Use of air bellows for low-speed drive mechanisms

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ABSTRACT

Purpose. The monitoring at the enterprises of the mining and metallurgical industry showed that a number of machines and mechanisms require the organization of low rotational frequencies - 0.25 ... 15 r / min. To do this, use 2 ... 3 speed gearboxes, which complicates the design of the drive, reduces the reliability of its work and efficiency. To create a low-speed drive without the use of multi-stage gearboxes is proposed to use the original pneumatic actuator to solve this problem.

Methods. During research a concept of a universal pneumatic module (UPM) of the pneumocamera type was developed and a valid model was made, which confirmed the module performance and the provision of the necessary operating parameters - rotational speed and torque using compressed air with a pressure of 0.15 MPa.

Findings. The developed design of an unified pneumatic module allows direct low-speed drive of machines and mechanisms to operate with high reliability and high efficiency. The methodology for calculating the geometrical and technical parameters of UPM has been developed and tested.

Originality (novelty). For the first time, the possibility of using a low-speed pneumochamber drive for a number of machines and mechanisms used in the mining and metallurgical industry was theoretically substantiated, and the processes occurring in such drive were investigated.

Practical implications. The developed design and method of calculating the design and technical parameters of the proposed module allows the replacement of multi-stage drives in many machines and mechanisms that are complex in design and used in many branches of industrial production.

Keywords: pneumatic actuator, speed, gearbox, chain transmission, compressed air, pressure, model, stand.

1 INTRODUCTION

The monitoring of technological chains of a number of mining and metallurgical enterprises in Kazakhstan revealed a rather large list of low-speed process equipment. These include: plate feeders, belt feeders, continuous dispensers for various purposes and performance, vacuum filters, magnetic separators of various modifications and a number of other equipment. The rotational speed of the specified equipment is 0.25 .... 15 rpm, and the drive power does not exceed 10 kW.

The drive of the machine occupies a special position in technology, because without it the mechanical movement of any device is impossible. From the rational choice of the kinematic drive circuit and the correct kinematic power calculation largely depends such an important requirements for the designed machines as increasing power with the same dimensions, increasing speed and productivity, increasing efficiency, as well as minimum weight and low cost of production.

Currently, the most common in the machines are mechanical drives. At the same time, their constructive solutions can be very different, so the designer’s task is to find the best option that best suits the task (corresponds to request). Mechanical drives for general purpose in all transmission mechanisms are most common in drives of technological and light transport vehicles. A generalized scheme of a mechanical drive of a working machine includes an engine, transmission mechanism, working machine and couplings. And since the angular velocities of the motor shaft and the drive shaft of the working machine are not equal to each other in most cases, a gear mechanism consisting from a set of mechanical gears of various designs is used to match the mechanical drive.

Gear drive - one of the most common types of modern mechanical systems for general industrial use. The gearbox is designed to reduce angular speed and increase torque. The availability of the required functional parameters and the reliability of the machine depends from the efficiency and resource of the gearboxes and gearmotor motors. The wrong choice of gearbox can lead to significant economic losses due to unplanned downtime, increased repair costs, etc.

An alternative to existing multi-stage drives may be without gear drives, but they also suggest the use of additional devices, albeit with minor additional relationships.

A comprehensive solution to the issues of improving modern drives requires special attention to the design and implementation of mechanical motion transducers. Currently, there is an increasing tendency to simplify the mechanical devices of the process equipment and to use other sources of energy besides electrical.

In this regard, modern pneumatic actuators have a number of technical advantages in comparison with traditional electromechanical actuators, namely:

- simplicity and low cost of construction;
- significantly less weight compared to existing machines that perform the same functions;
- no rubbing and rotating parts;
- possibility of regulation in a significant range of operating characteristics of power elements;
- high coefficient of sliding of the power element;
- high ability to absorb shock loads due to the elasticity of the material and the compressibility of air;
- use of only one type of energy.

In combination with free-wheel ratchet mechanisms, they can significantly improve the design of the drives of technological machines with a low-speed working body.

However, this type of drive is not that well researched and requires special attention for widespread use.

2 METHODOLOGY

In the process of developing and researching a low-speed pneumocylinder drive in combination with a ratchet free-wheeling mechanism, a concept of a unified pneumatic module (UPM) was developed, which suggested methods for calculating and substantiating its geometric and technical parameters. To test the performance of the proposed design, a physical model was fabricated, on which a series of experiments were carried out. To test the methodology, a low-speed pneumatic-air drive for the dozer was calculated.

