Safety mechanisms for Mining Winches

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Abstract: - Mining winches can be used for horizontal traction, on railroad, and inclined planes. These can be with one or two drums, and with friction washer. High power inclined plane winches, higher than 40 ... 50 kW have a similar design tot hat of extraction machines, with safety brakes, position indicator for the hauled load and other signaling and automation elements. Ratchet mechanism and brake blocks or ribbon from structure mining winches are designed for prevent to fall of high load in case of failure of mechanical transmission winch. Is presented destruction of a winch when the safety mechanisms did not work and the placement of these mechanisms in the construction and operation of winches. This paper will analyze CAD/CAE ratchet mechanism and brake blocks or ribbon of winches used to change the extraction vessel, cable connections devices and cable extraction and balancing. With finite element analysis and simulation of the is optimizing their construction with the following results: optimization of operation function of the number of teeth and the head coefficient of the wheel for the ratchet; the wheel module for the ratchet has no influence on the operating conditions, but only on the mechanism strain; the length of the ratchet has little influence on the degree of strain, but it greatly influences the contact pressure between the ratchet and its bolt. The circular block brake has advantages over the band brake regarding the strain on the shaft of the washer brake and the evenness of the braking pressure. Band brakes allow a finer adjustment of the braking moment when the load is moved down.

Key-Words: - ratchet mechanism, brake blocks or ribbon, design optimization.

1 Introduction
The paper analyzes mining winches safety mechanisms, also called windlasses, used to change extraction vessels, cable connecting and winding and balancing cable safety mechanisms. Safety mechanisms with ratchet and block or band brakes are very important in the winch operation.
Fig. 1 shows the destruction of such a cable used to change a maximum 30 tons skip, made two years ago, which fell in the shaft from more than 200 m high and led to the drum being torn, and a 75 kW reduction gear being destroyed. In this case there were no casualties, only material damage and blockage of coal extraction flow, the mine’s production being stopped.
The ratchet mechanism or the block brakes in the mining winches are mounted on the sides of the drum, having the role of hindering the lifted load from falling, in case of a defect in the mechanic transmission of the winch.
Fig. 2 shows the constructive solution of a mining winch to change the winding cable, which is fitted with a block brake between the motor and reduction gear, with two band brakes on the brake shaft, parallel to the entering shaft, and two ratchet mechanisms on the second shaft of the windlass, and the drum being on the third shaft.
2 Mining Winch CAD Analysis

Fig. 3 shows the design solution for the winding cable changing winch in No. 1 Auxiliary Shaft in Livezeni Mine, made up of: 1 – metal frame; 2 – four compartement drum; 3 – entering shaft; 4 – braking shaft; 5 – hand wheel; 6 – band brake; 7 – intermediary shaft; 8 – ratchet mechanism; 9 – entering shaft bearing.

Fig. 3. 3D model of winding cable changing winch

Movement transmission is made from ASAMm-16M-4 electric motor, 11 kV nominal power and \( n = 1430 \) rot/min drum rotation by an elastic coupling with bolts, a conical-cylindrical reduction gear to the drum 2CH-B-160, \( i = 31.5 \), a chain transmission with \( i = 17/9 = 1.89 \) and two double winch gears with the ratio \( i = 100/17 = 5.88 \), resulting a 2.9 m/min cable traction. As safety element son the cinematic chain there is a circular block brake FC 315, with electric-hydraulic indicator, having as brake washer the semi-coupling mounted on the entering shaft to the reduction gear, and the ratchet mechanism mounted on the left side of the drum, blocking the drum when the load is lifted.

3 Ratchet mechanism

The most frequent gearing position of the ratchet and the wheel is the contact point of the tangent passing through the rotation centre of the ratchet with the outside circle of the ratchet wheel. In this case the force exerted on the ratchet has the value of peripheral force of the wheel for the ratchet.

The number of teeth of the wheel for the ratchet varies according to its destination and can be in the range of 6 - 25.

The tooth of the wheel for the ratchet with outer tooth construction is sized from the condition of bending test according to the formula,

\[
m \equiv 2 \sqrt[3]{\frac{M}{z \psi \sigma_{ai}}} , \quad \text{mm},
\]

(1)
where: \( m \) is the wheel module for the ratchet, in the range of 6 – 26 every second one, and determines the outer circle diameter \( D = \pi m \), in mm; \( M \) – the moment transmitted, in Nmm; \( z \) – number of ratchet wheel teeth; \( \psi \) – ratio of tooth width and width of the tooth head \( \psi = b/a = b/m = (1,5...3,0) \); \( \sigma_{ai} \) – admitted resistance to bending \( (\text{cast iron} \sigma_{ai} = 10 \text{ N/mm}^2, \text{steel} \sigma_{ai} = 25 \ldots 40 \text{ N/mm}^2) [3] \).

