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Improvement of the railway track efficiency by minimizing the rail wear in curves

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Abstract. The article presents the analysis results for the parameters measurements of the rail track and the ratio between values of the vertical and side wears of rails in curves of different radii under different operating conditions. It is shown that the installed elevations of the outer rail do not meet the contemporary requirements in increasing the efficiency of the track while minimizing the rail wear. At the second stage of the research, various sections were examined by type of traction, technical equipment, plan parameters and the longitudinal profile. As an example, the results of calculations are presented in Lviv-Rava-Ruska section as a promising project that can ensure the integration of railway transport in Lviv-Warsaw direction. Analysis of the results obtained with the help of the software package – MoveRW and RWPlan programmes, allowed to determine such a combination of elevations of the outer rail in curves, so that trains of different categories realize the lowest values of cross unbalanced accelerations, which provide the minimum wear of rails in compliance with regulatory requirements for unbalanced acceleration, changing this acceleration in time, elevating speed of a wheel on the removal of the outer rail.

1. Introduction

The problem in increasing the intensity of the wheel flange wear of rolling stock and gauge face is so acute that there is a risk of loss in the efficiency of a number of sections for this reason. To date, it has not been fully resolved, as evidenced by numerous publications on the "wheel-rail" problem. This can be explained by a number of factors that affect the wear of rails to varying degrees.

Thus, factors affecting the rail track wear in curves in paper [1] are divided into uncontrolled, partially controlled and controlled. The main controlled factors, according to the authors, are track gauge, the value of elevation of the outer rail and rail lubrication. The experiment was carried out on 19 curves of Lithuanian railway lines, according to the results of which it was found that the curve radius has a decisive impact on the intensity of rails wear in curves.

In paper [2], the impact of DC electric locomotives and AC locomotives on the railway track wear in small radii curves (up to 240 m) at a constant speed of 20 km/h was studied. The simulation shows that the replacement of DC locomotives for AC locomotives with the increase in tractive effort torque by 31.4% will result in 68.4% quite significant increase of the maximum wear in the "wheel-rail" system. It is found that at a relatively low speed of 20 km/h, the total wear on the inner rail is always greater than on the outer rail regardless of the type of locomotive. The authors [3] deals with the parameter of detecting the wear of the wheel-rail contact based on the radiated noise. The field tests conducted by the authors showed that noise can be used as an indicator of transition from the normal wear to a critical one. This transition is accompanied by a significant increase in sound pressure and its spectrum spreading. In [4] the results of numerical research of the vehicles-railway track interaction, taking into account the existing and assumed designs of rail fastenings are presented. The authors concluded that the train motion modes and the structure of a rail base affect the speed of side wear of the railhead in small radius curves.

The authors [5] discuss the problem of reducing the wear itensity in the "wheel-rail" system through the use of lubricants that do not harm the environment. The method of reducing the friction of wheels on the rails by a decrease in temperature directly in the contact zone is considered. The idea of the method is based on the provision that at lower temperatures the wear occurs to a lesser extent. To solve the problem of reducing the wear of rolling stock wheels and rails, the authors proposed to use liquid nitrogen as a cooling agent.

The authors [6] set forth the results in research of the longitudinal and transverse displacement impact of the center of gravity for the gondola car load, in the light of the possible increase of movement speed on the figure of the wear factor of the wheels and rails surfaces.

The authors [7-9] provide data concerning the nature and amount of the rails wear. As a rule, the additional vertical wear caused by unbalanced acceleration is considered [8], and the additional side wear for the outer rail at unbalanced accelerations directed outwards of the curve is also considered. [9].

