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ASSESSMENT OF ROLLING BEARINGS OPERATING CONDITIONS

The article examines the possibilities of ensuring the reliability of the rolling bearings of the equipment used in the process of painting aluminum sheets. It was noted that the fully mechanized production line at the enterprise ensures the production of high quality aluminum sheets. However, the productivity of the technological equipment used in the dyeing process and the rejection of the bearings have a negative impact on the efficiency of production.

Technological machines and equipment work in Azeraluminum OJSC in particularly difficult conditions, and therefore there is a need to increase the reliability and longevity of the used roller bearings. The operating conditions of the bearingss, the distribution of loads between the rolling elements, as well as the contact stresses in the bearings details were assessed.

Keywords: *rolling pads; operating conditions; load distribution; contact voltages; painting process.*
Fig.: 2. References: 12.

Urgency of the research. One of the main features of the economic landscape of Azerbaijan in recent years is to ensure the rapid development of the regions. The current regional development strategy is a clear example of this. Azeral-Minium is one of the leading enterprises in the non-oil sector in the country. The company is a leader in the production of aluminum oxide, primary aluminum and other semi-finished metal products.

The company's main enterprise - Azeraluminum OJSC is located in Ganja. The complex includes an Electrolysis Plant, Anode Processes Plant, Metal Casting and Continuous Rolling Plant, Pressure Processing and Dyeing Plant, other workshops, ancillary production areas and infrastructure facilities. The Azeraluminum OJSC was founded in March 2008. The company uses modern technologies in the production of long aluminum sheets. Unlike traditional technological processes, a number of operations that limit the efficiency of the production of long sheets of aluminum alloys have been eliminated.

Target setting. At present, a highly efficient production process has been achieved at the OJSC using advanced technological operations. The company implements continuous casting technology of aluminum ingots. It combines several important technological operations. The basis of production is a ball casting process, in which the processes of crystallization and deformation of the liquid metal are carried out simultaneously.

As a result, a number of technological advantages are achieved: low energy capacity and high environmental friendliness of production; low capital and operating costs; application of the temperature of the liquid metal supplied to the rolling shafts to the deformation of the paste; direct purchase of the product by continuous casting of liquid metal. One of the important joints used in the roller casting process is the pads, which are attached to the rolling shafts.

Actual scientific researches and issues analysis. The longevity and reliability of roller shafts largely depend on the service life of the bearings [1; 2]. Observations showed that the reliability of the technological equipment used in the Pressure Processing and Dyeing Plant of Azeraluminum OJSC is not high and is mainly due to the bearings joints of the equipment. Pillow joints act as the most responsible knot of technological equipment in the dyeing process. Failure of these nodes leads to disruptions in process equipment and production processes [3; 4].

Uninvestigated parts of general matters defining. Therefore, the Azerbaijan University of Technology (UTECA) has studied the possibilities of increasing the reliability and longevity of the bearings joints of equipment used in the process of painting aluminum sheets at Azeraluminum-OJSC. As part of the research, complex research was conducted in the paint shop of the plant.

The research objective. This article examines the following issues: assessing the operating conditions of the bearings and the distribution of loads between the rolling elements; calculation of contact stresses in pillow details; reasons for failure of bearings; technological process of painting aluminum sheets; technical characteristics of bearings in painting equipment.

The statement of basic materials. It is known that the rejection of pillow joints leads to equipment downtime, reduced productivity and increased cost of production. The reliability of pillow joints depends on the service life of its individual elements. Therefore, increasing the longevity of bearings is a topical scientific and technical issue [3; 4].

Our observations in the painting shop of Azeraluminum OJSC showed that the longevity of bearings is related to the degree of wear of their individual elements [5; 6]. During the operation of the bearings, wear occurs due to the friction force on its elements. As a result, the pillow elements change their size, their accuracy decreases and abnormal gaps appear. There are shocks on the pillow elements and they break down in a short time. Therefore, it is important to take effective preventive measures against the wear of pillow elements in the painting shop.

It has been determined that the main types of wear on the elements of roller bearings are as follows [7; 8]: mechanical wear occurs as a result of mechanical impact; mechanical-corrosion erosion occurs as a result of both mechanical and chemical effects; Abrasive corrosion occurs as a result of solid particles falling between friction surfaces and scratching surfaces; erosion is caused by the action of liquid or gas jets; Fatigue is the result of the abrasion of friction surfaces that have been working under load for a long time [9; 10].

It was determined that the wear of rolling pads in the painting shop takes place in two stages: in the first stage, the roughness on the surface of the newly prepared parts is eaten and falls to normal size; in the second stage, wear occurs during subsequent operation of the parts [11; 12].

