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Research on the Resource in the "Wheel-Rail" Pair during the Life Cycle of Traction Rolling Stock

D. Yagoda[1], M. Babyak[2], R. Keršys[3], L. Neduzha[4]

[1]*Limited Liability Company "Scientific and Production Enterprise "UKRTRANSAKAD", Sviatoslava Khorobroho 44, 49000, Dnipro, Ukraine, E-mail: dmitryyagoda@gmail.com*
[2]*Lviv Polytechnic National University, Stepan Bandera 12, 79000, Lviv, Ukraine, E-mail: mykola.o.babyak@lpnu.ua*
[3]*Kaunas University of Technology, Studentu 56, 51424, Kaunas, Lithuania, E-mail: robertas.kersys@ktu.lt*
[4]*Ukrainian State University of Science and Technologies, Lazaryan 2, 49010, Dnipro, Ukraine, E-mail: nlorhen@i.ua*

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Abstract

The wear of wheelset bandages largely depends on the shape of the rolling surface. Therefore, the choice of a rational bandage profile is of great importance. At the same time, both technical and economic indicators are taken into consideration. The choice of rationality criteria should be justified and based on statistical regularities of bandage wear and peculiarities of traction rolling stock operation. Researching the resource in the "wheel-rail" pair (considering operational and technological bandage wear) will allow more effective planning of financial costs for the operation and repair of traction rolling stock during its life cycle.

KEY WORDS: *wheel-rail, resource, life cycle, traction rolling stock*

1. Introduction

Research on the interaction of the "wheel-rail" pair is extremely important, as they require: – a constant increase in the cost of replacing wheelsets, rails, and their elements [1,2]; – maintenance/repair/monitoring of the pair (in particular) [3-6] and the ballast-track-rolling stock system (in general) [7-9]. With a constant increase in the mass of trains and an increase in the power of locomotives, this is possible with:

- the use of reliable [10-12], environmentally friendly [13-15], energy-efficient [16-19] rolling stock;
- the application of modern materials, the latest methods, and advanced technologies [20-24].

The components of traffic safety, environmental safety, and energy efficiency are the most relevant [25-27]. Therefore, one of the important problems facing railway transport is reducing the wear of the "wheel-rail" pair [28-32].

2. Research and Discussion of Results

At the end of the 80s in the last century, an increase in the wear rate of the side surface of the rail head and the wheel flanges in rolling stock on the 1520 mm track network in Ukraine was recorded by 7-10 times. Since 1995, JSC "Ukrzaliznytsia" has implemented several effective measures to reduce the wear of wheels and rails, which gave a positive result.

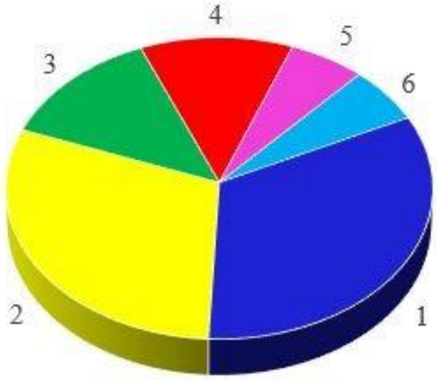

Fig. 1 Distribution of components in the life cycle in an electric locomotive:
1 – Electricity, 33%;
2 – Cost of an electric locomotive, 30%;
3 – Labour remuneration of locomotive crews, 13%;
4 – Repair of an electric locomotive, 12%;
5 – Maintenance and equipment, 6%;
6 – Infrastructure development, 6%

At one time, for VL8 electric locomotives on the Donetsk and Prydniprovsk railways, the average specific flange wear of the locomotive per 10 thousand kilometres of mileage was about 0.3 mm, and for VL11m electric locomotives on the Lviv railway, it was about 0.65 mm. However, the values of this indicator still remained significantly higher compared to the value of 0.15 mm of the base period.

Fig. 1 shows the distribution of components of the life cycle in an electric locomotive [33].

It should be noted that the metal consumption (by mass) for the wheelset bands accounted for about 40% of the total costs during the repair of an electric locomotive [33]. Electricity costs reached 33% of the life cycle cost in an electric locomotive and depend significantly on the state of the wheel profile surface (rolling surface, flange).

