

The Interrelation of Information System Characteristics and Parameters of Controlled Processes

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Abstract—To increase the efficiency of using agricultural powered machinery, it is necessary to improve the switching mechanism on the power take-off shaft. On tractors produced by the Minsk Tractor Plant, the power take-off drive is switched on by braking the power drum by tensioning the brake belt of a mechanical drive. The operation of such a switching mechanism leads to rapid wear of the brake belt due the belt impact on the drum during switching leads to an uneven decrease in the frequency of rotation of the drum. At the same time, during the standard on-time, the drum makes a significant angular displacement. This leads to significant wear of the friction lining of the belt. It is proposed to use electromagnets, instead of a mechanical drive, for tensioning the brake belt, which at the moment of switching on will press it against the switching drum in a mode that ensures a decrease in the angular displacement of the drum and, accordingly, ensures significantly less wear on the friction lining. A mathematical model of the angular displacement of the drum is proposed, on the basis of which an analytical expression for the belt wear rate is substantiated. Electromagnets must be connected through a microprocessor device that provides a change in the force of pressing the belt to the drum, at which the required intensity of reducing the angular velocity is achieved. In this case, the power of the agricultural machine drive will be taken into account. This mode of switching the power take-off drive will increase the service life of the brake belt. In this case, as the friction lining wears out, the braking efficiency will increase. This will require appropriate programming of the microprocessor control device for the electric drive to activate the power take-off shaft. Entering of inclusion of the wear maximum values of brake belt friction lining into the control module of the electric drive the will automate the processes of monitoring the technical condition and predicting the residual life of the belt to the maximum state.

Keywords—power take-off shaft, switching mechanism, microprocessor device electric drive.

I. INTRODUCTION

In the domestic agro-industrial sector, units and machines with active working bodies are widely used, mechanical energy to which is supplied through the power take-off shaft (PTO). In particular, on tractors produced by the Minsk Tractor Plant, such a PTO is a planetary mechanism, the sun gear of which is connected to the switching drum. When braking this drum, the planetary mechanism transmits torque through the carrier to the shaft of the working body. The drum is braked by the mechanical drive of the brake belt tension. With this braking, the belt is pressed against the surface of the drum and slows it down.

During operation of that kind of PTO there are difficulties associated with the rapid wear of the friction layer of the brake belt and the technology of replacing the belt. Monitoring the condition of the friction belt and regulating the control mechanism of the adjusting screws due to the design features of the PTO are also difficult. Therefore, this adjustment is often not done in a timely manner, which leads to rapid wear of the friction layer of the brake belt.

It is possible to eliminate these difficulties if we significantly modify the braking mechanism of the PTO switching drum. If we use an electromagnetic device is applied that presses the belt to the drum at several points at once and not at the same time, but with a time shift, instead of a mechanical drive of pressing the friction belt against the drum, this will improve the belt adherence to the switching drum, and the ability to control the pressure of the belt by changing the current in the windings of electromagnets will allow you to set the most optimal (from the point of view of reducing brake belt friction layer wear) law of change of this force. [1-3] To study similarly designed braking devices, various dynamic models were used that describe the braking process of rapidly rotating shafts. [4]

II. METHODS

The law of change in the force of pressing the brake belt to the switching drum can be determined by Newton's second law and the brake curve of the switching drum, as a function $\omega(t)$ of time t , where ω — is the angular velocity of drum rotation. [5-6] In this case, the braking moment

$$M_{mp} = J \frac{d\omega}{dt} + M_{\mu} = F_{mp} R, N \cdot m, \quad (1)$$

where $J = \frac{mR^2}{2}$ is the moment of inertia of the switching drum relative to its axis of rotation, M_{μ} is the moment of resistance force of the mechanism, rigidly connected with the switching drum, which in this case can be considered as a constant value; R is its radius, m; m is its mass, kg; $F_{mp} = f \cdot F_{np}$ is the friction force between the belt and the switching drum, N; F_{np} is the force of pressing the belt and the switching drum, N; f is the coefficient of friction between

the belt friction lining of the belt and the switching drum. [7-8]