Aluminum sheets entering from the pressure treatment plant are placed on the slope of the loading cart with a bridge crane. The loading cart is lifted up and brought to the center line of the sheet unloading device. To make a closer contact with the sheet, the shaft is opened, then the loading machine is lowered and stops in the holding position, waiting for the next sheet.

The device is equipped with a clamp that holds the outer diameter tightly to prevent sudden separation of the sheet when cutting the winding tape of the sheet, and makes it easier to send the last sheet to the tension shafts. The traction block is used to send the end of the sheet to the scissors and the sewing machine. The incoming sheet is brought to the reference position on the machine, and when the next sheet is completely emptied, it reaches the seam position of the two strips.

There is a centering block at the end of the entrance storage block. The operating panel with the first control buttons automatically controls the operation of the equipment at the entrance. The sheet entering from the inlet storage cart enters the primary cleaning unit (9) through the traction shafts and the accumulator junction. The block is equipped with a water tank and rotating brushes, where both sides of the sheet are washed with hot alkaline solution.

The second cleaning tank with rotating brushes is used to remove any oil residue stuck to the surface of the sheet. Heated solid alkaline solution and brushes clean both sides of the sheet. Subsequent spray tanks are designed for complete washing. The sheets with oily substances on the surface are washed again with hot water, and the last tank removes various residues from the surface.

The cleaned sheets pass through a drying oven and enter between the chemical shafts, where a galvanic coating of chromium is applied on both sides of the sheets. After passing through the chemical shafts, the sheets again enter the drying oven. The sheets leaving the drying oven are passed through a centering mechanism and sent to the painting machine for painting.

The coloring machine can paint both sides of the sheet, and the painting can be done in the forward and reverse directions. The sheets leaving the dyeing machine pass through the vulcanization furnace. Here the solvents are evaporated, the sheets are heated to a certain temperature and vulcanized. After leaving the oven, the sheets are cooled with a water jet. The cooling system also provides centralized wrapping of the sheets. The cooled sheets are first dried with hot air, then passed through the tension rollers to the primer (19), and then to the primer on the back of the sheet. The painted sheet passes through the drying oven, water and air to the hot air drying position.

The dried sheet is fed to the outlet accumulator by means of traction shafts, and from there by means of traction shafts to the guide table, cutting shears, transmission shafts and finally to the roll winding device. Photoelectric regulators are located between the winding and traction cylinders, where the sensors read the relevant information and send a signal to the control system when an error is detected. Thus, the measurement accuracy of the sheets is fully automated. When the required roll diameter is obtained, the winding machine stops and the cutting machine cuts the sheets to the required length.

Thus, the fully mechanized technological line at Azeraluminum OJSC provides the production of high quality sheets with a thickness of 0.2…1.0 mm and a width of 700…1300 mm. The reliability and longevity of the pads have a direct impact on the productivity and continuous operation of the technological equipment used in the dyeing process. Research conducted at the dyeing plant has led to the following conclusions [7]:

1. One of the most responsible parts of the technological equipment used in the painting process is the pillow joints, the productivity of which is directly determined by the reliability of the bearings. Failure of bearings joints leads to downtime of technological equipment and processes, which reduces production efficiency.

2. The maintenance measures provided to the pillow joints during operation are not sufficient to extend the service life of the bearings. The low quality of the lubricants used also has a negative effect on the longevity of the bearings.

3. Violations in the assembly and installation of roller bearings have a negative impact on longevity. The low quality and improper selection of sealing elements also have a significant negative impact on the reliability of the pads.

4. Technological machines and equipment work in Azeraluminum OJSC in particularly difficult conditions and therefore there is a need to increase the reliability and longevity of the used roller bearings.

The roll opener operates radial spherical bearings 3616 with two rows of rollers. These bearings have a greater carrying capacity than bearings of the appropriate size. These bearings are produced at the pillow factories in Samara (Russia) and Minsk (Belarus).

11311 double-row ball bearing radial pads are used in roll tension shafts. These bearings are produced at the Kharkiv (Ukraine) pillow factory. The roller winding device uses radial spherical pads with two rows of rollers No. 3520. The rollers are placed on the inner rings with two runways and the outer rings with one spherical runway.

The technical characteristics of the rolling pads **3616, 11311 and 3520** listed above are as follows: Internal diameter of pillow **No. 3616** (d) - 80 mm; outer diameter (D) - 170 mm; width – 58 mm; number of rollers - 28 pieces; dimensions of the roller - 24.5x22.11 mm; weight - 6.6 kg; dynamic lifting capacity - 392 kN; static lifting capacity - 480 kN; rated speed - 2600 rpm.

