To watch these materials is advised
IneternetExplorer (version 5.0 or higer) and resolutiun 1024x768
If you would like to see the Conference's Publications
is necessary to have installed AcrobatReader
(this programme is included on the CD-ROM).

SILESIAN TECHNICAL UNIVERSITY
DEPARTMENT OF RAILWAY TRANSPORT IN KATOWICE
EUROPEAN CENTRE OF EXCELLENCE "TRANSMEC"

RAILWAY WHEEL SETS

PROJECTING PRODUCING OPERATING REPAIRING

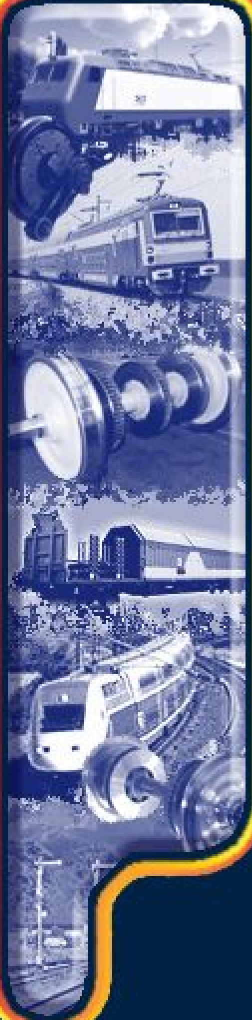
V International Scientific Conference for Middle and Eastern European Countries

Official sponsor:
KLW-Wheelco S.A.

Katowice
03 - 05 July, 2002

Railway Wheel Sets

Projecting.Producing.Operating.Repairing.



V International Scientific Conference
for Middle and Eastern European Countries

Silesian Technical University
Department of Railway Transport
European Center of Excellence
TRANSMEC

A. KOZLOVSKY[2)], Yu. TARAN[1)], M. STAROSELETSKY[2)], V. ESAULOV[1)],
S. GUBENKO[1)], A. SŁADKOWSKI[3)], A. SHRAMKO[2)]
1) National Metallurgy Academy of Ukraine, Dnepropetrovsk, Ukraine
2) Joint Stock Company "Nizhnedneprovsky Tube Rolling Plant", Dnepropetrovsk, Ukraine
3) Silesian Technical University, Katowice, Poland

IMPROVEMENT OF PROFILES OF THE WORKING SURFACE FOR CARLOAD AND LOCOMOTIVE WHEELS

Summary. During the course of investigation focused upon contact interaction improvement in twain wheel-rail, new complex-curvilinear tread profiles for locomotive and car wheels of main line and industrial transport have been developed and implemented as a result of analysis of wheel set and carriage falling within limits of rail gauge, friction, slipping and wearing out of contact surfaces, dynamic of their interaction, contact stresses and other factors.

Theoretical investigation and experimental research have been conducted as to strain fields in both rail-wheel contact area and in three-contact area, which have revealed adhesion and slip areas. Contact stresses in twain wheel-rail for various tread profiles have been determined. Maximum level of contact stresses is 25 % higher for complex-curvilinear profile than for other known ones. As a result of theoretical investigation conducted the impact of working surface profile on stressed-strained state of wheel steel in general has been determined.

Recently at railways of CIS countries wear out of car and locomotive wheel tread in flange area has considerably increased. There are many reasons for this phenomenon, but one of them being of much importance is non-adjustment of working surfaces of basic rail P65 applicable at main lines with standard wheel profiles. There are several direct reasons for flange wear out. They can be revealed while analysing contact interaction of twain wheel-rail. Under high lateral loads affecting a wheel considerable contact stresses occur in flange contact area resulting in plastic distortion of wheel working surface as well as those of rail. Here two contact areas are observed: the first one is on tread surface and the second one is in flange area. If the angle of attack does not equal to zero, the flange contact area "overleaps" the first area. Here due to difference in tread radiuses for given areas considerable slipping of wheel and rail surfaces occurs, which results in their galling.

Technique to determine amount and location of contact areas has been developed, as well as technique to analyze stress state for specified areas based on theory of elasticity, i.e. plastic strain was ignored [1-3]. Figure 1 shows allocation of contact areas for two-area contact of standard profile wheel as per GOST 9036-88 and rail P65.