In the expression (1), instead of the values F_{mp} and J , we substitute the corresponding values and solve the obtained equation with relation to the pressing force of the belt. We get [9]:

$$F_{np} = \frac{M_M}{fR} + \frac{mR}{2f} \frac{d\omega}{dt}, H \quad (2)$$

The switching drum is braked to a complete stop in a fairly short time $\tau \approx 2 \dots 5$ s. For this short time interval, we can assume the coefficient of friction $f = const$. Thus, the law of change in the force of pressing the belt to the drum during one switching cycle is directly proportional to the deceleration (time derivative) of the drum rotation speed. The curves $F_{np}(t)$ and $\frac{d\omega}{dt}$ completely coincide in shape and differ only in scale and shift along the ordinate of the force by constant value $\frac{M_M}{fR}$.

These curves are determined by the $\omega(t)$ curve, where the braking distance depends on the shape. The length of this distance, measured in radians, will be [10]

$$\varphi = \int_0^\tau \omega(t) dt, \text{ rad.} \quad (3)$$

Therefore, you can set the corresponding function of the pressing force $F_{np}(t)$, using electromagnets, providing such a length of the braking distance, which would give the least wear on the friction layer. When the angular velocity decreases linearly (line 1 in Fig. 1) from a certain initial speed of the switching drum to zero, the braking distance is equal to the area of the triangle $\Delta O \omega_0 \tau$, i.e.

$$\varphi_l = \frac{1}{2} \omega_0 \tau, \text{ rad.} \quad (4)$$

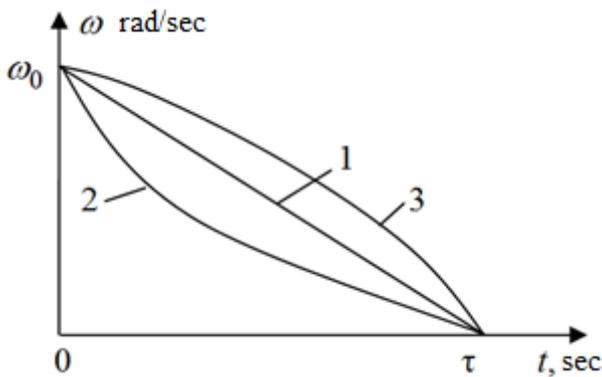


Fig. 1. Velocity decrease curves $\omega(t)$: 1 - straight line; 2 - hyperbole; 3 - parabola

With the hyperbolic law of decrease $\omega(t)$ (curve 2 in Fig. 1), the braking distance (the area of the curved trapezoid under curve 2) will be $\varphi_h < \varphi_l$ and with the parabolic (curve 3 in Fig. 1) will be $\varphi_p > \varphi_l$, on the contrary.

III. RESULTS

Consider the case of the hyperbolic law of reduction. Let where A be some constant coefficient given arbitrarily. Axes of coordinates and in Fig. 2 are shown in dashed lines.

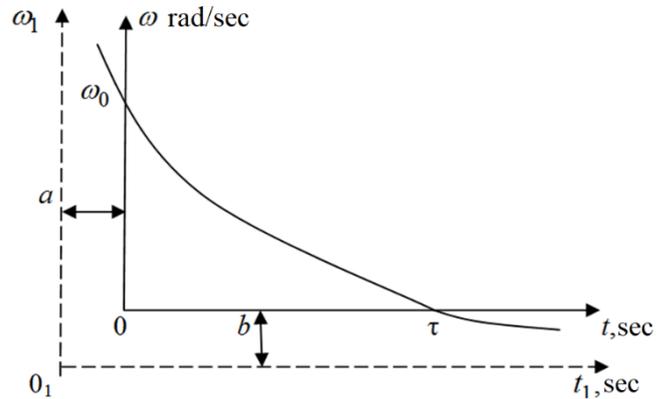


Fig. 2. Curve $\omega(t)$ that varies on the braking interval according to the hyperbolic law