Starting from these data, Fig. 5.a shows the ratchet wheel tooth construction. The outer circle is described with radius \( R=D/2 \), and the inner circle of radius \( R-h \), where \( h=0,75 \) m. The outer circle is divided by the angular pitch \( \delta = 360/z \). From any point of divisions thus obtained, \( AB = a = m \) span is taken. On span \( BC \), from point \( C \) a line is drawn at 30° angle towards the inside of the wheel to \( BC \). From the middle of \( BC \) span a perpendicular is drawn, intersecting the line drawn through \( C \) to point \( D \). From point \( D \), with \( DC \) radius, a circle is drawn, intersecting the inner circle in point \( E \). BCE triangle is the profile of the empty space between two teeth of the ratchet wheel, with the angle in \( \text{E} \) of 60° and a connecting radius of \( r = (0,1...0,15) \) m.

\( \text{OO}_1 \) line between the centers of ratchet wheel and the ratchet is considered the diameter, a semi-circle being built up, whose intersection in point \( C \) with the outer circle of the ratchet wheel will determine the position of the tooth gearing the ratchet, and \( \text{CO}_1 \) segment representing the length of the ratchet, in general, is equal to two times \( AC \) segment or the pitch of the ratchet wheel. \( \text{CO}_1 \) segment will be perpendicular to the wheel’s OC radius for the ratchet, according to the triangle inscribed in the semi-circle. The ratchet head’s angle of 60, equal to that of the wheel’s empty space, the peak radius \( r_1 = r+ 0,5...1 \) mm, and the head sides \( b=(1...1,5) \) m and \( c=(0,6...1) \) m.

Fig. 5.b shows the forces acting on the ratchet mechanism in case of gearing the ratchet with the wheel for the ratchet, resulting that for a good functioning it is required that \( F_f \) friction force should be less than \( T \) component, that is the angle of the wheel \( \rho \) should be less than \( \varphi \) friction angle. Ratchets are tested to off-centre compression for the minimal section of the ratchet.

Based on the presented design conditions, a calculus algorithm was drawn up allowing \( \rho \) angle variation mode to be established depending on the number of teeth of \( z \) wheel, Fig. 6.a, and the head coefficient of the tooth, \( \psi \) (\( a=\psi \) m), Fig. 6.b. It is noticed that \( \rho \) angle decreases when the number of teeth of the ratchet wheel grows for a unit head coefficient, without being modified by the value of the module. For a 3,0 friction coefficient the number of wheel teeth should be less than 22, to avoid the ratchet being blocked. In case of large modules for wheel ratchet with large diameter for a small number of teeth, reduction of the tooth head is required to obtain the best possible constructive shape, an increase of \( \rho \) angle being noticed when the head coefficient decreases and a decrease when this increases over the unit value.

To see the influence of ratchet length on the strain of the ratchet mechanism, a finite element analysis was made for the 15 tons winch mechanism, Fig. 7, which has a head coefficient of the 0,5 tooth a 28 mm module and is stressed for a moment of torsion of 6452 Nm. It is noticed that the equivalent von Mises tension is 3,4 % less in case of 250 mm
ratchet length (Fig. 7,b), twice the wheel pitch for the ratchet. The contact pressure between the ratchet and the bolt is approximately double in the first case compared to the second case.

Fig. 7. Analysis with finite element of the ratchet mechanism with different length

4 Block or band brake
The brakes in the structure of mining winches have the role of blocking the drum rotation or of reducing the lifting or descending speed of the load.

Fig. 8 shows the design of the FC 314 circular block brake, made up of: 1 – basic plate; 2 – heightening plates; 3 – M16x70 screws; 4 – M8x50 screw; 5 – Φ30 bolt; 6 – shoe; 7 – shoe support stand; 8 – Φ24 bolt; 9 – shoe free play adjusting rod; 10 – connection part; 11 – arm; 12 - Φ20 bolt; 13 – electric-hydraulic elevator.

Fig. 8. FC 315 circular block brake design[4]

By the use of an REH 80/60 electric-hydraulic elevator, with a nominal pressure force to the spring of 80 daN for a 60 mm stroke, a 52 daNm braking moment is achieved.

With the help of rod 9 and screws 4 the free play between the braking washer and the shoes are adjusted, that is the position of the shoes to the axis of the braking washer.

Fig. 9 shows the band brake design at the extraction cables changing winch, where: 1 - braking shaft; 2 – nose wedge; 3 – braking washer; 4 – steel band with ferredo; 5- metal frame of winch; 6 – hanger; 7 – hand wheel; 8 – rod support; 9 – tapered hook rod.

Fig. 9. Band brake design

5 Conclusion
Safety mechanisms in the structure of mining winches improve their technical performances. The ratchet mechanism has the advantage of blocking the load lifted for a longer duration and in safety conditions, but it cannot be used in only one direction.

The paper analyzed this mechanism both from the design point of view and regarding strain, the following resulting:
- optimization of operation function of the number of teeth and the head coefficient of the wheel for the ratchet;
- the wheel module for the ratchet has no influence on the operating conditions, but only on the mechanism strain;
- the length of the ratchet has little influence on the degree of strain, but it greatly influences the contact pressure between the ratchet and its bolt.

The circular block brake has advantages over the band brake regarding the strain on the shaft of the washer brake and the evenness of the braking pressure. Band brakes allow a finer adjustment of the braking moment when the load is moved down.

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