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Tribotechnical Aspects of Wheel-Rail System Interaction

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Abstract

The work studied and solved several issues, one of which was defining the reasonable roughness of the effective area at the wheel-rail pair, that provides their extended useful life period. 5 samples with different asperity in the range of R_z 1,322 to R_z 320 (the total number- 25) made from rails with different roughness, including rail withdrawn from service while replacement of the track structure at the open pit of SUEK company (Krasnoyarsk) were prepared for the study.
As a result of the conducted theoretical and practical studies of wheel-rail tribosystem interaction for open-pit locomotives the study defined the rational value of the roughness while forming of the rails within R_z40 - R_z20 μm, which helps to reduce worn-in time of wheel-rail pair, which in turn will prolong the period of effective service of the open-pit railway transport. Detection establishment of rational roughness of wheel-rail working surfaces will allow for the theoretical forecast of the expected calculated value of the adhesion coefficient of locomotive`s tire with the rail, and to increase its tractile efficiency.

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Keywords: tribotechnical system; friction coefficient; roughness of rail effective area; curvature radius of asperity tips; aggregated factor of roughness; rational roughness; tractile efficiency.

1. Introduction

Classical mechanics predicates that "the friction force over rather wide range is independent of the contact area".

The modern science of friction, i.e. tribology, worked out in the scientific works of Ishlinski, Kragelsky, Chichinadze, Luzhnov, Garkunov, Demkin and their students, ascertains that the friction force depends upon array of physical and mechanical properties of interacting surfaces, among them actual contact area of coworking surfaces and their roughness [1-3].

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The backend of the tribounit derivation process, i.e. units, components and friction couples, is the subject of study of triboengineering [4,5]. An example of a tribotechnical system of mining machinery is a wheel-rail interaction of mining locomotive. The basis for the functioning of the wheel-rail system is the friction coefficient at the contact area and, as a consequence the realizable with that a coefficient of engagement. In the scientific works carried out under guidance and direct involvement of Y.M. Luzhnov [6] have been found that coefficient of engagement at the wheel-rail system for trunk railway transport depends on over 50 factors, due to ranking of which 20 basic parameters, which have impact on the realized coefficient of engagement. In particular, the particulate contaminations, significantly reveal itself in the open-pit mining [7], essentially affects on the coefficient of engagement.

The out-cut rail transport due-to specialties of operational conditions has several factors, which considerable effect on shaping of the coefficient of engagement [8] under the conditions of opencast mining. This should include:

- increased pollution density of working surfaces and enhanced rail grades up to 60 ‰;
- comparably low speeds and high axle loads on wheel pairs (up to 300 kN)
- short track curvature radiuses (in the region of 40-60m)
- presence of significant amounts of curved track areas , with curve radiuses 100-200m;
- application of used rail, decommissioned from Russian Railways system;
- availability of portable tracks and, as a general, presence of a subsize trackbed or total lack of track ballast.

Considering the above, the authors have studied and solved several issues, one of which was the definition of the reasonable roughness of effective area at the wheel-rail pair, that provides their extended useful life period [9].

Numerous theoretical and experimental research works have established that the friction coefficient in-between coworking surfaces depends on physical and mechanical properties of conjugated surfaces including their roughness [1-3,10-13].

To facilitate impact assessment of surface roughness in the literature [2] is introduced the complex roughness indicator Δ:

$$\Delta = h_{max} / Rb^{\frac{1}{\nu}} \quad (1)$$

where *R*- design radius of curvature of asperity tips, calculated as geometric mean of asperity tips radiuses of working surfaces profilograms both longitudinally and transversally,

$$R = \sqrt{r_{\text{longitud}} \cdot r_{tranvers}} \quad (2)$$

h_{max} - height of biggest asperity; b and ν- parameters of the supporting curve of the roughened surface[9].

According to the molecular-mechanical theory of friction of Kragelsky I.V. [13], the friction coefficient for solids has two components – the molecular (f_{mol}), determined by molecular interaction, and the deformation component (f_{def}), characteristics of which cannot be estimated till now by impact of molecular forces in view of the difficulty of solid structure [6]. And that is why it determines by special experiments and well-known concepts about nature of matter:

$$f = f_{\text{mol}} + f_{\text{def}} \quad (3)$$

For small values of complex indicator, i.e. in case of fine gauge surface roughness, the molecular component of friction will be a dominant factor. In the contact area dominate elastic deformations, and therefore the mechanical component of the friction forces is small in compare with the molecular one, and is approximately 5% from the total friction coefficient. With increasing of Δ the plastic deformations dominate in the contact zone and, as a consequence, the molecular component of friction decreases, and the main friction coefficient is provided by mechanical, or so cold, deformation component of friction. Depending on the Δ indicator, contour load p_c and on the physical and mechanical properties of contacting materials (μ – Poisson ratio, μ=0,3; E- elastic modulus, E=2,1·10^5