3 RESULTS AND DISCUSSION

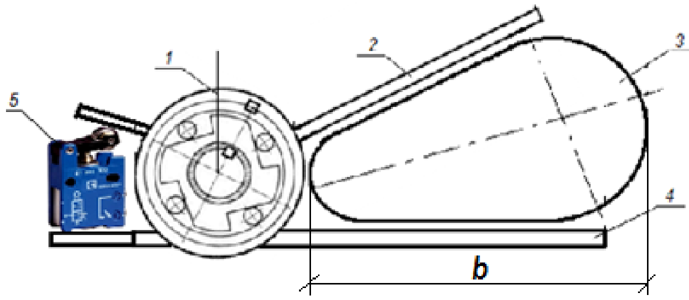
The authors have proposed an original variant of using push-type pneumatic pads in combination with a ratchet mechanism as a low-speed drive for solving the problem posed.

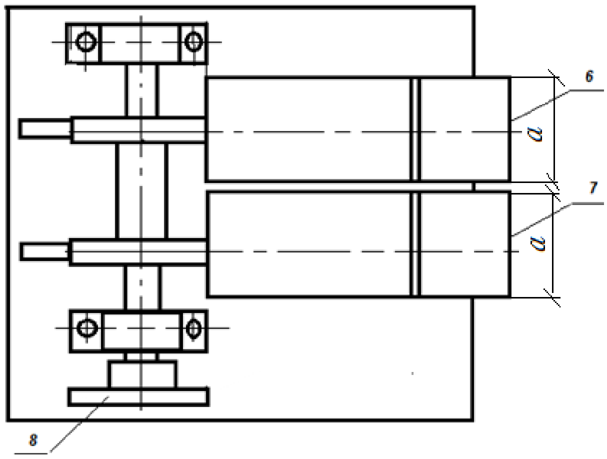
Flexible shells filled with compressed air have a number of advantages in their use, as a working body and energy carrier. As an energy carrier, compressed air has such advantages as safety; it is able to do useful work and at the same time does not pollute the environment, is easily transported, its cost is low. It should be noted that in all mining and metallurgical enterprises there are branched networks of compressed air with a pressure of 0.5 ... 0.6 MPa for technological needs, which is quite enough for the operation of a pneumatic actuator.

The concept of a low-speed pneumo-chamber version of UPM technological machines is as follows. The UPM drive should replace the complex multicomponent drive, due to the large gear ratio: at the frequency of rotation of the drive shaft n = 0.25 min − 1 the gear ratio i can be 3000 ... 4000, and the torque - Mcr = 24000 N * m. Speed control should be carried out by throttling, stabilization - by installing an air collector with a pressure-reducing gear. The working pressure in the supply line must be at least 0.3 MPa, since a decrease in pressure can significantly affect the torque, up to the stop of the drive, or it will be necessary to increase the size of the pneumatic chambers in the plan, which will increase the size of the drive. Important moments for the stable operation of UPM are also such moments: the temperature in the drive installation area should not be negative, since there is a risk of condensate freezing in the drive elements, as well as torque ripple, which can affect the operation of the drive should be minimal.

Taking into account the stated requirements, a conceptual diagram of the pneumocameral UPM variant has been developed, which is presented on Figure 1. The mechanism of operation of such a drive is as follows.

When air is forced into the first chamber, it moves apart and pushes the blade attached to the outer race of the overrunning bearing. In turn, the balls mounted between the inner and outer collars are wedged (engaged), the collars, the drive shaft rotates, due to the dimensions of the chamber envelope at an angle. The pushing speed can be quite insignificant due to the throttle control capabilities. As the pushing stroke is completed, the bracket fixed on the back of the outer yoke will press the limit switch that switches the spool of the two-position four-way distributor, as a result of which the air from the chamber will be released into the atmosphere (exhaust) and the air will be redistributed to the second chamber. Under the action of the second camera mounted on the same plane next to the first one, under the second blade fixed on the outer race of the second overrunning bearing mounted on the same shaft, the rotation of the drive shaft will continue.



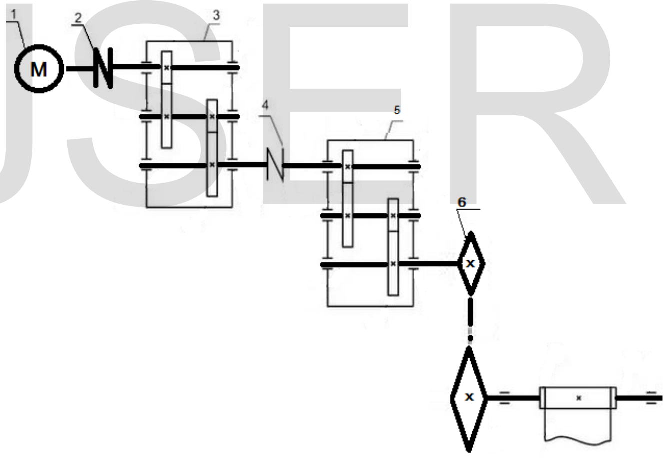


1 – overrunning bearing; 2 - drive blade; 3 - angular chamber; 4 - reference sheet; 5 - limit switch; 6 - camera 1; 7 - camera 2; 8 - half coupling.