It is believed that the calculated elevation of the outer rail h at the weighted-average quadratic speed $V_{\text{weav qu}}$ provides the same average force impact on the inner and outer rails, that is:

$$\sum Q_{\text{out}\,i} = \sum Q_{\text{inn}\,i}\ . \tag{1}$$

The theoretically correct approach to determining elevation h (formula 2) by the weighted-average quadratic speed $V_{\text{weav qu}}$ (formula 3), in practical use has significant disadvantages.

$$h = \frac{12.5 \cdot k \cdot V_{\text{weav qu}}^2}{R}\ , \tag{2}$$

$$V_{\text{weav qu}} \cong \sqrt{\frac{\sum n_j Q_j V_{\text{run}\,j}^2}{\sum n_j Q_j}}\ , \tag{3}$$

where $n_j, Q_j, V_{\text{run}\,j}$ – number of trains, a mass of train, running speed of train movement *j*-th category on this curve.

Condition (1) does not mean fulfilling the requirement of the equal rail wear in the curved sections of the track. A simplified view of the relationship between the forces acting on the rails and the wear satisfied the engineers for a long time. At the same time, it is known that the same force acting on the outer and inner rails leads to different wear results. This is one of the reasons why in the regulatory documents of some countries the concept of weighted-average speed has been excluded in recent years.

2. Methodology

To assess the features of the rolling stock impact on the outer and inner rail lines the following methodology was implemented.

2.1 The first stage
At the first stage, the curve examination was carried out on various sections of the railways and rail wear measurements were made. It was found that the small (up to 2-3 mm) vertical wear of both rails was observed on all 25th examined curves. The side wear of the inner rail was in the range of 2-3 mm (rarely up to 5-6 mm). The side wear of the outer rail is 3-4 times higher than the wear on the inner rail. This ratio was observed in curves of different radii with the excessive elevation of the outer rail, which led to negative transverse accelerations and caused an overload of the inner rail by vertical forces.

The unbalanced accelerations always lead to the additional wear of the rails and rolling stock. A distinctive feature of the track operation in curves is the wear unevenness of the outer and inner rail lines. If the actual cant of the outer rail is greater than the calculated one, then the inevitable longitudinal sliding, caused by the rigid mounting of wheels on the axis, occurs on the outer rail, if less – on the inner one.

The main feature of the side wear (formula 4) lies in its unevenness along the length of the track:

$$h_s = h_{ave} + h_{loc}, \qquad (4)$$

where h_{ave} – relatively the constant average wear along the entire length of the circular curve; depends on the passed tonnage and the curve radius; h_{loc} – the increased local wear on short sections.

It is confirmed that in places of the greatest change of the versine (20-m chord method) the maximum local wear is observed. Such zones are located, as a rule, at the beginning of the transition curves, at the conjunction of the transition and circular curves and near the middle of the circular curve, that is, where the unbalanced accelerations change (Figure 1). From the beginning of the transition curve at a distance of 40 meters, the versine on the section of about 10 meters vary from 20 to 59 mm (2.9 times). And on the same section the side wear increases from 1.7 to 8.3 mm, that is, 4.9 times (in Figure 1 the values are increased by 4 times). The next zone is located at the conjunction of the transition and circular curves. On the section of about 8 meters, the versine change from 85 to 95 mm, and the wear has increased from 9.2 to 13.3 mm (1.4 times). The same dependencies were observed on other curves.