Internal diameter of pillow number **№ 11311** (d) - 55 mm; outer diameter (D) - 130 mm; width (B / L) - 31/47 mm; weight - 2.37 kg; diameter of the ball - 15,875 mm; number of balls - 32 pieces; dynamic lifting capacity - 57.2 kN; rated speed - 5300 rpm. № Internal diameter of pillow number 3520 (d) - 100 mm; outer diameter (D) - 1480 mm; width - 46 mm; weight - 5.15 kg; number of rollers - 38; dimensions of the roller - 20x16.7 mm; dynamic lifting capacity - 330kN; rated speed - 2400 rpm.

It was found that the radial force acting on the rolling pads is unevenly distributed between the rolling elements of the pad (Fig. 1). All loads are accepted by rolling elements located in arcs smaller than 1800. The rotating element in the direction of the radial force is more loaded. Depending on the plane of action of the radial force, the rotating elements symmetrically placed are evenly loaded.

The distribution of force between the elements of rotation is a statically unsolvable problem. The radial force acting on the pad is Fr, the force acting on the heavily loaded rolling element is F0, the force acting on the rolling element at an angle γ with respect to the plane of impact of the load is F2, and so on; We denote Fn by the force acting on the rolling elements at an angle nγ.

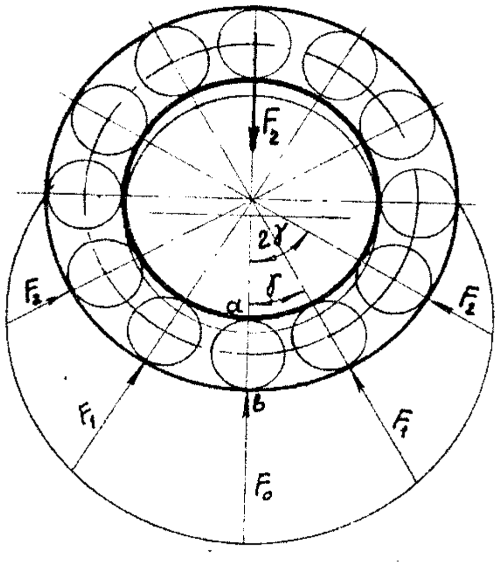

Fig. 1. Distribution of forces acting on the rolling pad

The equilibrium condition of an inner ring loaded with a radial force can be written as follows:

$$F_r = F_0 + 2F_1\cos\gamma + 2F_2\cos 2\gamma + ...2F_n \cos n\gamma, \quad (1)$$

where γ = 3600 / z is assumed; z is the number of balls; n is half the number of rolling elements in the loaded zone. In addition to the equilibrium equation, we use the displacement equation to solve the problem. Assuming that there are no radial gaps in the pads, it can be assumed that the rolling element and the deformation of the rings are equal to the corresponding projections of the complete displacement of the ring δ0:

$$\delta_1 = \delta_0 \cos\gamma; \quad \delta_2 = \delta_0 \cos 2\gamma; ....; \quad \delta_i = \delta_0 \cos n\gamma; \quad (2)$$

where i is the number of the scroll element. According to the theory of elasticity, there is the following relationship between the displacement of two compressed elastic bodies, ie the balls of the pads and the rings, and the compressive force [5]:

$$\delta = C \cdot F^{2/3} \quad (3)$$

where C is the coefficient of proportionality; F is the compressive force.

If we express the deformations in the displacement equations by force, then

$$F_1 = F_0 \cos^{3/2}\gamma, \quad F_2 = F_0 \cos^{3/2} 2\gamma, \quad ... \quad F_i = F_0 \cos^{3/2} i\gamma. \quad (4)$$

If we consider these dependencies in the equilibrium equation, then

$$F_r = F_0 (1 + 2 \Sigma_{i=1}^{n} \cos^{5/2} i\gamma) \quad (5)$$

By multiplying and dividing the right side of the formula by z, we determine the force F0:

$$F_0 = KF_r / z \quad (6)$$

Replaced with $K = \dfrac{z}{1 + 2\sum_{i=1}^{n}\cos^{5/2} iy}$ i here. The number of balls is K = 4.37 ± 0.01 for bearings with z = 10 ... 20. If we take into account the gap in the pads used in real conditions, we can assume K = 5 for single-ball radial pads. Then you can write:

$$F_0 = 5F_r/z. \tag{7}$$

Given the uneven distribution of the load between the rows in two-row spherical pads, the force acting on the heaviest load can be determined as follows:

$$F_0 = 6F_r/(zcosa). \tag{8}$$

For roller bearings, this problem can be solved in the same way as for ball bearings. However, the line of dependence between the displacement δ and the compressive force F is assumed, ie δ = C1 · F (C1 is the coefficient of proportionality). Similar to ball bearings, the maximum force for roller bearings is expressed as follows:

$$F_0 = KF_r / z. \tag{9}$$

For roller pads between z = 10 ... 20, we assume K = 4, K = 4,6, taking into account the spacing. For spherical pads with two rows, we assume K = 5.2, taking into account the unequal distribution of force between the rows.

