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INNOVATIVE REDUCER FOR RAILROAD SWITCH DRIVES AND EVALUATION FRICTION WORK ON DOUBLE SLIDING BEARINGS

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A B S T R A C T

Railway transport plays a special role in the transportation of oil and petroleum products. Ensuring the speed and reliability of transportation is one of the important issues. The role of railroad switch electric drives in solving this problem is great. Package type «AN» reducer have a number of advantages over traditional ones. The article presents the features and the essence of increasing the technological and exploitational parameters of the transmission mechanism of railroad switches with the help of a new innovative package type «AN» reducer, developed at AzTU. An analysis of the work of friction on plain bearings used in package reducers, instead of keyed connections in traditional gearboxes, is given. The effectiveness of the use of package type «AN» reducers in the transmission mechanisms of railroad switch electric drives has been revealed.

K E Y W O R D S

Railroad switch drive;
Mechanism;
Innovative;
Increase;
Reducer;
Reliability.

Introduction

In the modern era of high development of science and technology, the creation of complex mechanical systems continues against the background of meeting the requirements of technical means in all areas of production and operation and healthy competition. One of the main conditions for a complete and accurate problem solving for such systems is to ensure their high reliability.

These issues remain relevant in the field of railway transport, as well as in addressing issues of ensuring the intensity of cargo transportation.

Railway transport plays a special role in the transportation and delivery of oil and oil products to the customer. One of the important issues is to ensure the speed and reliability of transportation. The role of railraod switch electric drives in solving this problem is great. Improving the operational reliability of switchs is of particular importance for increasing train speeds traffic and maintaining railroad throughputs [1].

In connection with expanding political, economic and cultural ties, the role of Azerbaijan's railway transportation, having an advantageous strategic position, has significantly increased. The Azerbaijan Railway (AR) mainline participates in several international corridors as a transit route, including the TRACECA and North-South corridors.

Despite the difficulties, the AR system is being purposefully improved, its management structure is progressing, joining the development and technological progress events taking place in the world. In particular, measures are being taken to use modern achievements of science and technology to increase the speed, maneuverability, reliability, energy efficiency and competitiveness of the means of the transport system.

One of the components of the railway transport system is the device-switch electric drives that connect and disconnect rails to transfer vehicles on railways from one track to another [1-3].

Azerbaijan Railways was part of the CIS railway network, that's why the organization of transportation and management of the railway system, as well as the technical means of supply, were determined by the standards of this network.

At present, on the main railway transport, modernized electric switch drives of the «СП» type are widely being used, both in the new construction of railways and in the replacement of switch electric drives that have exhausted their service life [1-3]. However, transmission mechanisms of the «СП» type have a number of disadvantages, the main ones are the following:

- the presence of an open heavily loaded transmission in the mechanical system;
- relatively complex manufacturing technology;
- low efficiency;
- the impossibility of unifying structural elements;
- the impossibility of increasing the total gear ratio by increasing the width of the gear mechanism.

The disadvantages of «СП» railroad switches are detrimental to their reliability. Increasing the speed and reliability of railroad turnouts is always a topical issue.

The purpose of the work is to develop an innovative mechanical transmission and improve the reliability of the transmission mechanism of railroad swich electric drives,

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simplify the design, ensure the unification of gear wheels, include an open heavy-duty transmission in the gearbox and exclude from it the intermediate shaft with all related elements.

Research method

Multi-stage package type reducers «AN» have a number of advantages over traditional gearboxes, industrial tests have been carried out recently for their use in various designs, and the test results are positive. In particular, for the elevator used in buildings, for the purpose of opening and closing doors, as well as for raising and lowering the cab; for pumping units used in the oil industry [4]. The main advantage of multi-stage package type reducers are:

- high compactness
- the number of component parts of the gearbox is much less,
- designs are technologically advanced;
- as statistical information show and calculations the reliability is high [5].

To solve the above problem, under the leadership of Professor Ayaz Abdullayev at the Azerbaijan Technical University, a new innovative package type reducers «AN» was developed [6].