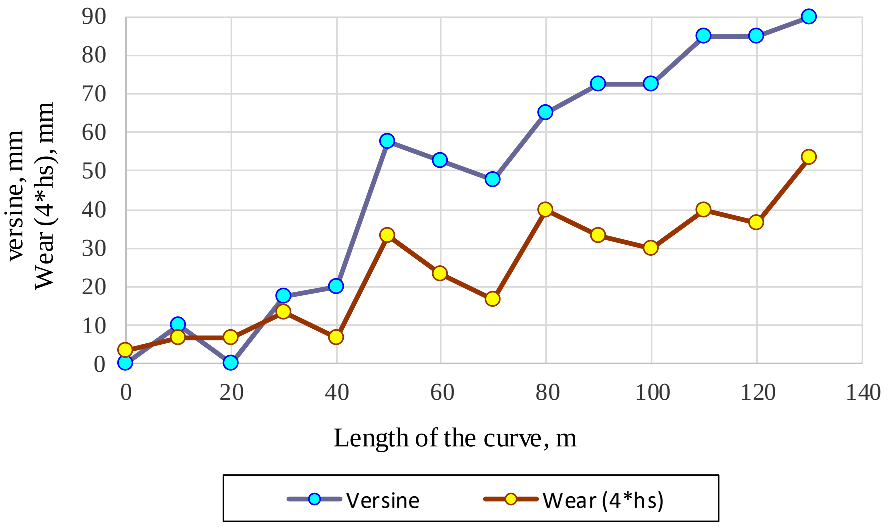

Figure 1. Change of the versine (20-m chord method) and wear along the length of the curve (curve No. 39, radius 615 m)

According to the measurements of wear and gauge parameters, the intensity of the side wear (mm/10 million tons) was determined, Figure 2.

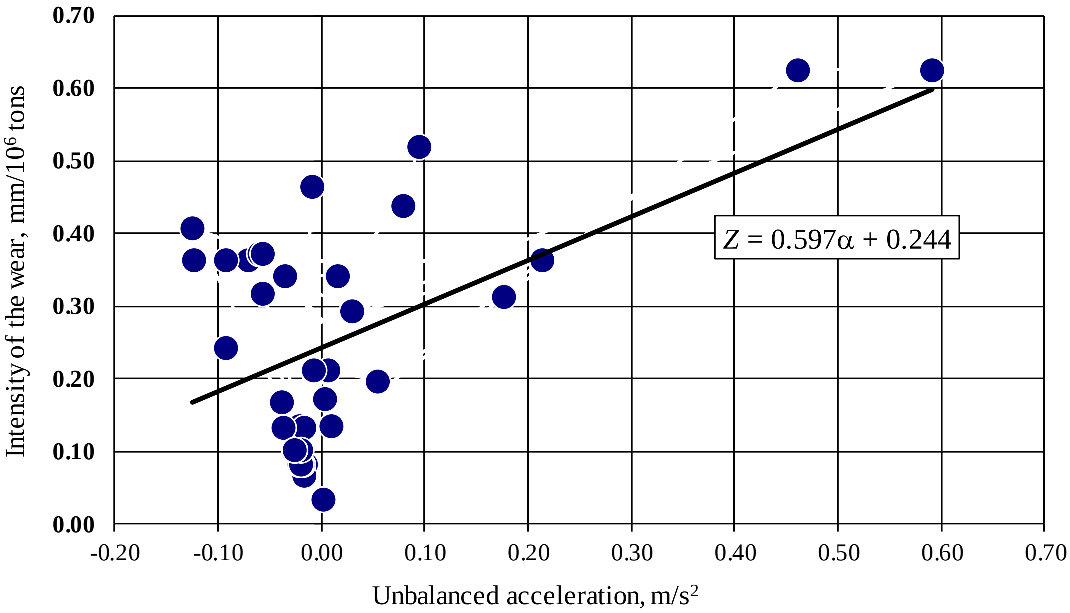

Figure 2. The intensity of the side wear, depending on unbalanced acceleration

2.2 The second stage
The second stage consists in performing calculations and analyzing the results. For this purpose, we used software package (MoveRW program is for traction calculations and RWPlan is to set the design parameters of curves, including the elevation of the outer rail by the weighted-average speed of the train movement and by the balance speed of vehicles while driving along the curve at unbalanced acceleration $\alpha \to 0$ [10]). However, the character in guiding of the vehicle in curves is such that due to the presence of sliding the wheels on rails, even when $\alpha = 0$ transverse horizontal forces appear, acting on the outer rail and causing its wear.