Consider this hyperbola in the coordinates (ω, t) in which

$$\omega(0) = \omega_0, \quad \omega(\tau) = 0 \quad (5)$$

The equations of transition from the coordinate system $t_0\omega$ to $t_1\omega_1$ will be $t_1 = t + a, \omega_1 = \omega + b$. Then

$$\omega_1 = \omega + b = \frac{A\omega_0\tau}{t+a} \quad \text{or} \quad \omega(t) = \frac{A\omega_0\tau}{t+a} - b. \quad (6)$$

Values a and b being calculated in conditions of (5). We get

$$a = \frac{\tau}{2} (\sqrt{1+4A} - 1); \quad b = \frac{\omega_0}{2} (\sqrt{1+4A} - 1). \quad (7)$$

After substituting them in (6), we find the desired hyperbolic law of the velocity decrease during braking of the switching drum

$$\omega(t) = \omega_0 \left(\frac{A\tau}{t + \frac{\tau}{2} (\sqrt{1+4A} - 1)} - \frac{1}{2} (\sqrt{1+4A} - 1) \right). \quad (8)$$

The braking distance for this particular braking is determined from the expression (3)

$$\begin{aligned} \varphi_h &= \omega_0 \tau A \left(\int_0^\tau \frac{dt}{t + \frac{\tau}{2} (\sqrt{1+4A} - 1)} \right) - \frac{\omega_0 \tau}{2} (\sqrt{1+4A} - 1) = \\ &= \omega_0 \tau A \left(\ln \frac{\sqrt{1+4A} + 1}{\sqrt{1+4A} - 1} - \frac{(\sqrt{1+4A} - 1)}{2A} \right) \end{aligned} \quad (9)$$

Function
$$\Phi_h(A) = A \left(\ln \frac{\sqrt{1+4A} + 1}{\sqrt{1+4A} - 1} - \frac{(\sqrt{1+4A} - 1)}{2A} \right)$$

monotonically increases with parameter A , and in the limit

$$\lim_{A \rightarrow \infty} \Phi_h(A) = 0,5, \text{ i.e. with } A \rightarrow \infty \text{ braking distance } \varphi_h \rightarrow \frac{\omega_0 \tau}{2} = \varphi_l$$

. Therefore, using the parameter A introduced by us, it is possible to change the length of the braking distance in the direction of its decrease relative to φ_l .

In this case, the law of the force of belt pressing (2) should be

$$F_{np} = \frac{mR}{2f} \frac{d\omega}{dt} + \frac{M_m}{fR} = \frac{M_m}{fR} - \frac{mR}{f} \cdot \frac{A\omega_0\tau}{[\tau + \frac{\tau}{2}(\sqrt{1+4A}-1)]^2} \quad (10)$$

An analysis of a large number of studies of the wear of various materials under conditions of boundary friction and friction without lubrication shows that in the general case, the wear rate can be expressed by the dependence [11]:

$$\gamma = kp^m v^m, \quad (11)$$

where $m=0,5-3$ and for most friction pairs $n=1$; k is the wear coefficient characterizing the material of the pair and the wear conditions; p is the pressure on the friction surface; v is the relative slip velocity.

For abrasive and a number of other types of wear $m=n=1$,

$$\gamma = kpv \text{ or } U = \gamma t = kpv t = kps, \quad (12)$$

where $s=vt$ is the slip distance.

Taking into account the measurement of the angular path in radians

$$U = kp\phi_n R, m \quad (13)$$

It can be seen from the last formula that, for $n=1$, wear does not depend on the relative slip velocity, but only on the slip distance.

The wear of the belt U taking into account (9) is determined from the expression:

$$U = k \frac{A\omega_0\tau R}{fS} \left(\frac{M_m}{R} + \frac{A\omega_0\tau m R}{[\tau + \frac{\tau}{2}(\sqrt{1+4A}-1)]^2} \right) \cdot \left(\ln \frac{\sqrt{1+4A}+1}{\sqrt{1+4A}-1} - \frac{(\sqrt{1+4A}-1)}{2A} \right) \quad (14)$$

where S – the area of the friction layer in contact with the surface of the drum, m^2 .