Features of the innovative design solution of the transmission mechanism of the railroad switch are schematically shown in figure 1. The diagram shows the components of the railway switch electric drives with an indication of their connections according to their purpose, the nodes selected for renovation are highlighted, the types of renovation are given, as well as the positive results obtained as a result of drive renovation. As shown in the scheme, in the new innovative gearbox, in contrast to the transmission mechanism of transmissions of the «СП» type, gear transmission of an open type is included in the gearbox , the gear stages are located only on two shafts (axles), the gears transmissions provided in the structure are mounted on plain bearings mounted on the axles and can rotate freely around their axes, while the friction clutch is located between the gears of the gear unit, and so on. As a result, the number of parts of the transmission mechanism of the railroad switch transmission has been significantly reduced, the level of unification and manufacturability of the design has increased, and at the same time, the reliability of the developed package type reducers «AN» transmission mechanism was compared with the reliability of the corresponding analogues and positive results were obtained [7].

It is appropriate to note that when pairing a gear wheel with shafts using a keyed connection, the errors of the keyed connection elements negatively affect the quality of the connections, which double when the teeth mesh, become more complex, and also depend on the number of meshed pairs and on the gear ratio. The proposed constructive and technological measures determined the minimization of the influence of errors in the keyed connection on the formation of a difference in the angles of the directions of the engaged teeth, which made it possible to improve the conditions for their contact [8].

An innovative electromechanical switch drive was developed for transferring, closing and controlling four positions of wits during the operation of railways (fig. 2).

Switcher electromechanical drive contains a reversible servo DC or AC electric motor (1), a coupling (2), a transmission mechanism (3), which is a torque amplifier of a low-power electric motor; a friction device (4) designed to avoid compressing stock rails with a point rails (fig. 3); rack and pinion mechanism (5), designed to convert the rotational motion of gear into reciprocating motion of the rack.

In this case, the transmission mechanism is presented in the form of a single-line three-stage gear reducer on two shafts, which includes a housing (6), a drive gear (7) mounted on the drive shaft (8) and rigidly connected to it by means of a keyed connection (9); on the same shaft on a plain bearing (10) there is a two-ringed gear unit (11,12), which has free rotation around its axis.

