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WPŁYW KRZYWIZN LINII KOLEJOWEJ NA ZUŻYCIE SMAROWANYCH I NIESMAROWANYCH OBRZEŻY KÓŁ

THE INFLUENCE OF RAILROAD CURVES ON THE WEAR OF LUBRICATED AND UNLUBRICATED WHEEL FLANGES

W artykule omówiono konieczność wyznaczania stanu lokomotywowych zestawów kołowych i jego zmian. Przedmiotem badań jest obrzeże koła lokomotywy. Bezpieczny ruch kolejowy w dużej mierze zależy od niezawodności zestawu kołowego lokomotywy. W przedstawionej pracy skonstruowano złożony model ścierania obrzeża koła lokomotywy dla niesmarowanych i smarowanych obrzeży kół. Model ten uwzględnia przebieg lokomotywy i promień krzywizny.

Słowa kluczowe: *niezawodność zestawu kołowego, obrzeża kół, smarowanie, krzywizny linii kolejowej, promień krzywizny.*

Therefore, the condition of the locomotive wheelsets and its variations should be determined. Research object is the locomotive wheel flange. Safe railway traffic largely depends on the locomotive wheelset reliability. A complex model of the locomotive wheel flange abrasion, taking into account the locomotive run and curve radius, was constructed for unlubricated and lubricated wheel flanges.

Keywords: *wheelset reliability, wheel flanges, lubrication, railroad curves, curve radius.*

1. Introduction

Safe railway traffic largely depends on the locomotive wheelset reliability. Therefore, the condition of the locomotive wheelsets and its variations should be determined. The latter depend not only on the state of the locomotive under frame but on the railway and traffic conditions as well.

2. Research object

Research object is the locomotive wheel flange. The purpose of a wheel flange is to prevent derailing of the wheel along its circumference [1, 2]. The rolling radius of a wheel flange on the rail is larger than the rolling radius of a wheel. Therefore, the contact surface slips causing the flange to wear. In particular, the wear is a product of the friction force F equal to the reaction force N and friction coefficient φ ($F = N \varphi$).

A schematic view of the contact zone of the wheel flange and the rail is presented in figure 1.

Measurement of the flange abrasion is made 20 mm below the flange top. The thickness of the new flange should be 33 mm. The difference between the actual thickness and the above dimension will be referred to as flange abrasion y.

Theoretically, the abrasion of the flange is calculated by the formula:

$$y=IL \tag{1}$$

where I is intensity of abrasion; L is the slide path of rubbing surfaces, m.

Abrasion intensity is calculated by the formula:

$$I = K\,\alpha\sqrt{\frac{h}{r}}\,\frac{p_a}{p_r}\,\frac{1}{n} \tag{2}$$

where K is coefficient of surface roughness (for rail and wheel contact K≅0.2); α is the relationship between the contiguous areas of the rubbing surfaces at the contact area (usually, α≅1); p_a is the highest pressure at the contact area, p_a; p_r is the average

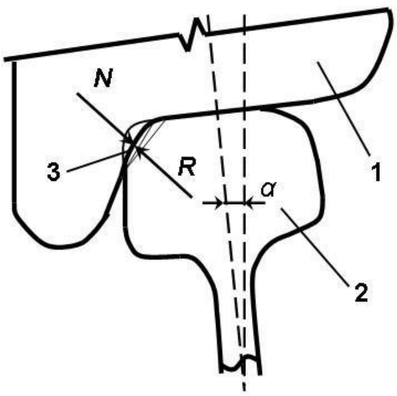

Fig. 1. A schematic view of the contact zone of the wheel flange and the rail: 1 – wheel; 2 – rail; 3 – contact zone

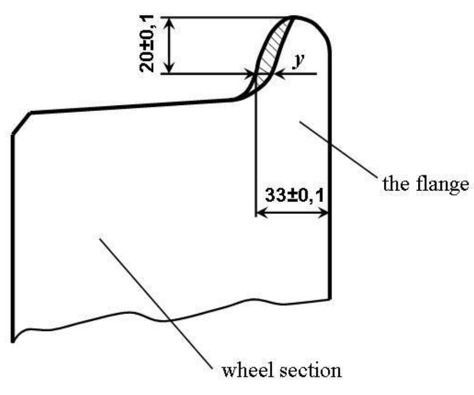

Fig. 2. Measurement of tyre flange abrasion

pressure at the contact area, p_a; n is the number of cycles; h/r is the ratio of the rubbing surface roughness height to radius.

