IOP Conf. Series: Journal of Physics: Conf. Series **881** (2017) 012034 doi:10.1088/1742-6596/881/1/012034

The clearance control system of the lever-hinge mechanism of the mine winder braking device using the capacitive sensors

A V Yurchenko[1,3], A D Mekhtiyev[1,2], F N Bulatbaev[2], Y G Neshina[1,2], A D Alkina[1,2] and M M Kokkoz[2]

[1] National Research Tomsk Polytechnic University, 30 Lenin Ave., 634050 Tomsk, Russia
[2] Karaganda State Technical University, 56 Mira, 100000 Karaganda, Kazakhstan
[3] National Research Tomsk State University, 36 Lenin Ave., 634050 Tomsk, Russia

E-mail: 1_neg@mail.ru

Abstract. The article presents the results of research to develop a method and means for monitoring the in situ condition of the joints braking devices in accordance with the gap value and the angle of rotation between segments of "Straight pin" kinematic pairs.It was obtained a mathematical model of the overlap area dependency of the sensor of plates from their relative displacement in the parameters With the help of capacitive sensors it is possible to control not only the hinged joints, but other mechanical parts of the mine winder that allows you to create the monitoring system of the technical condition in real time.

1. Introduction

The study of braking devices of operating coal mine winders in Karaganda and Ekibastuz region showed that over 70% of the total number of examined hinged joints of brake executive device are in operation with clearances that exceed the maximum allowable values. We identified the decrease in motion of "Bushing-pin" mating parts and noted the cases of their contact surfaces adhesion, the reduction of the stiffness of the brake mechanism and inadequate lubrication of the rubbing surfaces of the hinge. All of this can lead to a change of the operating braking parameters, disruption of kinematic lever-hinge mechanism accuracy, the unacceptable reallocation of load between elements of the braking device and cause the rupture of the brake rods, which ultimately may lead to emergency situation. It should also consider the appearance of zones of limiting stresses leading to the formation and growth of fatigue cracks in the elements of the brake kinematic chain due to a seized joint. The application of diagnostic methods of mechanism wear of the braking device solves the problem of robust, long-everlasting and safe operation of mine winders. This allows identifying the damaged elements of lever-hinge mechanism of the mine winders braking device without dismantling and disassembly them at an early stage, defining the parameters of clearances during the operation. Thus, it is solved the problem of improving the reliability of these elements [1].

In practice the assessment of hinged joints status is performed by dismantling of 2, 3 joints followed by measurement of the mating elements which does not provide sufficiently rapid determination of "Bushing-pin" mating parts wear parameters. Currently there are no technologies needed for rapid diagnostics of the hinged joints and this problem is still not solved. We have conducted the studies with the aim of developing the method and means for monitoring in place the status of hinged joints of braking devices according to clearance value and rotation angle between the segments of "Bushing-pin" kinematic pairs. This method consists in monitoring the electrical capacity between two plates placed at the ends of the contact pair. The change in capacity value was due to the wear and play of the hinge which is fixed by the control and measuring instrument.

2. Research method

Let’s consider a solid body of the mating segments of the lever-hinge mechanism of the braking device as a stable system of material points located on a circle the diameter of which is equal to the diameter of the hole in the hinge segment (Figure 1). For that purpose, the following assumptions may be made: the direction of force applied to the hinge is consistently and in the same plane, as shown in Figure 1; the change of hinge segments position is performed in the direction of force; the diameters of the holes are equal among one another in the mating segments of the hinge. Arbitrarily draw a secant of circles and there choose the points A and B belonging to segment 1 (bushing) and segment 2 (pin), respectively. In the process of "braking action and release the brake" the circles will move in the direction of the impact of force and the segment 1 adopt the position of segment 2, and the segment 2 – the position of segment 1, i.e. points A and B adopt A1 and B1 position, respectively. Rotating the secant around the point A it is possible to find the point C in the system of material points of the segment 2, where the sum of the displacements AA1 and CC1 will be maximum. Rotating the secant about the point C it is possible to find the point D in the system of material points of the segment 1 where the sum of the displacements AA1 and DD1 will be maximum and more than the clearance l. Considering the displacement of one segment relative to the fixed another segment one can see that the secant method allows detecting the maximum relative movement of the segments regardless of the direction of the force applied to the hinge.