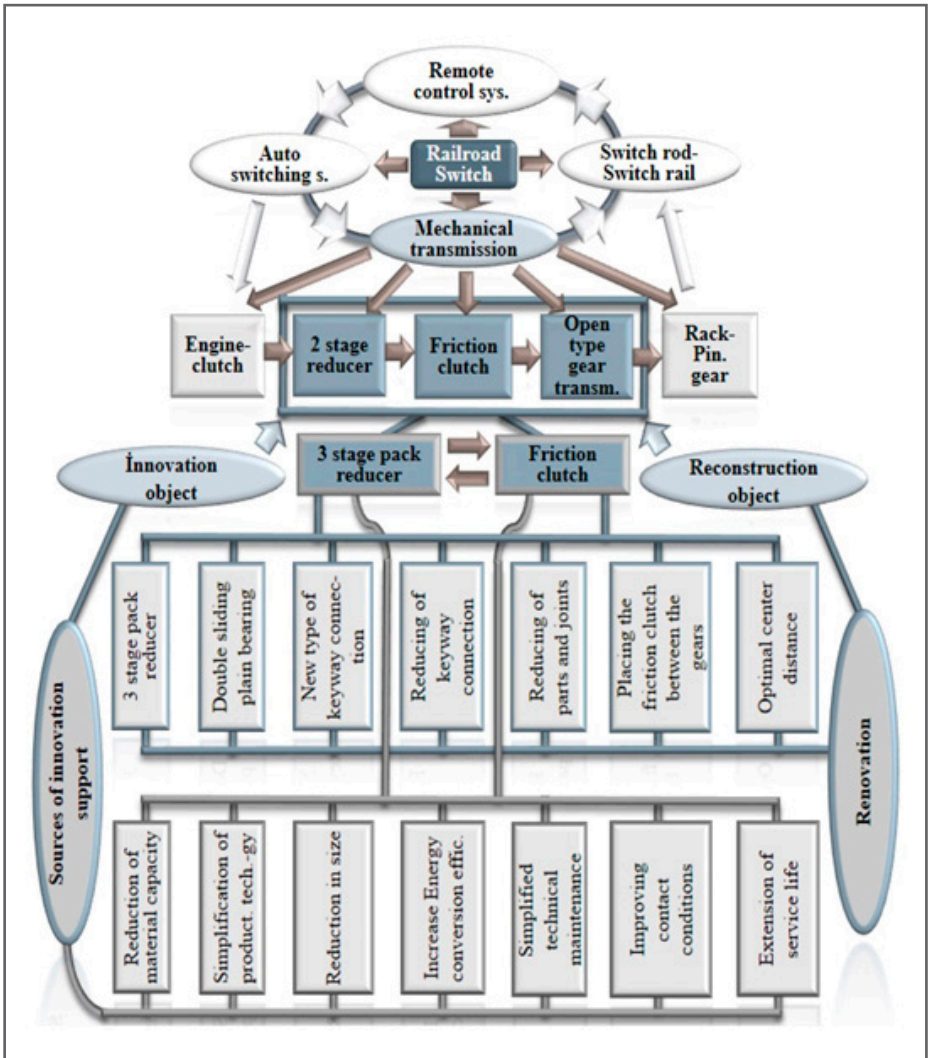

Fig. 1. Scheme features of the innovative design solution of the transmission mechanism of the railroad switch drives

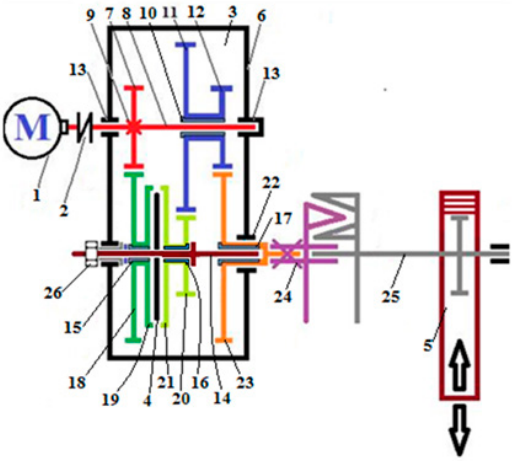

Fig. 2. Scheme of an innovative electromechanical switch drive of railways

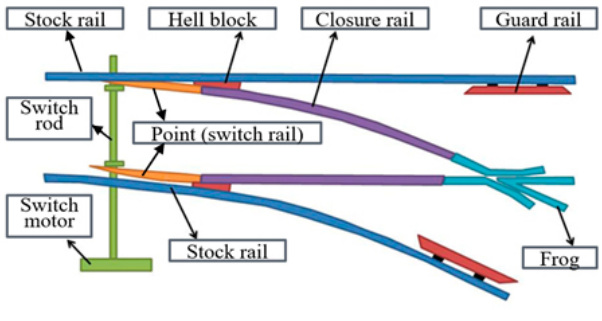

Fig. 3. Railroad switch elements

On the driven shaft (14) on bearings (15,16,17) there is a gear wheel (18) rigidly connected to the left steel disk (19), a gear wheel (20) rigidly connected to the right disk (21) of the friction device and a gear wheel (23), the output end of which is simultaneously mounted on rolling bearings (22) directly in the gearbox housing.

At the same time, by means of a cam clutch (24), the output end of the driven gear is connected to the rack and pinion mechanism (5) by means of coupling halves and the main shaft (25). Moreover, the required value of the friction moment between the steel discs is regulated by the adjusting nut (26).

