation of a driving half-clutch of a device, the driven half-coupling of the conveyor stops as well.

Fig. 1 – The constructive scheme of the safety device (а) and the scheme of the reamer of the working surface (b) / Конструктивна схема запобіжного пристрою (а) та схема розгортки робочої поверхні ведучої півмуфти (б)
clutch, balls return to their initial state moving along inclined reverse grooves with \( \gamma \) slope angle on the head plane of a driving half-clutch, in other words, smooth and “soft” reconditioning of the working capacity of a screw conveyor takes place.

Figure 2 shows the constructive scheme and the general form of the working surface of the driving half-clutch of a safety device [9].

![Figure 2 - The constructive scheme (a) and the general form (b) of the working surface of the driving half-clutch of a safety device](image)

In order to analyze the variations in the value of the moment of rotation from turning the half-clutches of a safety device at different stages of its actuation, power calculation was conducted.

At the first stage, the linkage of the balls and the holes of a driving half-clutch is to be considered (Fig. 1. b).

The initial \( T_{o1} \) and the maximum \( T_{max} \) moment of rotation is determined using the following formula (1):

\[
T_{o1} = T_{max} = \frac{Rc_1 \delta_c}{\sqrt{r^2 - (r-h)^2} + (r-h)tg \varphi},
\]

where \( R \) - radius of balls disposition; \( c \) - spring stiffness; \( \delta_c \) - preliminary spring pull; \( r \) - radius of a ball; \( h \) - maximum value of the movement of balls on the surface of holes; \( \varphi \) - angle of friction.

At the second stage, when balls with a driven half-clutch move along the inclined working groove of a driving half-clutch, which causes the axial shift of an overloaded screw (fig/ 1, b), the initial \( T_{o2} \) and the maximum \( T_{max} \) moment of rotation is determined using the following formula (2):

\[
T_{o2} = T_{max} = \frac{cR(\delta_c + h + x_2)}{tg(90^\circ - \beta - \varphi)},
\]

where \( x_2 \) - is the running value of a ball coming out from a working groove.

At the third stage, when balls with a driven half-clutch move along the inclined flat surfaces of a driving half-clutch towards the holes in order to recondition the initial position of ведучої півмуфти кульки заходять у початкове положення, рухаючись при цьому по похилій зворотній канавці з кутом нахилу \( \gamma \) на торцевій поверхні ведучої півмуфти, тобто відбувається плавне “м'яке” відновлення робочого стану шнекового транспортера.

На першому етапі розглянемо зажеблення кульок з лунками ведучої півмуфти (рис. 1, б).

При цьому початковий \( T_{o1} \), та максимальний \( T_{max} \) крутий момент визначається за формулой (1):

\[
T_{o1} = T_{max} = \frac{Rc_1 \delta_c}{\sqrt{r^2 - (r-h)^2} + (r-h)tg \varphi},
\]

де \( R \) - радіус розташування кульок; \( c \) - жорсткість пружини; \( \delta_c \) - попередній натяг пружини; \( r \) - радіус кульки; \( h \) - максимальна величина переміщення кульки по поверхні лунок; \( \varphi \) - кут тертя.

На другому етапі, при якому кульки з веденою півмуфтою переміщаються по похилій робочій канавці ведучої півмуфти, що спричиняє осьове відведення перевантаженого шнека (рис.1,б), початковий \( T_{o2} \) та максимальний \( T_{max} \) крутий момент визначається за залежністю (2):

\[
T_{o2} = T_{max} = \frac{cR(\delta_c + h + x_2)}{tg(90^\circ - \beta - \varphi)},
\]

де \( x_1 \) - біжча величина виходу кульки з робочої канавки.

На третій етапі, при якому кульки з веденою півмуфтою переміщаються по похилих плоских поверхнях ведучої півмуфти в напрямку лунок для
the whole system (Fig. 1, b), the initial \( T_{0} \), and the maximum \( T_{\text{max}} \) moment of rotation are determined using the following formula (3):

\[
T_{0} = T_{\text{max}} = \frac{cR}{f_{g}(90° - \gamma + \varphi)}
\]

where \( x_{1} \) - running value of a ball entering a reverse groove.