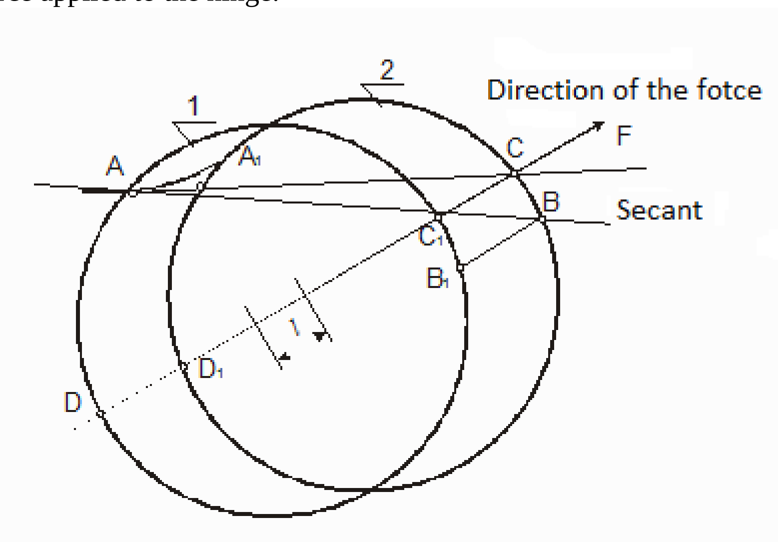


Figure 1. Position the mating links.

The stress state of the elements of the braking devices depends on the change of the angle between the segments of the kinematic pairs. Let’s consider the method to determine the change in the relative position of the kinematic pair segments. Figure 2 shows the positions of two hinged segments of the mind winder braking device in braked and unbraked conditions in the absence of bending moments and clearances in the mating elements. For unbraked condition of the mind winder let’s indicate two material points A and B equidistant from the axis of the hinge on the segments (the solid line shows the position). The braked condition is depicted as the dashed line. The change of the segments position is determined by the travel of point A (AA1), and the change of the angle between the segments Δα at selected l and measured Δl is determined by the dependency:

$$\Delta\alpha = 2\alpha rc\sin\frac{\Delta l}{2l}, \quad (1)$$

where Δα is the change of angle between the segments, 0;

Δl is the length of travel of the segments, mm:

l is the length between the mating parts, mm.

The error of the clearance influence on the definition of Δα will be the smaller, the greater the selected value of l. The described method can be implemented using the device containing a sensor associated with an electronic module. The capacitive sensor of the device is schematically presented in Figure 2 where positions 1 and 2 are the circular condenser plates arranged parallel at a distance δ from each other [2].

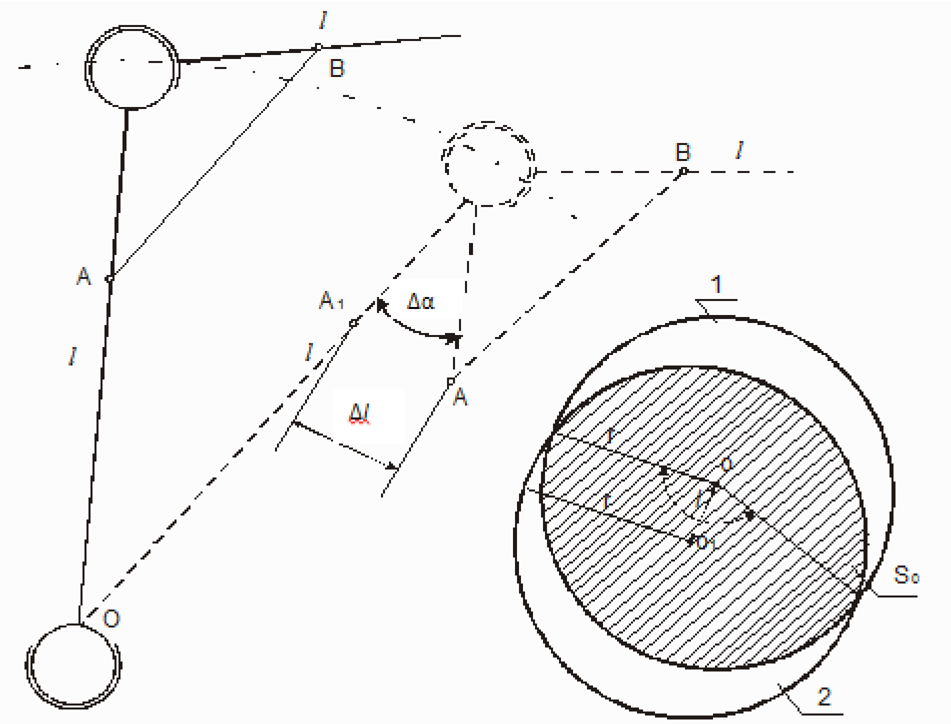


Figure 2. Segments position in braked and unbraked conditions of the mine winder.

$$C = \frac{\varepsilon_0 \varepsilon S_0}{\delta}, \quad (2)$$

where C is the capacitive of the condenser, f;

ε_0 – the dielectric constant, f/m;

ε – relative dielectric permittivity;

S_0 – the overlap area of the plates (the shaded area), mm2.

