На рис. 3 приведено изменение износов цилиндрических поверхностей пятникового узла для 4-осной цистерны с учетом величины их пробега в период приработки по одному и тому же маршруту.

ВЫВОДЫ

Из полученных данных видно, что в начальный период зона контакта имеет небольшую протяженность, а при пробеге размер ее увеличивается за счет возрастания износов.

Численные исследования показали, что износ поверхностей пятниковых узлов зависит от распределения контактных давлений и зазоров между пятником и подпятником. В расчётах учитывалось, что при перевозке нефтепродуктов цистерна возвращается порожняком.

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RUNNING IN OF CYLINDRICAL SURFACE OF CENTRE PLATE UNITS OF CARS

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ABSTRACT

This article presents an algorithm and its description to determine wear in center plate units of cars and rail tanks. It is shown that in the beginning of operation contact area has a small length, and with the growth of the car`s distance run, wear of cylindrical surfaces occurs and its size increases. At the same time the method of calculating the respective quantities and source data, numerical analysis of wear of rubbing parts of the structure is demonstrated. The calculations took into account that when the oil was transported, rail tank returned empty, and their own results show that wear of center plate units' surfaces depends on the contact pressure distribution and gaps between center plate and center pad.

ENGLISH SUMMARY

Background.

Centre plate unit provides connection between the frame of the car and bogie, passes vertical and horizontal loads. Modern cars are equipped with various designs of centre plate units, differing mainly in geometric dimensions. Tribocoupling of centre plate units consists of contacting support and cylindrical surfaces of centre plate and centre pad. They turn relative to each other about a common axis, but the nature of the wear of these surfaces varies considerably.

A number of studies [1, 2, etc.] describes a method of estimation of distribution of contact pressure and wear on the supporting surfaces of centre plate units of freight cars. Studies have shown that wear depends on the load of cars, their geometrical dimensions, as well as on the materials from which centre plates and centre pads are made, and on operating conditions – primarily on the presence of track curvature, etc.

Cylindrical surfaces of centre plates constructively can have different diameters of centre plate as well as of centre pad due to inherent manufacturing allowances. In this connection, at the initial moment of operation contact zone between them is of varying length and hence the magnitude of the contact pressure in the running-in period is not the same during the operation of friction pairs of rubbing surfaces. This changes such an important parameter in the contact zone as the distribution of contact pressure.

Increased wear of supporting and cylindrical surfaces is particularly significant for centre plate units of 8-axle rail tanks. As it is shown by the data of the pilot survey, in such rail tanks after 400 thousand km mileage wear of cylindrical surface of centre pads is more than 11 mm [3].

Objective.

The objective of the authors is to show methodological approaches to justification and creation of a special algorithm of calculating wear of center plate units of cars and rail tanks.

Methods.

The study is based on mathematical methods and calculations.

Results.

During operation of centre plate unit, wear of contact surfaces occurs, which leads to the increase in the gap between cylindrical surfaces and changes in their geometrical dimensions. Besides there are changes in the area of contact between the parts and the distribution of contact pressure on it. That is, in the calculation model background should be considered in every time moment thereafter.

Since the radial wear depends on the force N (t), and it is dependent from the mode of conducting trains, getaway, braking, availability of ascents and descents, loading of wagons, track condition – wear of supporting surfaces of centre plates and centre pads also depends on these factors. When the freight train starts moving, centre plate is displaced relative to centre pad. It is observed up to contact of cylindrical surfaces, and their further elastic deformation occurs due to the tensile forces acting between cars of the train and the rolling resistance force of wheels on the rails. The resultant of these forces will be denoted via N (t), the radius of unworn cylindrical surface of the centre pad – via R_2, and the radius of the unworn cylindrical surface of a centre plate – via R_1, then the initial radial clearance Δ_0 between cylindrical surfaces of a centre plate and a centre pad will be (1).