Fig. 3 shows the dependency of the change in the moment of rotation of a driven half-clutch and a screw \( T \) on the change of the angle of the relative turning of half-clutches \( \rho \), in static state in different angle positions of half-clutches in one cycle of the actuation of a safety device.

In order to determine the pattern of the change in the maximum moment of rotation at different stages of the actuation of a safety device and also, in order to determine the adequacy of the theoretical calculations, static experimental investigation was conducted.

For this reason the half-clutches of a safety device were installed in the grips of a pilot machine KM-50-1. The load of the driving half-clutch was performed with the help of rotating the lower grip by an electric motor through a gearing system. The value of the moment of rotation was measured using a circular scale while the relative deviation of the half-clutches was measured using an angular scale. Furthermore, the machine is equipped with a recording device, with the help of which the curve of the dependence of the moment of rotation on the angle of the lower grip turn was traced.

The general view of the test bed, in which a safety device is installed, is shown in fig. 4.
In the process of experimentation, the value of the moments of rotation depending on the angle of the turning of a driving half-clutch was measured in a tenfold trial.

RESULTS AND DISCUSSION

Based on the results of the investigation conducted, it was determined that the uncoupling of half-clutches took place at the maximum moment of rotation, which greatly decreased when the balls were coming out of holes onto the inclined working grooves of a driving half-clutch. During the movement of the balls along the working grooves, there is no significant increase in the moment of rotation. In case of the movement of the balls along the inclined reverse grooves the antimoment arises, but its value does not exceed the moment of the actuation of a safety device.

Fig. 5 shows the results of theoretical (solid line) and experimental (dashed line) investigation.

The analysis of the graphical dependence shows that the error between the results of the theoretical investigation and the experimental investigation ranges from 3.5…19.1%.

Thus, based on the results of the comparative studies, it was determined that previously deduced analytical dependences (1), (2) and (3) for measuring the moment of rotation, transmitted by a safety device, adequately depict the real processes of the actuation of the designed safety mechanism. That is why the analytical dependences can be used in the engineering design of different standard sizes of a safety device.

Fig. 5 - Graphical dependency of the change in the moment of rotation of a driven half-clutch and a screw on the change of the angle of the relative turning of half-clutches / Графічна залежність змін крутих моментів запобіжного пристрою від зміни кута відносного повертання півмуфти
CONCLUSIONS
On the basis of the conducted patent survey and having analyzed the existing constructive and technological schemes of the safety devices of screw conveyers, a new construction of a safety device is propounded. The construction allows reducing the dynamic load of the drive, which greatly increases the longevity and improves the operational reliability of screw conveyers. Moreover, power analysis of the operation of a safety mechanism is conducted, which gives the opportunity to estimate the change in the moment of rotation of a driven half-clutch and a screw T depending on the change in the angle of the relative turning of half-clutches ρ. Based on the results of the static experimental investigation of the safety device, it was determined that the error between the results of the theoretical investigation and the experimental investigation ranges from 3.5…19.1%. That is why the given static analytical dependences can be used in the engineering design of different standard sizes of a safety device.

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На основі проведеного патентного огляду, та аналізу існуючих конструктивно-технологічних схем захисних пристроїв гвинтових конвеєрів запропоновано нову конструкцію запобіжного пристрою, яка дозволяє суттєво зменшити динамічні навантаження на привід, що значно підвищує довговічність та експлуатаційні характеристики шнекових транспортерів. Також проведені силовий аналіз роботи запобіжного механізму, який дає змогу оцінити зміни крутного моменту веденої півмуфти і шнека T від зміни кута відносного провороту півмуфту ρ. Виконані статичні експериментальні дослідження запобіжного пристрою, за результатами яких встановлено, що похиба між результатами теоретичних і експериментальних досліджень знаходиться в межах 3.5…19.1%. Тому представлені в статті аналітичні залежності можуть бути використані при інженерному проєктуванні різних типорозмірів запобіжного пристрою.

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