Between the overlap area of the circular plates and the offset of their centers O and OI there is a dependency: the overlap area of the circular plates:

$$S_0 = r^2\left[\pi - \alpha rc\sin 2(\frac{l}{d})\sqrt{1-\left(\frac{l}{d}\right)^2} - 2\frac{l}{d}\sqrt{1-\left(\frac{l}{d}\right)^2}\right], \quad (3)$$

where S_0 is the overlap area of the circular plates, mm2;

d=2r is the diameter of the circular plate, mm.

According to the results the processing of experimental data was done by using the computer programs. It was obtained a mathematical model of the overlap area dependency of the sensor of plates S0 from their relative displacement in the parameters (l/d), Figure 3.

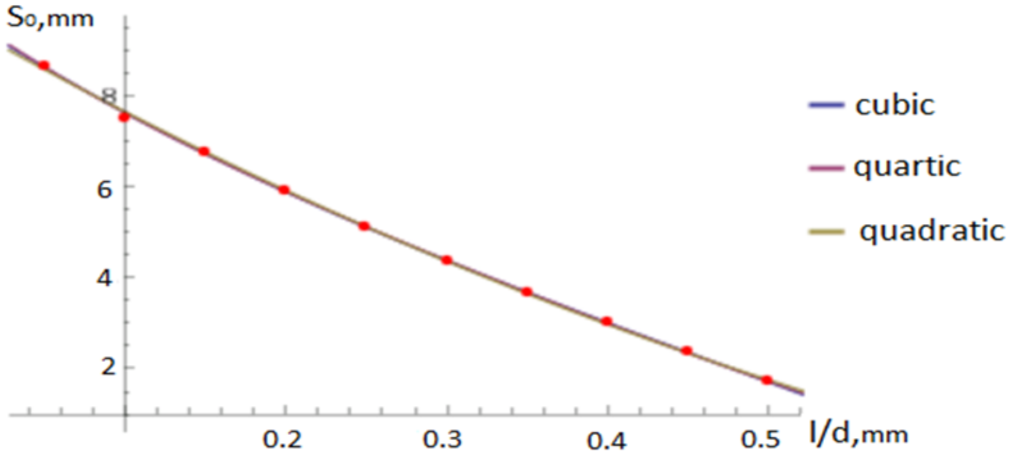


Figure 3. Dependency graph S0= f (l/d).

Analytically the dependency of the plates overlap area S0 from their relative displacement (l/d) is presented as follows:

- biquadratic (quartic) approximation:

$$S_0 = 41,6037\left(\frac{l}{d}\right)^4 - 59,8542\left(\frac{l}{d}\right)^3 - 24,7368\left(\frac{l}{d}\right) + 9,77382 \ ;$$

- cubic approximation:

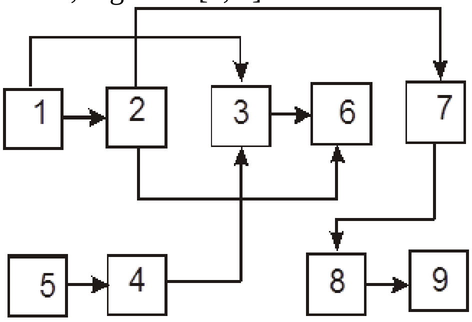
$$S_0 = -14,0901\left(\frac{l}{d}\right)^3 + 20,0522\left(\frac{l}{d}\right)^2 - 22,4486\left(\frac{l}{d}\right) + 9,68458 \ ;$$

- quadratic approximation:

$$S_0 = 8,42788\left(\frac{l}{d}\right)^2 - 19,7679\left(\frac{l}{d}\right) + 9,53346 \ .$$

The experimental data were processed and the mathematical model was obtained which was estimated according to the following criteria: Akaike (AIC) and Schwartz criterion (BIC). The analysis showed that the quadratic approximation will be most accurate, because it has the lowest value of the criterion: AIC=-22.411, BIC=-21.2007. The boundary conditions of the mathematical model are the value of the relative displacement in parameter (l/d)=0.05÷0.5. The initial conditions of the relative displacement are (l/d)=0.