Thus, calculations have shown that the balls of radial-bearing pads loaded with radial force are loaded 1 / cos α (α is the angle of inclination of the contact line) 1 times more than those of radial bearing pads. This argument leads to the wider application of roller bearings in technological machines and equipment [5].

After determining the distribution of the radial force acting on the bearings between its elements, it is necessary to determine the contact voltages on the pads. It has been found that the contact voltages at any point on the surfaces of the rings and balls vary with the pulse period. The period of tension at any point on the escape routes of the rings is equal to the time it takes for the next ball to reach a given point.

Such variability of contact stresses leads to fatigue wear of the working surfaces in the pillow details. It has been found that fatigue resistance depends on the rotation of the inner or outer ring of the bearings. The rotation of the inner ring is considered more favorable, because at a value equal to the force F0 of the load, the voltage at point a of the ring is greater than the voltage at point b. Thus, the ball meets a convex surface at point a and a concave surface at point b. In this case, the equality of the number of cycles of stress leads to the collapse of fatigue, especially at point a. To equalize the operating conditions of the rings, the number of voltage cycles at point a must be reduced compared to point b. This can be achieved by rotating the inner ring. Thus, in the middle of the turn, point a is completely empty, and most of the other half of the inner ring is not fully loaded.

It has been found that tensions in ball bearings occur at the starting point of contact between the ball and the rings. After the load is applied, the contact takes the form of an ellipse, in a small area. The maximum stress on the contact surface of the inner ring with the ball in the contact zone can be determined according to the Hers formula as follows [9]:

$$\sigma_H = m\sqrt[3]{FE^2\left(\frac{2}{D_w} - \frac{1}{\rho_i}\right)^2}, \tag{10}$$

where F is the load acting on the sphere, N; E - modulus of elasticity of the material, MPa; m is a special coefficient, which is selected depending on the ratio of inverted head curves [8]. To determine the maximum stress on the contact surface of the outer ring with the ball, write ρa instead of ρi and ra instead of ri in the formula. For radial-bearing pads, the radii of curvature ri and ra are defined as the ratio of the radius of curvature to cos ɑ (Fig. 2).

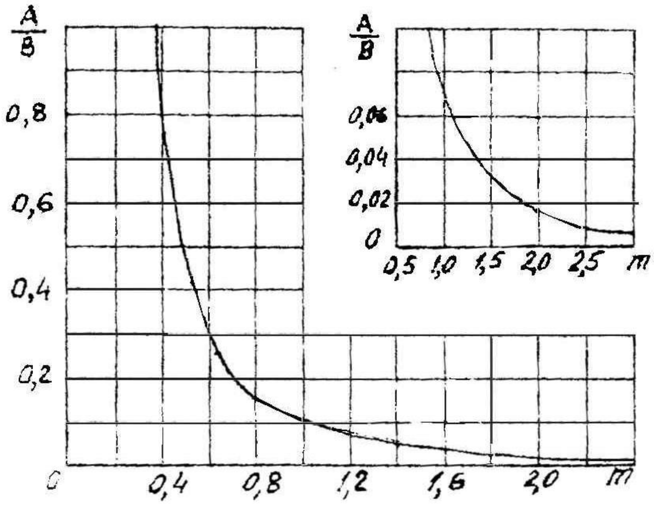

Fig. 2. Correlation between A / B ratio and m coefficient

It has been found that in roller bearings, the initial contact between the roller and the rings occurs in a straight line [7]. The maximum contact voltage between the roller and the inner ring can be determined as follows:

$$\sigma_H = 0,418\sqrt{\frac{FE}{L_{We}}\left(\frac{2}{D_w}+\frac{1}{r_i}\right)}, \tag{11}$$

where D_{we} and L_{we} are the diameter of the roller and the effective length of the contact line, mm.