The proposed design solution for the switch electromechanical drive works as follows

The rotational movement from the reversible electric motor of direct and alternating current is transmitted by means of a coupling to the drive shaft mounted on rolling bearings in the gearbox housing, from where the rotation is transmitted by means of a drive gear rigidly connected using a keyed connection with the drive shaft to the left double-crown block, consisting of a gear wheel and a steel disk rigidly connected to it, freely rotating around the axis of the driven shaft by means of the steel disk of the right double-crown block, pressed against the left steel disk by means of a spring; rotational motion is transmitted to the gear wheel of the two-crown block with a rigidly connected gear, therefore, the gear is rigidly connected to it and freely rotates around the axis of the drive shaft.

By means of a heavily loaded stage, consisting of a pinion, a driven gear and a cam clutch, the rotational movement is transmitted to the main electromechanical switch drive of the railways. In this case, the value of the friction moment between the steel discs is regulated by means of an adjusting nut [7].

Assessment friction work on double sliding bearings

One of the main features of package gearboxes is the use of a plain bearing instead of keyed (or splined) connections in the shaft-gear joints, and naturally, one of its main working elements is a sleeve bearing.

The wear of the working surfaces of rubbing parts and thermal phenomena during the relative sliding of the elements of the bearing pairs are the most important performance characteristics that determine the reliability of the interface [9].

In these gearboxes, plain bearings can be used in two versions: - the sleeve is seated on the main hole of the gear wheel with an interference fit - a rigid connection; a double plain bearing is used, the sleeve is freely installed between the working surfaces of the shaft and the gears unit.

The essential difference between the sliding unit of the package type of «AN» gearboxes from the existing ones used in the sliding units used in modern technology is that in the package gearboxes both elements of the plain bearing have rotational motion (even in a double bearing, all three elements of friction pairs rotate by sliding: – shaft, bushing and wheel). As a result, friction and wear of the elements (usually a bushing) of a friction pair, unlike the traditional one, do not occur locally, one-sidedly, along a certain part of the working surface of the bushing, but along the entire contour of its inner working surface. The wear of the bushing occurs, relatively evenly, over its entire working surface, and its reliability (service life) increases.

Thus, the analysis of the above considerations shows that by controlling the speeds of the contact surfaces in the friction units of double plain bearings, it is possible to provide a relatively low coefficient of friction in tribological pairs. Therefore, in order to create favorable friction conditions and determine the functional dependencies $v = F(t, d, n)$, we construct a plan for the speeds of the elements of the friction unit (figs. 4, 5).

All three elements of friction pairs of package reducers (shaft, pinion and double plain bearing) rotate in the same direction [5]. That is, the relative sliding speed in a friction pair is equal to the difference in the speeds of the rotating elements. The thickness of the double plain bearing plays a special role in the formation of the speed difference.

It is known that in traditional bearings, sliding surface contact and wear occur at a certain angle of the female surface, along its certain part, but along the male detail along the entire contour of the covered surface.

One of the most important features of sleeve bearings of package gearboxes is that relative sliding occurs in both rotating parts over the entire circumference of both the female and male surfaces. Thus, contact and wear of both parts of the friction pair occur along their entire perimeter. That is, the worn mass of the female part is also distributed over its entire surface, and therefore the amount of wear in the radial direction is smaller. Therefore, ensuring the rotation