The measuring system works as follows: the pulses of standard oscillator 1 simultaneously arrive to the input of the single-pulse oscillator 2 and to one of the inputs of the frequency calculator 3, on the second input of which the pulses are applied from the measurement oscillator 4. In this time the capacitive sensor 5 is connected to assigned circuit of the measurement oscillator. The frequency difference of the reference and measurement oscillators from the output of the frequency calculator is entered to one of the inputs of the counting approval device 6. In the presence of counting pulse at the input of the single-pulse oscillator, the counting approval device transmits the frequency difference from the output of the frequency calculator to the input of the pulse counter 7. After the end of the counting pulse from the single-pulse oscillator output, the counter writes in a binary code the number which will be greater if the displacement of the circular plates of the capacitive sensor will be greater. At the beginning of each measurement cycle the counter is reset to zero by the short pulse from the single-pulse oscillator. The signal from the counter through the decipherer 8 is supplied to the travel indicator 9, Figure 4. [3, 4]



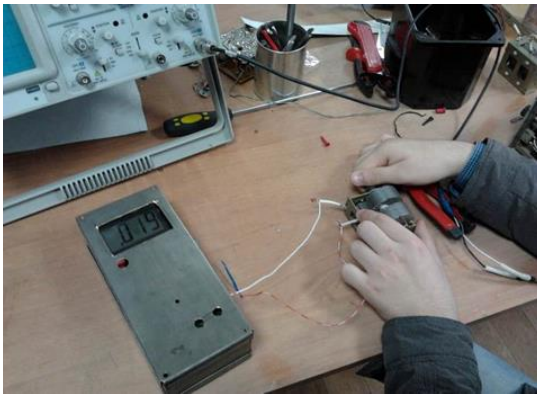


Figure 4. Functional diagram of electronic module and laboratory sample testing.
1 - Standard oscillator; 2 - single-pulse oscillator; 3 - frequency calculator; 4 - measurement oscillator; 5 - capacitive sensor; 6 - counting approval device; 7 - pulse counter; 8 - decipherer; 9 – travel indicator

3. Conclusions

Summing up the aforesaid it is possible to make the following conclusions. With small relative displacements of the circular plates it is essentially observed the linear dependence of the capacitive C from displacement l/d. Between the overlap area of the circular plates and the displacement of their centers O and O1 there is the dependency on which you can assess the degree of wear and establish the parameters of clearance in the hinge. At the same time the pulse coming from the control cable of the standard oscillator 1 is supplied to the input circuit of the oscillator, oscillating the single pulses 2, on one of the linear inputs of the frequency identifier (meter) 3, and the pulse from the measurement oscillator 4 is supplied to its second input. The capacitive sensor 5 is activated while assigning the circuit. It is determined the frequency difference between the reference and measurement oscillator coming from the output of the frequency calculator and supplied to the input of the counting approval device 6. The counting approval device passes only the frequency difference of signals from the outputs of the frequency calculator, which is fed to the input of the pulse counter, 7. In the presence of the counting pulse at the input of the single-pulse oscillator after the end of the pulse counting from the single-pulse generator output, the counter works with binary code, and the number is greater, the greater the offset of the circular plates of the capacitive sensor. At the beginning of each new cycle of the parameters of lever-hinge mechanism the counter resets to zero by short pulse from the single-pulse oscillator. The information signal from the counter is supplied to the decipherer 8, and when it is works the signal is generated at which the travel indicator is flashed on 9.

The clearance control system of the lever-hinge mechanism of the mine winder braking device is a tool to control the parameters of wear of "Bushing - pin" kinetic pair and provides the information transfer on status of the hinges to the operator and the server where it is archived and stored. Even minor changes in capacitive parameters between the disc plates are recorded by the information converter. Information may be transmitted via the communication channels, for example, sensor network, to a single point of data collection on the status of the hinges of the lever-hinge mechanisms and their level of wear. With the help of capacitive sensors it is possible to control not only the hinged joints, but other mechanical parts of the mine winder that allows you to create the monitoring system of the technical condition in real time. In practice, this will reduce operating costs related to instrumental control of the technical condition of hinges, as well as the equipment downtime and avoid the accident-prone situations of braking device seizure.

IOP Conf. Series: Journal of Physics: Conf. Series **881** (2017) 012034 doi:10.1088/1742-6596/881/1/012034

References

[1] Yurchenko A. V. , Gorlov N. I. , Alkina A. D. , Mekhtiev A. D. , Kovtun A. .. Research of the Additional Losses Occurring in Optical Fiber at its Multiple Bends in the Range Waves 1310nm, 1550nm and 1625nm Long // Journal of Physics: Conference Series. - 2016 - Vol. 671, Article number 012001. - p. 1-7

[2] Zyatkov D. O. , Yurchenko A. V. , Balashov V. B. , Yurchenko V. I. The Capacitive Magnetic Field Sensor // Journal of Physics: Conference Series. - 2016 - Vol. 671, Article number 012065. - p. 1-7

[3] Trigub M V, Evtushenko G S, Torgaev S N, Shiyanov D V and Evtushenko T G 2016 Copper bromide vapor brightness amplifiers with 100 kHz pulse repetition frequency *Optics Communications* **376** 81-5

[4] Yurchenko A, Jakubov V, Shipilov S and Satarov R 2015 Remote ultra-wideband tomography of nonlinear electronic components. Technical Physics **60(2)** 279-82