The task of reducing the wear of the belt friction layer can lead to the mathematical problem of finding the minimum of the function $U = U(A)$.

Determining the value of coefficient A , corresponding to the minimum of the function $U(A)$, will make it possible to obtain dependences for angular acceleration, in accordance with which it is necessary to change the braking force. This will be the basis for programming a microprocessor control device for electromagnets.

With the wear of the brake belt friction lining, the force of its clamping to the switching drum will increase. Therefore, during operation of the device, it is necessary to periodically control the thickness of the belt in order to provide a predetermined braking time of the switching drum. In addition, the drive power of different agricultural machines is different, and the torque on the switching drum changes accordingly. It also requires adjusting the force of the belt to the drum.

The control algorithm for the electric drive PTO switching is as follows (Fig. 3).

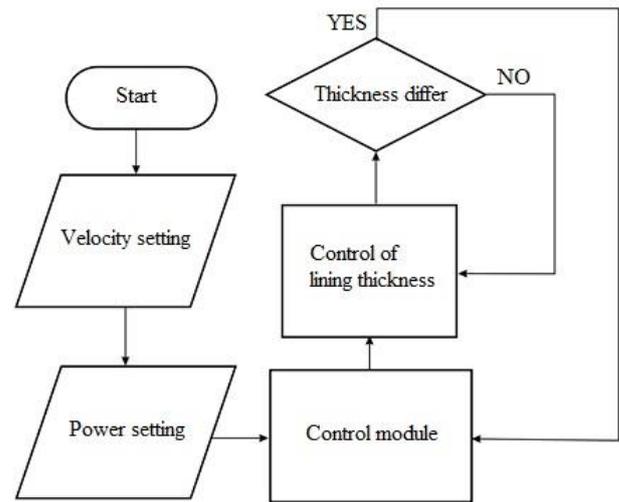


Fig. 3. Algorithm for controlling the switching PTO drive

Before aggregating the agricultural powered machinery, the corresponding speed of the PTO output shaft is set on the control module. Then, the power value for the drive of the agricultural machine is set according to its technical documentation. The switching device is ready for use. During operation of the unit, the PTO drive is periodically turned on and off, associated with stops for maintenance, moving between pens and fields.

As a result of this mode, the friction lining of the brake belt gradually deteriorates.

The control module periodically monitors the thickness of the lining. When a certain amount of wear is detected, the control module changes the force of pressing the belt to the drum. The wear rate of the lining is also calculated. If the wear rate increases, the control module reduces the frequency of inspection. Predicted value of operating time of the belt to the wear limit is shown at the control module display. Upon reaching 90% of operating time to the maximum wear of the lining, the control module gives an additional light signal. In addition, it controls the slipping of the drum relative to the belt. When slippage occurs due to a short-term increase in the load on the PTO output shaft due to fluctuations in the incoming volume of the biological mass processed by the agricultural machine, the control module increases the force of pressing the belt to the switching drum.

IV. CONCLUSION

The idea of using electromagnets to efficiently brake the PTO switching drum, protected by the patent [1], may well be implemented in practice. This was confirmed by the above studies and theoretical calculations. The practical implementation of this idea can have a significant economic effect in the operation, maintenance and repair of advanced PTO designs. The proposed design makes it possible to turn on the electromagnets not simultaneously, but with a certain time offset, with a gradual pressing of the belt, starting from the belt portion that is closest to the axis of its suspension. To determine the order of electromagnets switching, it is necessary to conduct experimental studies. When substituting a mechanical drive switching device with an electric device, the operation of periodically adjusting the switching lever is excluded, which reduces maintenance time and significantly increases the durability of the brake belt. The introduction of

feedback in the form of control of the drum slipping will ensure the optimal effort of pressing the belt to the drum and the allowable value of the wear intensity of the belt friction lining.

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