The research algorithm is as follows:

1. According to the results of scientific researchers at the DNURT from the previous years and similar researches of other authors [11, 12], wear indexes depending on unbalanced acceleration were accepted. Analytical expressions $Z(\alpha)$ (see as an example Figure 2) were introduced into the RWPlan program.

2. On the basis of traction calculations, authors determined speeds of movement $V_{\text{run}\,j}$ for trains of different mass Q_j and categories n_j that driving on the section.

3. For each segment of the way in the curve, unbalanced accelerations for all categories of trains α_j and the corresponding wear of the left Z_l and right Z_r rails were calculated.

4. As a result of calculations according to the above algorithm, the elevation of the outer rail was taken so that trains of all categories would realize the smallest values of transverse unbalanced accelerations $\alpha_j \to \min$.

5. Changing the elevation combination, we determined one that ensured the minimum wear on both rails while fulfilling all regulatory requirements (unbalanced acceleration, changing this acceleration in time, elevating speed of the wheel on the removal of the outer rail). Properly installed the elevation of the outer rail allows reducing the value of the guiding, lateral and frame forces and thereby increase

the strength, stability and reliability of the rail track.

3. Results

Various sections by type of traction, technical equipment, plan parameters and the longitudinal profile were considered for the research. As an example, the results of calculations are presented in Lviv-Rava-Ruska section as a promising project that can ensure the integration of railway transport in Lviv-Warsaw direction [13, 14]. The longitudinal profile of the Lviv–Rava–Ruska section, length 68 km, is mainly from 9 to 14‰ down-gradient. Plan of the line provides a significant impact on the maximum allowable speed. The length of curves is 31.7% of which the radius is less than 500 meters is 15.9% (Figures 3, 4).