Given that the force N_0, pressing a centre plate to a centre pad by the rectilinear motion, forms contact area, symmetrical with respect to its point of application, friction forces in this case can be neglected. Displacement of contact area is determined by the angle β, which depends on the radius of the curve and the base of the car, on which a centre plate is located [4]. Here see (2), where 2l – distance between track centers; $R_{кр}$ – curve radius of track section.

The length of the contact zone $2\alpha_0$ depends on the force N (t), but is usually much more than β, so that it is possible to assume that $\beta/\alpha_0<1$. See formula (3).

It is assumed that to the center of the shaft force N_0 and moment M_0 are applied, with respect to the axis OX force N_0 inclined at an angle β. Then projection of the force on the coordinate axes will be equal to (4).

With this choice of coordinate axes contact area is symmetrical with the axis OX. Assume that under the action of forces X_0, Y_0 and moment M_0 bodies are in a state of static equilibrium and at the contact area besides normal (radial) stress $\sigma_r(\alpha)$, frictional forces (shear stress) function. Then, according to Coulomb's law [5], for the limit state of equilibrium formula (5) can be written, where f – coefficient of sliding friction, α – angular coordinate of the point under consideration at the contact area.

It can be assumed also that the radius of the shaft and the hole and close, i. e. $R_1(t)\cong R_2(t)$, but the radial clearance $\Delta(t)$ is nonzero. See (6), where $R_j(0)$ – radii at the initial time moment, $h_j(t,0)$ – wears of a centre plate and a centre pad, $\Delta(0)$ – initial radial clearance.

The degree of wear in the center of the contact area is associated with the contact pressure p (t,0) and parameters of materials wear resistance by relations (7).

The magnitude of the contact pressure can be expressed as a trigonometric polynomial [6], comprising n summands. See (8), where b_i – unknown coefficients, which identically satisfy this equation for all n equally spaced points in the zone of contact.

The resulting algebraic system of n equations can be solved for the same number of unknown coefficients b_i.

Forces and moments occurring in the contact zone, are calculated after finding unknown coefficients b_i by the following expressions [4], See formulas (9) – (11), where $s=\mathrm{tg}(\alpha_0/4)$; f – friction coefficient.

To determine the angle of displacement of the center of the contact area β and the contact angle α_0 it is necessary to use relations (12) and (13).

The degree of wear of cylindrical surfaces of parts of tribocoupling of a centre plate unit can be determined by the equation (14).

Given the expression (14), the length of the contact area 2α is converted into a line segment [0, π]. Then the resulting segment is divided into n equal segments. Angle θ_k, formed by radii drawn through adjacent points can be defined by the expression (15).

In developing the algorithm for determining wears of cylindrical surfaces of centre plate units an algorithm for calculating wear on supporting surfaces was taken as the basis [1]. Taking into account that between cylindrical surfaces there are gaps processing of algorithm and calculation program was required. For this reason, cylindrical surfaces were presented in the form of plates spaced apart from each other by the gap. The initial contact area and its subsequent changes were determined by a specially created program, taking into account the contact interaction of two cylindrical surfaces of shaft- sleeve [7].

Gap value for each point of cylindrical surface of a centre plate unit can be found if the original dimensions of a centre plate and a centre pad are known. Pic. 1 shows a diagram explaining this problem. For the value of the gap at each point of a centre plate unit distances of line segments (ΔS_i), drawn from the center of the centre plate and bounded by cylindrical surfaces, are adopted.

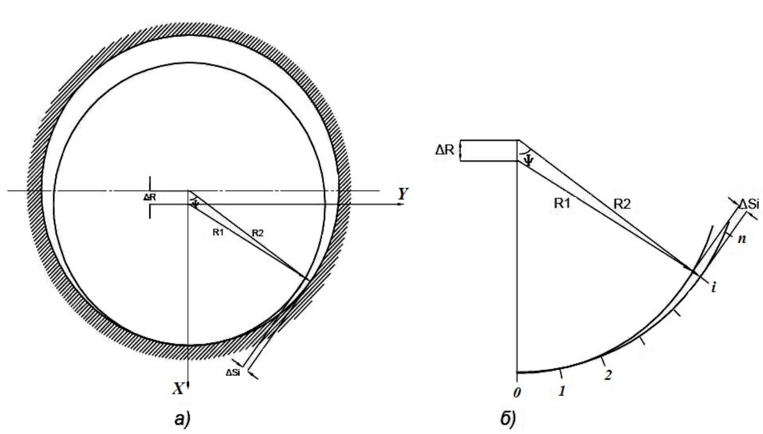
To determine the dependence of the segments ΔS_i dependence was obtained taking into account the radii of a centre plate and a centre pad, and the angle Ψ, formed by the drawn line to the point of the gap and the direction of the tensile force, which coincides with the longitudinal axis of the car.