The average pressure at the contact area is calculated by the formula:

$$p_r = \frac{N}{A} \tag{3}$$

where N is the proof load, N; A is the contact area, m^2.

The highest pressure at the contact area is calculated by the formula:

$$p_a = 0{,}578\sqrt[3]{\frac{N^2}{\Theta^2 r^2}} \tag{4}$$

where Θ is modulus of elasticity of the material, N/m; r is the radius of the surface curvature of the body in the contact area, m.

Since it is hardly possible to determine p_r, the value of which depends on the continually changing contact area, a full-scale experiment was made to determine abrasion intensity of the wheel flange.

Scientific novelty. A mathematical model has been constructed and validated, allowing wear intensity of wheelset flanges on the road curves to be determined, depending on the curve radius and the locomotive run.

Significance of research. The suggested model can be used for calculating the remaining service life of wheelsets and predicting the amount of the repair work and the need for wheelset replacement.

Description of research. Three freight (Russian-made) locomotives of the series 2M62 were tested. These locomotives consist of two sections of the total engine power reaching 2 940 kW and mass of 238 ton. Every section has six axles and the average speed of locomotives is 80 km/h. The rolling radius of the wheel circumference is 1 050 mm. The tests were made on the rail track, 75 % of which was straight, while the remaining section had curves with the radii of 650 and 1 200 meters. The stiffness ratio of the rolling wheel surface to rail was 1:1. Every time when the average distance of 10 thous. km was run, flange abrasion was measured by a measuring machine.

The research results. The values of the average wear of the wheels of all locomotives with lubricated and unlubricated wheel flanges, depending on the locomotives run, are given in figure 3.

The correlation coefficient is about one when the values are approximated by 3rd power polynomial [3, 4]. The approximated relationships between abrasions and the locomotive run are described for lubricated and unlubricated wheel flanges by the regression equations as follows:

for unlubricated wheel flanges:

$$y_1 = 4\cdot10^{-15}x^3 - 10^{-9}x^2 + 0.0001\cdot x \tag{5}$$

$$R^2 = 0.9183$$

for lubricated wheel flanges:

$$y_2 = 2\cdot10^{-15}x^3 - 6\cdot10^{-10}x^2 + 7\cdot10^{-5}x \tag{6}$$

$$R^2 = 0.986$$

where y_1 and y_2 denote wheel abrasion, mm; x is the locomotive run, km; R is a correlation coefficient.

3. Constructing a mathematical model

A mathematical model is based on the equations (5) and (6). The equations describe the variation of the wheel flange depending on the locomotive run for the case of a given reduced curve radius (1 740 m). The tests have shown that, among other things, the abrasion of both rails and wheel flanges depend on the reduced curve radius. Abrasion of the rail head, depending on the curve radius, is shown in figure 4 [5].

By approximating the relationship between an average abrasion and the curve radius, we get the equation:

$$y_b = 1476\cdot r^{-1.173} \qquad R^2 = 0.993. \tag{7}$$

where y_b is rail head abrasion, mm; r is a reduced curve radius, m; R is a correlation coefficient.