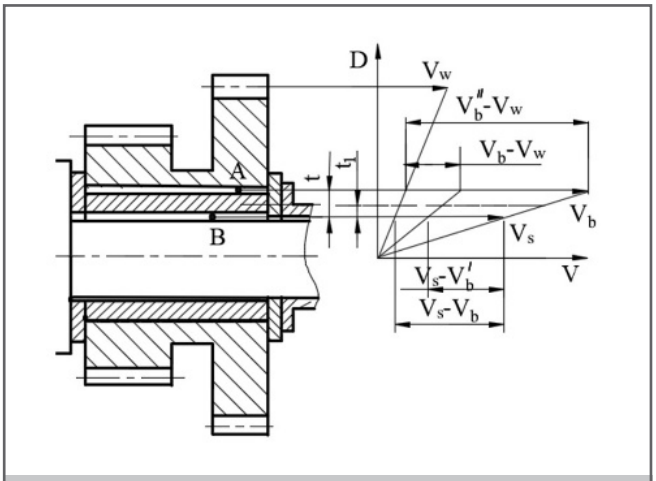

Fig. 4. The speed plan of the friction pairs located on the drive shaft

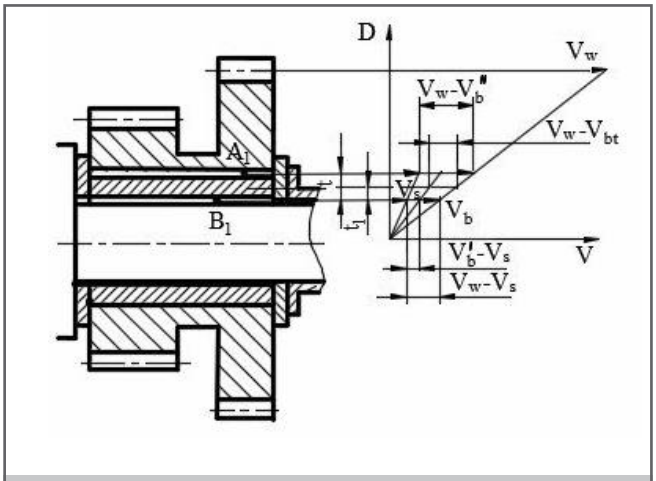

Fig. 5. The speed plan of the friction pairs located on the driven shaft

of the shafts in the gears of the package reducers creates the conditions for increasing the service life of the reducer.

The plan of velocities formed in the friction units on the driving and driven shafts is fundamentally different.

The speed plan of the friction pairs located on the drive shaft is shown in the figure 4 and the speed plan of the friction pairs located on the driven shaft is shown in the figure 5.

It is known that one of the main factors in ensuring the reliability of a plain bearing is friction work, or heat release [9]:

$$A = Pfv\tau \quad (1)$$

where f – is the coefficient of friction,

P– is the normal force acting on the sliding pair,

v – is the relative sliding speed,

τ – sliding time.

In package type «AN» gearboxes, two radial forces simultaneously act on the plain bearing, created during the engagement of both successive gears, through the gear unit, located approximately on the same plane and having the same directions (fig.2). Thus, according to (1), the work of friction on the friction unit is determined by the following dependence (fig. 4):

$$A = f(P_1 + P_2)(v_s - v_b)\tau \quad (2)$$

where P_1 and P_2 are the radial components of the forces generated in the gear stages,

v_s – is the speed of the contact points of the shaft surface,

v_b – is the speed of the points of the contact surface of the bearing-sleeve.

Since the sleeve also rotates in double plain bearings, the total work of friction in the assembly can be divided into two terms: the friction work formed on the shaft-sleeve and sleeve-wheel mates. That is, the product in expression (2) can be divided into two parts, and the relative sliding speed in the shaft-sleeve interface can be significantly reduced by controlling the speed of the elements of the sliding pairs [10]. In this case, the friction work in the shaft-sleeve friction unit is equal to (fig. 4):

$$A_1 = f(P_1 + P_2)(v_s - v_b')\tau \quad (3)$$

and the work of friction at the junction of the sleeve-wheel (fig. 4):

$$A_2 = f(P_1 + P_2)(v_b'' - v_w)\tau \quad (4)$$

where v_b' and v_b'' are the speeds of rotation of the points of the inner and outer contact surfaces of the sleeve, respectively, v_w is the circumferential speed of the points of the contact surface of the wheel.

Thus, $A_1 < A$. This means that it is possible to provide a relatively favorable friction mode in the friction unit if a double plain bearing is used in a tribological unit in which there are certain severe operating conditions (for example, friction occurs in boundary contact conditions). By reducing the relative sliding speed, it is possible to reduce the work of friction in the friction unit and thereby achieve an improvement in the friction condition.