Figure 1 – Conceptual diagram of the pneumo-chamber version UPM.

On the basis of the stated concept, a method was developed and a continuous dispensing of finely ground limestone and bentonite into a charge at the wet pellet factory of Sokolovsko-Sarbai Mining and Industrial Association (SSGPO) was calculated.

The metering drive (Fig.2) consists of an electric motor, gearboxes Ts2U-100, Ts2U-160, a chain drive (sprocket z13t25, Y and sprocket z40t25, Y) and couplings.



1 – electric motor; 2 - coupling; 3 - Ts2U-100 reducer; 4 - coupling; 5 - reducer Ts2U-160; 6 - chain transmission.

Figure 2 – Diagram of the existing version of the drive dispenser.

Drive characteristics:
- Frequency of rotation of the electric motor n = 1000 rpm,
- Motor power Nd = 5.5 kW,
- Shaft rotation frequency n = 0.25 r / min,
- Efficiency of the electric motor η = 0.86,
- the efficiency of the gearbox Ts2U-100 η = 0.9,
- the efficiency of the gearbox Ts2U-160 η = 0.9,
- Efficiency chain transmission η = 0.97.

The angular frequency of rotation is:

$$w = \frac{n \times 2\pi}{60} = \frac{1000 \times 2 \times 3{,}14}{60} = 104{,}66 \frac{rad}{s}. \quad (1)$$

Torque on the motor shaft:

$$M_e = \frac{W \times \eta э}{w} = \frac{5500 \times 0{,}86}{104{,}66} = 45{,}19 \text{ Nm} \quad (2)$$

For the calculated moment take the most long-acting moment.

$$M_{tor} = 9950\ N_д\ \eta_э / n = 9950 \text{ x } 5{,}5 \text{ x } 0{,}86 / 1000 = 47{,}06 \text{ Nm} \quad (3)$$

Estimated torque on the kinematic shaft

$$M_{tor} = M_v\ \eta / i\ , \quad (4)$$

where Min is the torque on the motor shaft, η is the efficiency of the kinematic chain section, i is the total gear ratio (gearbox Ts2U-100, Ts2U-160, chain transmission).

Efficiency of the kinematic chain:

$$H = \eta_1 \text{ x } \eta_2 \text{ x } \eta_3 \text{ x } \eta_4 = \eta = 0{,}86 \text{ x } 0{,}9 \text{ x } 0{,}9 \text{ x } 0{,}97 = 0{,}67\ , \quad (5)$$

where η1 is the efficiency of the electric motor, η2 is the efficiency of the reducer Ts2U-100, η3 is the efficiency of the reducer Ts2U-160, η4 is the efficiency of the chain transmission (z13 t25.4 asterisk)

Gear ratio:

$$i = n/n_0 = 0.25/1000 = 0.00025 \quad (6)$$

where n is the calculated frequency of rotation of the output shaft of the transmission, rpm, n0 is the calculated frequency of rotation of the input shaft, rpm

$$M_{tor} = 47{,}06 \text{ x } 0{,}67 / 0{,}00025 = 126120 \text{ Nm} = 126{,}12\ k\text{Nm}$$

To study the operation mode of the UPM, a physical model was developed and manufactured (Fig. 3). It has the following parameters:

- the area of the supporting surface of the camera rotary action

$$S = a\text{x}b = 0{,}3\text{x}0{,}7 = 0{,}21 \text{ м}^2 \quad (7)$$

- camera pushing force

$$P = p \cdot S = 0{,}3 \cdot 0{,}21 = 0{,}063 \text{ МН} = 63 \text{ kN } (6{,}3 \text{ т}) \quad (8)$$

- the torque developed by the camera

$$M_{кр.к} = P \cdot l = 63 \cdot 0{,}4 = 25{,}2 \text{ kN} \cdot \text{m} \quad (9)$$

To ensure the efficiency of the dispenser Mcr. K it is necessary to increase 5 times. This can be achieved: by increasing the size of the chambers in the plan - S = axb = 0.5x1.2 = 0.6 m2.

Then P = p · S = 0.3 · 0.60 = 0.18 MPa, and Mkr.k = P · l = 180 · 0.7 = 126 kN · m.

Figure 3 – Physical model of the concept of UPM

Conducted on the model of the study confirmed the performance of the proposed design UPM. With a pressure of compressed air of 0.1 MPa, the rotational speed of the drive was 1.5 $\min^{-1}$ and torque of 4.24 kN * m.

CONCLUSIONS

The proposed design of the pneumatic actuator effectively solves the problem of creating a gearless low-speed drive. Such a drive is distinguished by the originality of the solution of structural elements, small dimensions, high reliability and ease of manufacture.

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