The following parameters should also be considered in the calculation of economic indicators: the intensity value of wheel wear, the value of resources, and the frequency of turning. Among the number of statistical regularities for the wear of wheelset bandages [34] (occurring in the operation of locomotives) there is also the dependence of flange wear of wheelset bandages on their position in the wheelbase of the electric locomotive (Fig. 2).

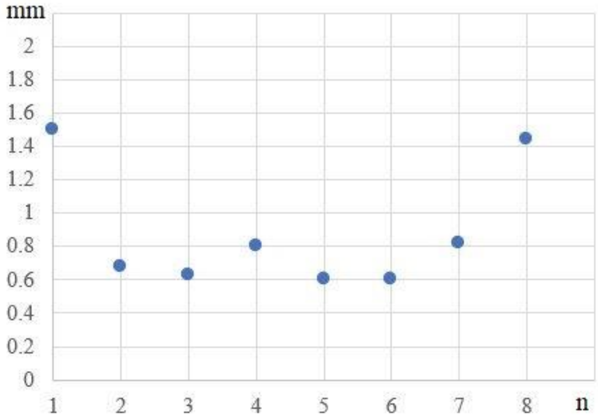

Fig. 2 Wear of the bandage flange for mileage of 10^4 km for the wheelsets in the VL8 the electric locomotive

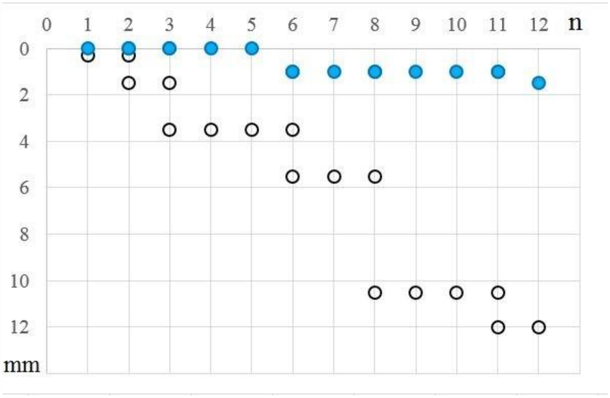

Fig. 3 Distribution of wear by components: technological and operational bandage wear for mileage of 10^4 km for wheelsets in the VL8 electric locomotive:

● – operational wear; ○ – technological wear

As can be seen, the wear pattern in the bandage of the first- and eighth-wheelsets is different from the wear pattern for other wheelsets: for the first and eighth-wheelsets, the undercutting of flanges is the most important, and for the other wheelsets – rolling. The dynamic impact on the second wheelset and others (in the direction of movement) is less than on the first "oncoming/leading" one, which determines the qualitatively different nature of its wear. That is, some wheelset function in the "flange undercutting" mode, and others – in the "rolling on the running surface" mode ("normal rolling").

For renewing the bandages profile to meet the requirements of current regulatory documents, it is necessary to perform the turning of the bandages profile. The loss of bandage thickness during the turning is technological wear. The complete wear of the bandages in terms of thickness must be divided into two components: – Δ_{Bnp} is wear from rolling and – Δ_{Btw} is technological wear when the bandage profile is renewed. The value of the ratio for these values $\gamma = \dfrac{\Delta_{Btw}}{\Delta_{Bnp}}$ characterizes the mode of wear.

For example, Fig. 3 shows the distribution of bandage wear by components for the right wheel of the first wheelset. The indicator $\gamma > 7$, which characterizes the "flange undercutting" mode. In the "normal rolling" mode, this indicator is $\gamma \le 1$.

The unevenness in the wear rate of the wheelset bandages leads to an increase in the difference in their thicknesses, and accordingly to an increase in the difference in the diameters of the wheels, which requires their change [34]. The average values of bandages wear per mileage indicator (10^4 km) for electric locomotives after complete overhauling are 1.2-1.6 times smaller in value compared to the values of wear before repair [33]. This is due to the improvement in the technical state of the running gear in the electric locomotive, which in turn improves the dynamic performance of the electric locomotive.