The total work of friction in a double plain bearing is slidings on contact pairs shaft-sleeve and sleeve-wheel:

$$A_i = f(P_1 + P_2)[(v_s - v_b') + (v_b'' - v_w)]\tau \quad (5)$$

By substituting the values v_s, v_b', v_b'' and v_w into formulas (5), the total work of friction for specific operating conditions is determined

$$A_i = 10^{-3}\pi f(P_1 + P_2)[d(n_1 - n_2) + (d + 2t)(n_2 - n_3)]\tau \quad (6)$$

where, n_1 is the rotation frequency of the shaft, n_2 is the rotation frequency of the sleeve-double bearing, n_3 is the rotation frequency of the wheel, t is the wall thickness of the sleeve.

Thus, by reducing the thickness of the sleeve to t_1, or by increasing it, one can control the relative sliding speeds (fig. 5).

The works of friction in the friction units of the driven shaft is determined in a similar way.

For the use of package gearboxes in the transmission mechanisms of railway switch electric drives, quantitative experiments were carried out. Calculations have been carried out and compared, almost all the input and output parameters of the gearbox (including an open gear) of an electric switch drive of the «СП-8» type with a corresponding three-stage package gearbox, and determined the expediency of using the latter is . An improved design of the transfer mechanism of switch electric drives has been developed at the patent level.

Numerical experiment

To confirm the main scientific provisions, a numerical experiment was carried out – a comparative analysis of the qualitative indicators of the proposed transmission

mechanism and modern switch electric drives of the SP-10 and SP-12 series, which are characterized by the following parameters: total gear ratio of the gearbox $u_\Sigma = 72.3$; torque on the gearbox input shaft $T_p = 3.485$ Nm; output torque $T^* = 229.1$ Nm; number of steps $C = 3$.

Based on the results obtained, it was revealed that the proposed transmission mechanism has the following advantages:

- the intermediate shaft, two rolling bearings on which it sits, two housing holes, two bearing caps, etc. are excluded from the mechanical system, the design is greatly simplified, the level of reliability of the mechanism is increased;
- the proposed transmission mechanism can be made on the basis of a set of unified gears and double-crown gear blocks, depending on the pre-selected number of its steps and the total gear ratio; This provides a favorable condition for the lubrication of all gears;
- the possibility of including a heavily loaded open gear in the gearbox is provided;
- in the proposed transmission mechanism, all parts of plain bearing assemblies, including the double-crown gear blocks on plain bearings rotate in the same direction, the resistance force is significantly reduced, which leads to an increase in efficiency mechanical system;

Thus, it has been established that, other things being equal, the use of the proposed transmission mechanism in electric switch drives instead of the existing one provides a certain economic effect by reducing the material consumption of the device and increasing its manufacturability.

Evaluation of the technical level of the innovative «AN» reducer

The conditions for the use of reducers, the technical level, reliability indicators and the accuracy of their manufacture are determined by the generally accepted standard [11]. According to the standard, gearboxes are characterized by the following quantitative indicator (γ), which reflects the ratio of the mass of the gearbox to the load capacity of its heavily loaded stage:

1. Low quality if $\gamma > 0.2$ (reducer outdated);
2. If $\gamma = (0.1 \div 0.2)$ – the average level (manufacturing of reducer is often not economically justified)
3. If $\gamma = (0.06 \ldots 0.1)$, then higher (the reducer complies with modern world standards)
4. High level if $\gamma < 0.06$ (reducer meets record standards)

With a known value of torque at the output value of the innovative three-stage gear train, $T^* = 229.1$ Nm, it is only necessary to determine the mass of this mechanical system in order to assess the technical level of the innovative electromechanical traction drive [12]:

$$M^* = V\rho\phi = \frac{\pi}{4}\left(d^*_{W1}\right)^3 \psi^*_{bd}\left(u_\Sigma^{\frac{1}{3}} + 1\right)\rho\phi \qquad (7)$$

where $(\psi_{bd})_\Sigma = \psi^*_{bd} + \psi_{bd_3} + \psi_{bd_4} + \psi_{bd_5}$ – is a total dimensionless gear width coefficient;

ψ^*_{bd}, ψ_{bd_3}, ψ_{bd_4}, ψ_{bd_5} – are the respectively, the width coefficients of the gears of the heavily loaded stage of the two-crown block 3, gear 4 and adjusting gears.

