CONTACT PRESSURE IN CYLINDRICAL SURFACES OF CENTER PLATE ARRANGEMENT

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ABSTRACT

Contact pressure is one of main factors that influence level and character of wear and tear of center plate arrangement. Distribution of contact pressure over the contact zone in the case of cylindrical surfaces is unbalanced. A software was developed in order to numerically analyze the influence of different diameters of top (pivot block) and bottom center plate (end thrust bearing) on changing of monitored values. The obtained results have shown that the values of contact pressure depend on clearance between top and bottom parts of center plate arrangement. At the initial stage of operation the values of contact pressure for nominal values of diameters of both top and bottom part of center plate are lower than when they are manufactured with admissible departure.

ENGLISH SUMMARY

Background.

The operation of rolling stock requires special attention to highly loaded parts and units, and central plate arrangement is one of them. The central plate arrangement ensures the support of a body by a bogie and is operated with friction and under loading, it should be solid and resistible to wear-and-tear.

Tribological connection of central plate arrangement consists of two pairs of interconnected support and cylindrical surfaces of top and bottom parts of the arrangement. They are rotating relative to each other around the common center, but contact pressure and character of wear-and-tear are considerably different for every surface.

Objective *is to create a software capable to assess the influence of different diameters of top and bottom center plate on changing of monitored values of contact pressure.*

Methods. *Some works [1–3 and other] describe methods of calculated assessment of distribution of contact pressure and wear-and-tear at the support surfaces of center plate arrangements of freight cars and show the influence of different factors on their performance. Contact pressure depends on empty weight and car's load, and the character of distribution of contact pressure changes depending on the rate or wearing, especially at the stage of running-in. The wearing of support surfaces depends also on the geometrical dimensions of a car, its wheelbase, material of which central plate is made, operation conditions, presence of curves of small radius etc.*

Cylindrical surfaces of central plate arrangement due to their design have different radiuses of top and bottom parts. During running-in stage of operation the contact zone between them is of a little distance, therefore the value of contact pressure, which depends on traction effort, has its highest value in the center of that zone. To describe initial distribution of contact pressure on cylindrical surfaces of top and bottom parts of central plate arrangement with different diameters, we assume that the contact zone is located symmetrically to acting force and diminishes as the distance from the center of application of this force grows.

Results. *In that case the computed scheme to determine contact pressure on cylindrical surfaces of top and bottom parts of central plate arrangement is developed, taking into account that top center plate is a thick round disk in the internal part of a hole, located in the center of a massive body and fastened at the periphery. Then the relation between radiuses of computed model can be written as R_3-R_2>>R_2-R_1=Δ_0 (pic.1), where R_3 – a distance to the points of fastening of a massive body.*

Taking into consideration that when the train is in rectilinear movement the force N_0, pressing top part of central plate against bottom part, creates a field of contact that is symmetric to the point of application of such a force, friction forces can be neglected for determining normal contact pressure. But for the movement in curve the traction effort doesn't coincide with longitudinal axle of a car and the contact field relocates (pic.2), and it is necessary to account for friction force. The position of contact field can be determined by angle β, which depends on curve radius and wheelbase of a car [4]. In that case

$$\beta = 2\cdot\arcsin\left(\frac{2l}{2R_{\kappa p}}\right), \qquad (1)$$

where 2l is a wheelbase; $R_{\kappa p}$ – radius of curve for a track section.

During operation of a rolling stock the loading schemes interchange, the time period of one or another process depends on track features.

Some works [5–8 and others] show the influence of friction forces in the internal contact of cylindrical bodies of similar radiuses taking into account peripheral forces. If elastic features of materials of contacting bodies are the same, then solution of a problem on contact pressure is simpler. The exact solution for that case is given in [6]. But top and bottom parts of center plate are usually manufactured of different materials and this is reflected in computation model.

In order to determine contact area with initial radial clearance $\Delta(t)$, which is other than zero, but has close values for shaft and hole $R_1 \cong R_2$, non-dimensional contact pressure can be expressed by trigonometric polynomial [9], containing n summands:

$$q(t,\alpha) = \frac{\Delta(t)}{R_1}\sum_{i=1}^{n} b_i \sin\left[i\arccos\left(\frac{\mathrm{tg}\,\alpha/2}{a}\right)\right], \qquad (2)$$

where b_i means unknown factors, identically satisfying to the solution of that equation in all n equidistant points of contact area.

The obtained sum of n algebraic equations can be solved relative to the same amount of unknown coefficients b_i.

Efforts and moments in the contact area can be calculated after finding of unknown factors b_i using expressions (3, 4, 5). In order to determine the angle of displacement of the center of contact area β and angle of contact α_0 it is necessary to use proportions (6) and (7).

The equation (7) presents transcendental equation relative to α_0. In order to make numerical analysis, using values of contact pressure, of extension of contact area and clearances between top and bottom parts in tribological connection of central plate arrangement with the help of obtained equations, the researchers developed an algorithm. The structure flow chart of it is shown in pic.3. There are the following blocks briefly explained in original text: «data input», «initial data processing» (if errors occur the system requires amendments to initial data), «filling-in of elements of matrix of equation system», «determining of clearance», «changing of clearance», «development of load vector». After completion of equation system and of vector of a column of constant terms the block of «solution of equation system» is enacted (the leading method is Gauss method).

The computation within the blocks «determining of contact area of cylindrical surfaces» and «determining of contact pressure and clearances between top and bottom parts within central plate arrangement» is accomplished as follows. The values α_0, f, R_1, Δ(0), E_i, ν_i, are plotted, then the factors b_i are calculated, and then using their values and equations (3) – (7) the values P_0, M, β are determined. By plotting consequently some values for α_0, it is possible to select such a dimension of contact area that calculated q (t, α) is conform to plotted value of load N_0.

The block of «saving the results of calculated values of contact pressure, contact area and clearances» is connected to the logical block «next step». After all the steps are accomplished, the computation process finishes. The block «processing of obtained results» fills in output data for graphic presentation of the results and block «results output» translates the results on the screen and the graphs of distribution of pressure in contact area are built.

Conclusions. The software program had been developed on the basis of described algorithm in order to calculate contact areas of cylindrical surfaces, contact pressure and clearances between the parts of central plate arrangement.

The pictures 4 and 5 give examples of distribution of contact pressure in central plate arrangements of 8-axle tank car in relation to longitudinal force and according to existing standards [10].

The obtained data on contact pressure are used in order to determine wear-and-tear and resources of central plate arrangements of rail cars.

Key words: railway, rail tank-car, tribology, central plate arrangement, contact pressure, numerical analysis.

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