Different wheel profiles have different values of flange wear rates. The frequency of turnings due to the thin flange in such profiles as standard, MINETEK, and others also differ significantly. This affects the economic efficiency of the profile. For the statistical analysis of the flange wear of bandages with different profiles, and the possibility of their comparison, the authors choose a parameter that shows the number of turnings by the flange wear per indicator, i.e. per mileage of the electric locomotive, which is 10 thousand km. Let's denote it by α_f. For bandages with a different profile, the value of the parameter is determined – the number of turnings by the flange wear α_f.

These data are given in Table 1 for some electric VL8 locomotives. The availability of such data makes it possible to predict the mileage of electric locomotives between turnings and, therefore, to correctly plan measures for technical inspection and repair of rolling stock. This indicator has significantly different values for electric locomotives before and after complete overhauling. Using the indicator α_f, it is possible to predict the mileage between turnings. The results of calculations of mileage between turnings are summarized in the last line of Table 1.

Table 1

Results of mileage calculations between turnings for VL8 electric locomotives

Indicator name	State of the electric locomotive	Indicator value α_f for VL8 electric locomotives		
		1	2	3
Frequency of turnings by flange wear per 10,000 km, α_f	before CO	0.166	0.254	0.262
	after CO	0.14	0.143	0.137
Mileage between turnings (prediction), km	before CO	60240	39370	38170
	after CO	71430	69930	72990

CO – a complete overhauling of an electric locomotive

It should be noted that the data in Table 1 are obtained based on the results of a linear prediction and are the average values between all wheelsets of electric locomotives.

One of the main criteria for the economic feasibility of this bandage profile is its resource. Based on bandage wear data, the bandage resource (km) of electric locomotives is calculated:

$$R = \frac{(n+1)\cdot \ell_i \cdot \Delta_0}{\Delta_B}, \tag{1}$$

where n – is the number of inter-overhauls runs between the wheelset placement on the electric locomotive and its roll-out; ℓ_i – is the mileage between measurements at repairs and technical inspections, km; Δ_B – is bandage wear in thickness between the wheelset placement under the electric locomotive and its roll-out (operational and technological wears are taken into account); Δ_0 – is permissible bandage wear in thickness.

According to the calculation results (1), the bandage resource of VL8 electric locomotives is about 400 thousand km, which is in good agreement with the statistical data obtained for VL8 electric locomotives (Nyzhnodniprovsk-Vuzol depot) and is 350-630 thousand km [5]. The bandage resource of VL8 electric locomotives at the Yasynuvata-Zakhidne depot of the Donetsk Railway was 740 thousand km according to the original data, which is consistent with the statistical data of JSC "Ukrzaliznytsia" for the same period – 680 thousand km.

The bandage resource can be also calculated using such an indicator as the number of turnings *n* during the life cycle. The number of turnings *n* during the life cycle is determined by formula (2):

$$n = \frac{T_{nom} - T_{\max}}{\Delta_B}, \tag{2}$$

where T_{nom} and $T_{\max}$ is respectively, the nominal (full) and maximum permissible thickness of the bandage; Δ_B – is the average bandage wear value in thickness for the reporting period (i.e. over a mileage of 10 thousand km);

In this case, the bandage resource (km) over the life cycle is:

$$R = \ell \cdot (n+1), \tag{3}$$

ℓ – is a mileage between turnings, km.

Under the conditions of the Lviv Railway, the bandage wear (mainly) occurs due to technological wear, i.e. due to the loss of metal during the turning.

The bandage resource of VL11m electric locomotives at the Mukachevo depot of the Lviv Railway, which operates on the Svaliava-Lavochne, Lavochne-Beskyd, Beskyd-Volovets sections, according to initial data, was 100-120 thousand km [5]. These values of the resource are obtained by calculations (3).

3. Conclusions

Removing locomotives from service for turning and wheelset change leads to significant financial costs and complications in organizing the transportation process. The priority assessment of decisions regarding the implementation of repair or operational measures is their profitability, which requires the use of integral indicators, including "life cycle cost". Life cycle costs are understood as the total costs at all stages – from the development of design documentation to the disposal of products.

Researching the resource in the "wheel-rail" pair (considering operational and technological bandage wear) will allow more effective planning of financial costs for the operation and repair of traction rolling stock during its life cycle.

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