Since surface stiffness ratio of the rail to the wheel is about one, it can be assumed that the abrasion of the wheel flange and rail head equally depends on the curve radius. To determine the influence of the curve radius on the wheel flange abrasion, let us combine equation (7) with equations (5) and (6). Wear intensity is inversely proportional to the curve radius, therefore, a term of the equation, determining the curve radius, can be used as a multiplier in the function:

$$y_1 = (4\cdot10^{-15}x^3 - 10^{-9}x^2 + 0{,}0001\cdot x)\cdot A\cdot 1\,476\cdot r^{-1.173} \tag{8}$$

for unlubricated flanges:

$$y_2 = (2\cdot10^{-15}x^3 - 6\cdot10^{-10}x^2 + 7\cdot10^{-5}x)\cdot A\cdot 1\,476\cdot r^{-1.173} \tag{9}$$

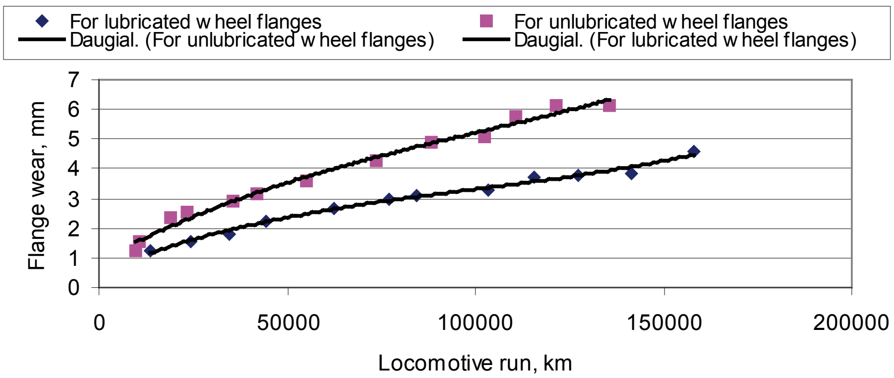

Fig. 3. Abrasion values depending on the locomotive run

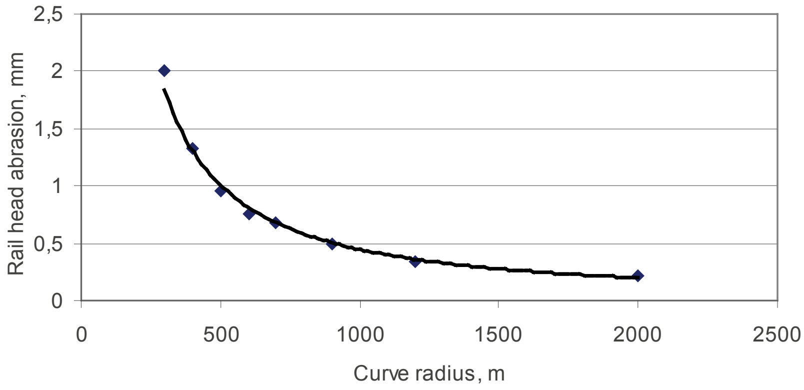

Fig. 4. Rail head abrasion depending on curve radius

for lubricated flanges, where A is a coefficient showing the relation between the abrasions of a rail and a wheel set.

It is known that when a reduced curve radius is equal to 1 740 m, then, y_b should be equal to:

$$\begin{cases} r = 1740; \\ y_b = A \cdot 1476 \cdot r^{-1.173} = 1 \end{cases} \quad (9)$$

It can be calculated from (9) that the product $(A \cdot 1740)$ is equal to 6 330 $r^{-1.173}$. The equations (7) and (8) will make a mathematical model determining the variation of abrasion, depending on the locomotive run and a reduced curve radius:

$$y_1 = (4 \cdot 10^{-15} x^3 - 10^{-9} x^2 + 0{,}0001 \cdot x) \cdot 6\ 330 \cdot r^{-1{,}173} \quad (10)$$

for unlubricated flanges:

$$y_2 = (2 \cdot 10^{-15} x^3 - 6 \cdot 10^{-10} x^2 + 7 \cdot 10^{-5} x) \cdot 6\ 330 \cdot r^{-1.173} \quad (11)$$

for lubricated flanges.

Implementing the constructed mathematical model. The dependence of unlubricated wheel flanges abrasion on the locomotive run and the radii of the road curves is shown in figure 5.

The relationship between lubricated wheel flange abrasion and the locomotive run, with the radius of railroad curve taken into account is presented in figure 6.