To calculate clearance around the circumference between cylindrical surfaces of a centre plate and a centre pad, segment of a circle is partitioned into п equal segments and distances ΔS_i are determined for them (see Pic.1). See formula (16), where $\Delta_R = R_2 - R_1$.

For the purpose of numerical analysis of wears of cylindrical surfaces in centre plate units of cars on the basis of the obtained equations an algorithm was developed, enlarged scheme of which is shown in Pic. 2, and the program, taking into account the degree of wear in conjunction of a centre plate unit. Parameters of the car, mechanical characteristics of materials of centre plates and centre pads, length of the contact area, as well as the gap between centre plate and centre pad, distance run, load of the car and other factors are used as outgoing information.

Block «Input of source data» in the diagram is used to enter in the computer memory geometric dimensions of a centre plate and a centre pad, characteristics of materials of which they are made, as well as characteristics of loading conditions necessary to conduct numerical experiments.

After entering a numeric value, control is passed to block «Processing of source data». It provides validation of input figures and clearing of scratch arrays used in subsequent calculations. The gaps in connection with the length, the contact area between cylindrical surfaces of a centre plate and a centre pad depending on their size deviations from the nominal specified in the drawings are calculated. For this purpose, circumferences are divided into п equal segments and distances ΔS_i to cylindrical surface of a centre plate are determined (see Pic. 1).



Pic. 1. Coupling of cylindrical surfaces of a center plate unit, when pulling force coincides with its axis.

In the block «Defining contact pressure» calculated values of contact pressures depending on the size of a centre plate and a centre pad and considering the tensile force N (t) are calculated.

In the block «Determination of wear on the first section of operation» possible wear in a limited area of contact is defined in the first period of operation, which is source information to further evaluate changes in the contact pressure and wears depending on the mileage of the car and the characteristics of the track.

In the block «Forming the system of equations and load vector» it is required to create array elements of the system of equations and vector loads. It provides filling in the values of contact pressure distribution in a centre plate, which help to record the magnitude of wear on different parts of tribocoupling.

After complete formation of the system of equations the baton is passed to the block «Solution of the system of equations».

In the block «Determination of wear in the contact area of cylindrical surfaces' nature of the change in wears is estimated based on quantities of contact pressures. Next is the turn of the block «Save calculated wear's values to the disk».

In logic block «Go to the next step», a need for further definition of wear is determined. When all steps are made, which are provided for by source data, calculation process ends.

Block «Processing the obtained results' provides a filling of arrays of graphical representation of the results using the data stored on the disk.

Block «Output of the result» displays in numerical form the available information and graphics of changes in wears in the contact area are built, based on this information.

On the basis of the developed algorithm a program is written for calculating wear of cylindrical surfaces in a centre plate and a centre pad depending on their geometrical dimensions, materials and operational conditions.

Pic. 3 shows the change in wears of cylindrical surfaces of a centre plate for eight-wheel rail with account of distance run in the running-in period on the same route.

Conclusion.

The obtained data show that in the initial period the contact area had a small extent, and then its size increases due to increasing wear.

Numerical studies have shown that wear of surfaces of centre plate units depends on the contact pressure distribution and gaps between a centre plate and a centre pad. The calculations took into account that when the oil was transported, the rail tank returned empty.

Keywords: railway, rail tank, car, tribology, centre plate units, cylindrical surfaces, contact pressure, numerical analysis, calculation methodology.

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