Based on design considerations, the following gear width factors are adopted for the corresponding steps of the innovative gear transmission mechanism: $\psi^*_{bd} = 0.6457 \approx 0.8$; $\psi_{bd_3} = 0.5$; $\psi_{bd_4} = 0.4$; $\psi_{bd_5} = 0.3$; $(\psi_{bd})_\Sigma = 2.0$

In this case, end clearances are also taken into account.

$u_\Sigma^{\frac{1}{3}} = 4.1666$ – the gear ratio of one stage;

$\rho = 7300$ kg/m^3 – the material density;

$\varphi = 0.9$ – the fill factor.

$$M^* = 0.735 \cdot 0.036^3 \cdot 2 \cdot 5.1666 \cdot 7800 = 2.9519 \text{ kg}$$

The technical level of the proposed innovative gear reducer:

$$\gamma = \frac{M^*}{T^*} = \frac{2.9519}{229.1} = 0.0129 < 0.06$$

This shows that the presented innovative transmission gear mechanism – a three-stage gear reducer on two shafts, corresponds to record-breaking samples.

Conclusion

1. An innovative package type «AN» reducer, developed at AzTU, provides an increase in the technological and exploitational parameters of the transmission mechanism of a railroad switch
2. By reducing the thickness of the sleeve, or by increasing it, one can control the relative sliding speeds, also friction conditions and wear.
3. The new, innovative package type «AN» reducer is recommended for use in railroad switch transmissions.

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Инновационный редуктор для приводов железнодорожных стрелочных переводов и оценка работы трения на двойных подшипниках скольжения

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Реферат

Железнодорожный транспорт играет особую роль в перевозке нефти и нефтепродуктов. Обеспечение скорости и надежности перевозок является одним из важных вопросов. Роль стрелочных электроприводов в решении этой проблемы велика. Пакетные редукторы типа «AN» имеют ряд преимуществ перед традиционными. В статье представлены особенности и сущность повышения технологических и эксплуатационных параметров передаточного механизма стрелочных переводов с помощью нового инновационного редуктора «AN» пакетного типа, разработанного в АзТУ. Дан анализ работы трения на подшипниках скольжения, используемых в пакетных редукторах вместо шпоночных соединений в традиционных редукторах. Выявлена эффективность использования пакетных редукторов типа «AN» в передаточных механизмах электроприводов стрелочных переводов.

Ключевые слова: стрелочный перевод; привод, механизм; инновационный; редуктор; повышение; надежность.

Dəmiryol yoldəyişənlərinin intiqalları üçün innovativ reduktor və ikiqat sürüşmə yastıqlarında sürtünmə işinin qiymətləndirilməsi

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Xülasə

Neft və neft məhsullarının daşınmasında dəmir yolu nəqliyyatı xüsusi yer tutur. Daşımanın sürətinin və etibarlılığının təmin edilməsi mühüm məsələlərdən biridir. Bu problemin həllində dəmiryol yoldəyişənlərinin rolu böyükdür. Paket tipli «AN» reduktorları ənənəvi olanlarla müqayisədə bir sıra üstünlüklərə malikdir. Məqalədə AzTU-da işlənmiş yeni paket tipli innovativ «AN» reduktorunun köməyi ilə dəmiryol yoldəyişəninin ötürmə mexanizminin texnoloji və istismar parametrlərinin yüksəldilməsi xüsusiyyətləri və mahiyyəti təqdim olunur. Ənənəvi reduktorlarda tətbiq olunan işgil birləşmələri əvəzinə, paket reduktorlarda istifadə olunan ikiqat sürüşmə yastıqlarının sürtünmə işinin təhlili verilmişdir. Dəmiryol yoldəyişənlərinin elektrik intiqalının ötürmə mexanizmlərində paket tipli «AN» reduktorlarının istifadəsinin səmərəliliyi aşkar edilmişdir.

Açar sözlər: dəmiryol yoldəyişəni; intiqal, mexanizm; innovativ; reduktor; yüksəlmə; etibarlıq.