The graphs presented in figures 5, 6 allow us to determine the locomotive run when the wheel flange abrasion reaches the highest admissible value of 8 mm for different curve radii. For this purpose, a section is passed through a horizontal plane towards the abrasion limit (in this case, 8 mm). The relationship between the longest locomotive run and the curve radius is given in figure 7.

The analysis of the curves presented in figure 6 shows that service life of the locomotive wheelsets can be increased by 1.25 times on the typical curves of Lithuanian railroads, with the radii ranging from 1 000 to 2 500 m, by lubricating wheel flanges.

4. Conclusions

1. The relationships (5), (5) between the wear of the locomotive wheel flanges and the locomotive run were established, taking into account the reduced radius of the road curves.
2. The abrasion model of the rail flange (7), taking into account the curve radius, was constructed.
3. A complex model of the locomotive wheel flange abrasion, taking into account the locomotive run and curve radius, was constructed for unlubricated (10) and lubricated (11) wheel flanges.

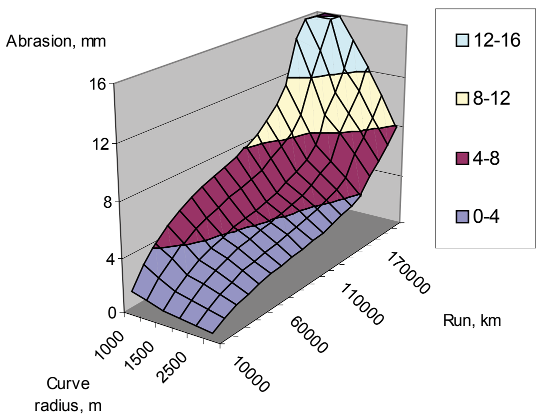

Fig. 5. The relationship between unlubricated wheel flange abrasion and the locomotive run, with the radius of railroad curve taken into account

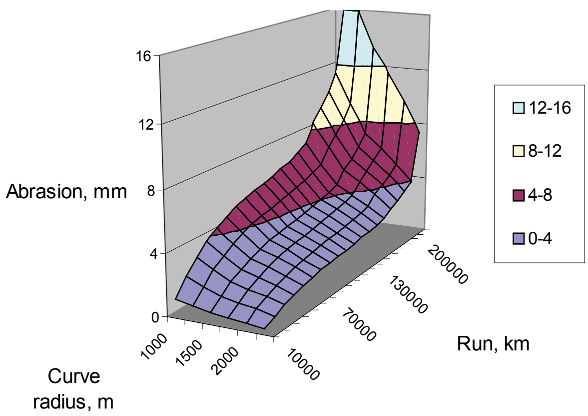

Fig. 6. The relationship between lubricated wheel flange abrasion and the locomotive run, with the radius of railroad curve taken into account

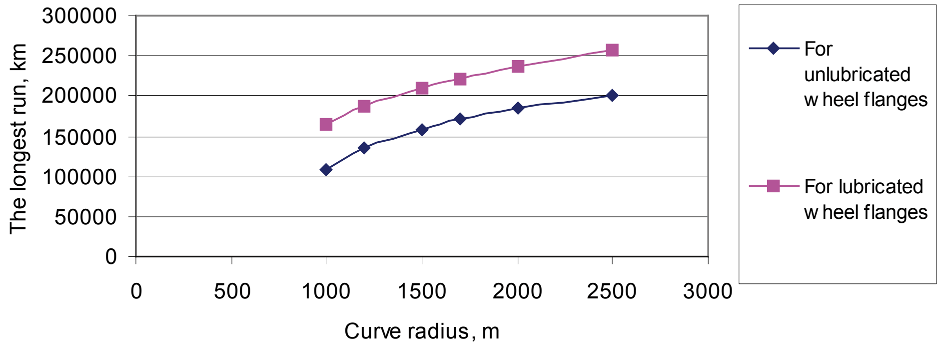

Fig. 7. The relationship between the longest locomotive run and the curve radius

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