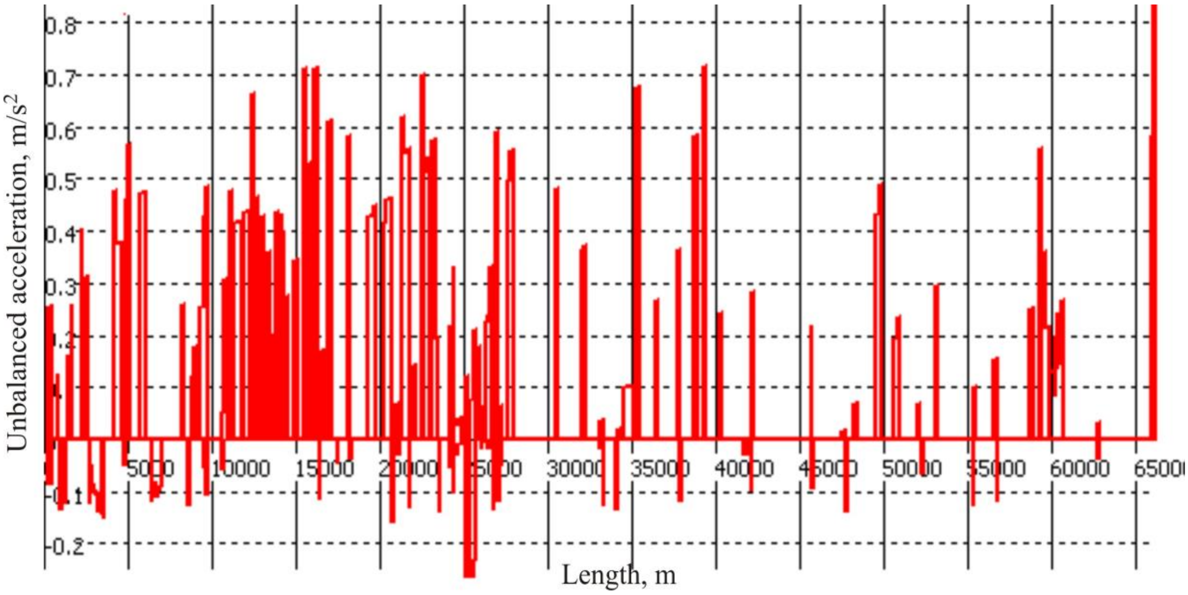

Figure 3. Unbalanced acceleration from the train movement

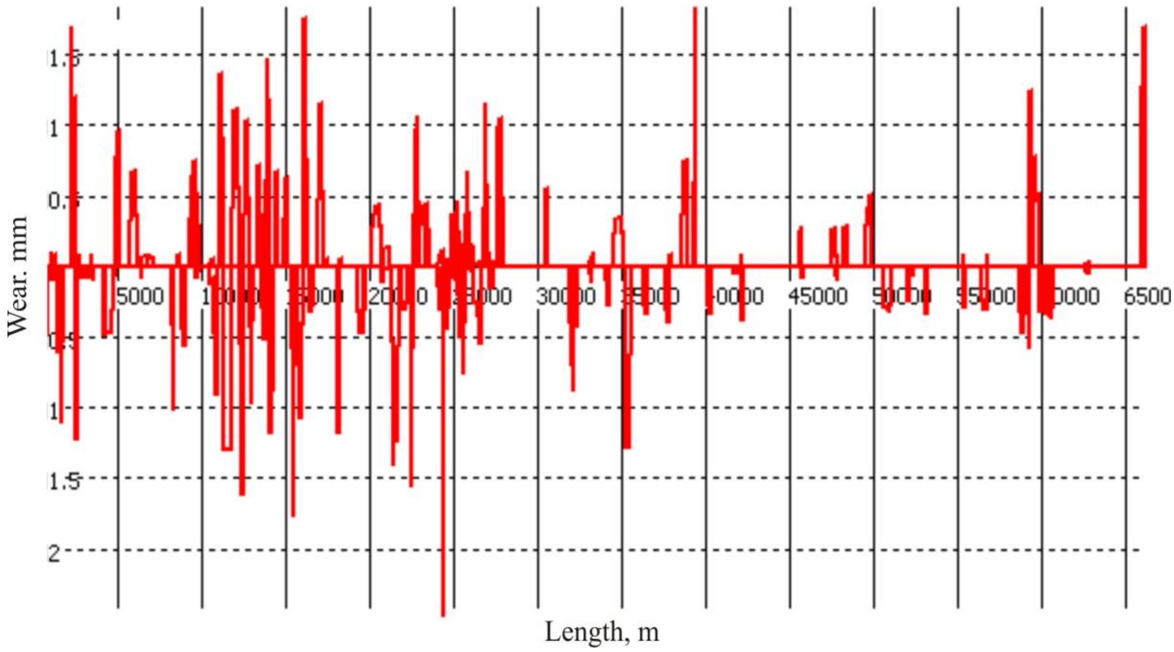

Figure 4. The wear of left and right rails from the train movement

The movement of trains in two categories is considered: passenger j=1 (locomotive M62, the mass of a train is 600 t) and freight j=1 (locomotive 2M62, the mass of a train is 2 200 t). The number of trains for the future ranged from 2 to 8 passengers and from 5 to 20 freight ones. On the basis of traction calculations, speeds of movement $V_{\text{run } j}$, unbalanced acceleration α_j for all categories of trains (Figure 3) and the corresponding wear of the left and right rails were determined (Figure 4).

Properly installed the elevation of the outer rail allows reducing the value of the guiding, lateral and frame forces and thereby increase the strength, stability and reliability of the rail track [15]. Therefore, as a result of calculations, the elevation of the outer rail was assumed that trains of all categories would realize the lowest values of transverse unbalanced accelerations.

Calculations are made for different values of the passed tonnage, and the results are presented in Figure 5.