When determining the contact voltage between the roller and the outer ring, instead of r_i in the formula, r_a should be written with a negative sign. For bearings materials, the maximum allowable contact voltage is assumed to be 5000 MPa at the point of contact and up to 3000 MPa at the line. Thus, on the basis of analytical calculations, generalization of experimental data and long-term observations of the technological equipment operated by Azeraluminum OJSC, the following characteristic damage was detected in the roller bearings.

Fatigue was observed in bearings that worked normally for a long time. Thus, the sign of the balls rolling in the rings occurs under the influence of changing forces. After a certain number of loading cycles, microcracks appear on the working surfaces. It is in these microcracks that abrasions occur as a result of the ingress of lubricant. Fatigue is the main cause of failure of roller bearings operating under heavy loads, which are well protected from contaminants [8].

It was determined that most of the technological equipment operated at Azeraluminum OJSC operates in abrasive conditions. Despite the use of various sealants and lubricants, the elements of the roller bearings are more prone to corrosion. The effect of centrifugal force and rolling elements on the separator, as well as on axially loaded airbags, is more pronounced.

It has been found that the diameters of the rolling elements are not the same and that they do not rotate at the same speed around their axis, so the separators are affected by different values of force. As a result, the rolling elements not only cause the separator to wear out, but also cause the slide to slip. These effects lead to the collapse of the separators. Disintegration of the separators was mostly observed in high-speed pads. External signs of pillow failure have been identified: poor rotation accuracy, high noise, a sharp increase in roll resistance, and heating of the pillow.

It has been found that the rolling elements of the pads and the splitting of the rings are due to the inaccurate assembly, which causes the rings to bend and rivet, operating under shock and vibration loading. Compression as a result of plastic deformation occurs mainly in slow-moving, heavily loaded pads, and crushing manifests itself in the form of depressions.

Conclusions. Thus, it was determined that the engineering calculations of roller bearings operated by Azeraluminum should be based on static load capacity due to permanent deformation and longevity due to fatigue abrasion. The possibilities of increasing the reliability and longevity of the bearings joints of the equipment used in the process of painting aluminum sheets have been investigated.

The operating conditions of the bearings, the distribution of loads between the rolling elements, as well as the contact stresses in the bearings details were assessed. The process of painting aluminum sheets and the technical characteristics of the pads used in painting equipment are analyzed. The main reasons for the failure of the bearings were clarified, the main types of wear on the pillow elements and their characteristics were identified.

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ОЦІНКА УМОВ ЕКСПЛУАТАЦІЇ РОЛИКОВИХ ПІДШИПНИКІВ

Розглянуто можливості забезпечення надійності роликових підшипників, що використовується в процесі фарбування алюмінієвих листів в умовах ВАТ «Азералюміній». Відзначено, що повністю механізована лінія на підприємстві забезпечує випуск високоякісних алюмінієвих листів. Однак продуктивність технологічного обладнання безпосередньо пов'язана надійністю підшипників, відмови яких негативно впливають на ефективність виробництва.

На основі аналізу умов експлуатації встановлено, що однією з найбільш відповідальних частин обладнання, що використовується у технологічному процесі, є роликові підшипники. Вихід із ладу підшипників призводить до простоїв технологічного обладнання. Заходи з технічного обслуговування, передбачені для підшипників під час експлуатації, є недостатніми для продовження їх терміну служби. Низька якість мастильних матеріалів також негативно впливають на тривалість роботи роликових підшипників.

Порушення при складанні та монтажі ролико-підшипників негативно позначаються на довговічності. Низька якість і неправильний підбір ущільнювальних елементів також істотно впливають на надійність. Технологічні машини та обладнання працюють в особливо складних умовах і виникає необхідність підвищення надійності та довговічності використовуваних ролико-підшипників. Оцінювалися умови експлуатації підшипників, технічні характеристики та розподіл навантаження між елементами, а також контактні напруження в деталях підшипників. Проаналізовано технологічний процес фарбування алюмінієвих листів та особливості обладнання в фарбувальному цеху.

Таким чином, визначено, що інженерні розрахунки довговічності роликопідшипників повинні ґрунтуватися на статичній вантажопідйомності, оскільки їх відмови відбуваються за рахунок постійної деформації та через втомне стирання. Можливості підвищення надійності та довговічності роликових підшипників, що використовується в процесі фарбування алюмінієвих листів, пов'язані з покращенням їх умов експлуатації, рівномірним розподілом навантажень між елементами, а також зменшенням контактної напруги в деталях підшипників. Уточнено основні причини відмов та виявлено види зносу елементів роликових підшипників.

Ключові слова: *роликові підшипники; надійність; умови експлуатації; розподіл навантаження; контактні напруги; процес фарбування; технологічне обладнання.*

Рис.: 2. Бібл.: 12.