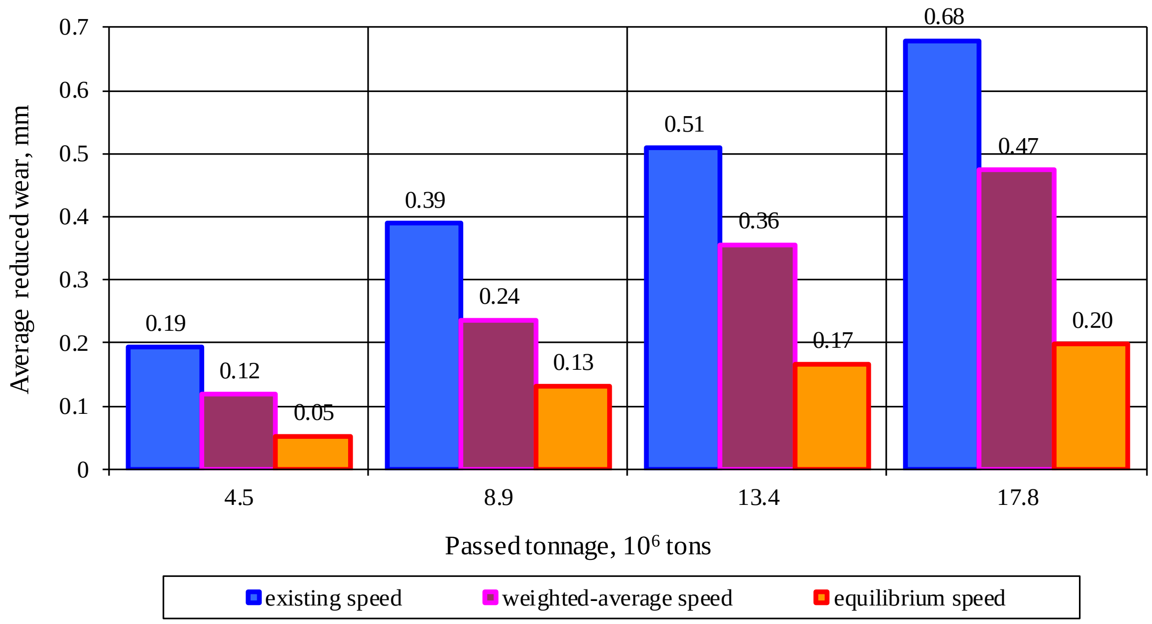

Figure 5. The average reduced wear depending on passed tonnage for existing, weighted-average and equilibrium speed

4. Conclusions

Taking into account the significant volumes of transportation direction as well as the favorable geographical position of Ukraine, it can be argued that creating an efficient modes for organizing the cargo and passenger transportation in international traffic with the EU countries with properly installed the railway track parameterswill allow attracting the additional volumes of transit traffic [13, 16, 17].

Analysis of the research results allows us to make the following conclusions:

- on the basis of analysis for the processes of increasing the rails side wear it is established that there is a fairly close correlation between the side wear, radius and unbalanced transverse acceleration along the length of the curve;
- with growth in unbalanced acceleration and the speed of train movement, the wear intensity increases, and with growth in the cant of the outer rail up to $\alpha = -0.3$ m/s^2 emergence, it decreases;
- zones of the high wear are located where there is a change of unbalanced acceleration: on the transient curves, at the conjunction with the circular curves and near the middle of the circular curves;

- one of the reasons for the uneven side wear is the violation of the smoothness of rail lines alignment. Therefore, the local side wear can be significantly reduced by systematically correcting curves. There is a relationship between the changing the curve of the versine along the length and the side wear: within the circular curve, the larger the versine, that is, the smaller the radius, the greater the wear;
- the use of the weighted-average speed to calculate the elevation of the outer rail to set the elevation of the outer rail in the curves does not allow minimizing the reduced wear from the train movement; with prevailing freight traffic, the elevation should be calculated based on the minimum of the wear, which will reduce the railway track deterioration;
- by changing the elevation, you can largely control the reliability of the track, train traffic safety and, to some extent, the costs associated with the wheel flange and rails wear.

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