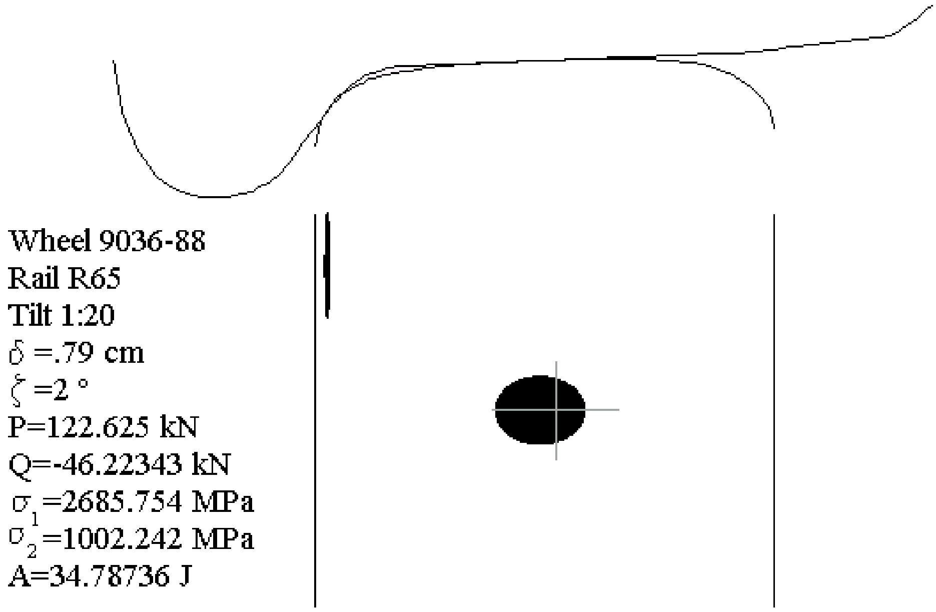


Fig 1. Contact in twain wheel-rail for standard profile under condition of two-area contact

It is obvious that the flange (elongated) contact area overleaps the first area when the angle of attack equals to ξ = 20. For calculation rail canting was considered (1:20). To execute the specified contact wheel set while wobbling should be displaced by the value of δ = 0.79 cm in axial direction relative to rail track. Here a wheel undergoes quasistatic force being equal to P = 123 kN and Q = 46.2 kN, vertical and lateral respectively. In contact areas maximum stresses occur being equal to σ_1=2686 Mpa for flange area and equal to σ_2=1002 MPa for tread contact area. It is clear that contact stress level is very high for flange area, which results in plastic strain of wheel flange at the area in question. The important parameter being determined while solving the task is power A=34,8 J consumed for friction at the flange area, which is finally the determinative factor for interacting surfaces galling.

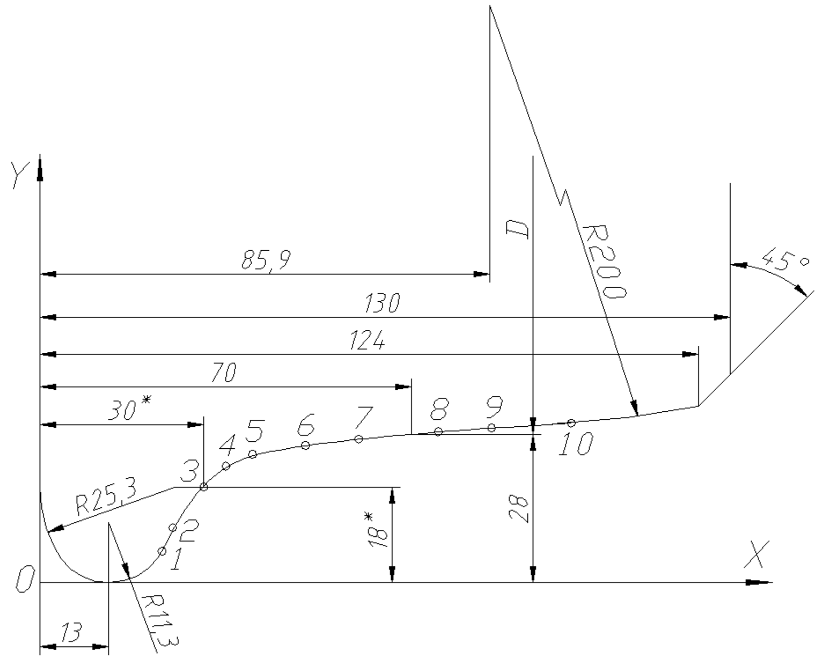
Through mathematical modelling and experimental research a number of new promising wheel tread profiles has been developed that are employed at railways of Ukraine, Russia and a number of other countries.

One of the developed complex curvilinear treads is shown on the figure 2. The figure 3 shows contact interaction of rail P65 with new profile called DMetI.

It is clear that for this profile two-area contact is executed for higher axial displacement δ=1,2 cm, i.e. conditions of rolling stock and carriage falling within limits are improved on the whole. Analysis of lateral force Q arising here reveals that the new profile ensures smoother increase in this force, and by the moment of two-area contact occurrence it achieves somewhat lower value comparing to the previous case. Contact stress σ_1=2164 MPa in flange area is also considerably lower.

And finally, the most significant effect of the new profile employment lies in relative position of contact areas. They are located considerably closer to each other, overleap of flange area is lower, this ensures essential convergence in values of local radiuses of contact areas, which results in relative slip reduction and consequently promotes contact area wear-out resistibility. Considerable reduction in parameter A = 6.75J allows to evaluate this fact.

While analyzing contact interaction in twain wheel-rail various factors were taken into consideration, such as elastic release of rail or change in wheel contact area relative position due to its strain under integrated load attack of both force and heat nature. The specified analysis was conducted based on finite element method. The figure 4 scales up wheel strain process under vertical and lateral forces applied to various contact areas with the impact of vertical and lateral loads over new design wheel strain being considered.



N точки	1	2	3	4	5	6	7	8	9	10
X	23	25	30	35	40	50	60	75	85	100
Y	5,95	10,36	18,00	21,93	24,14	25,86	27,05	28,41	29,13	30,05

* Размеры для справок

Fig 2. Complex curvilinear tread profile (DMetI VR)

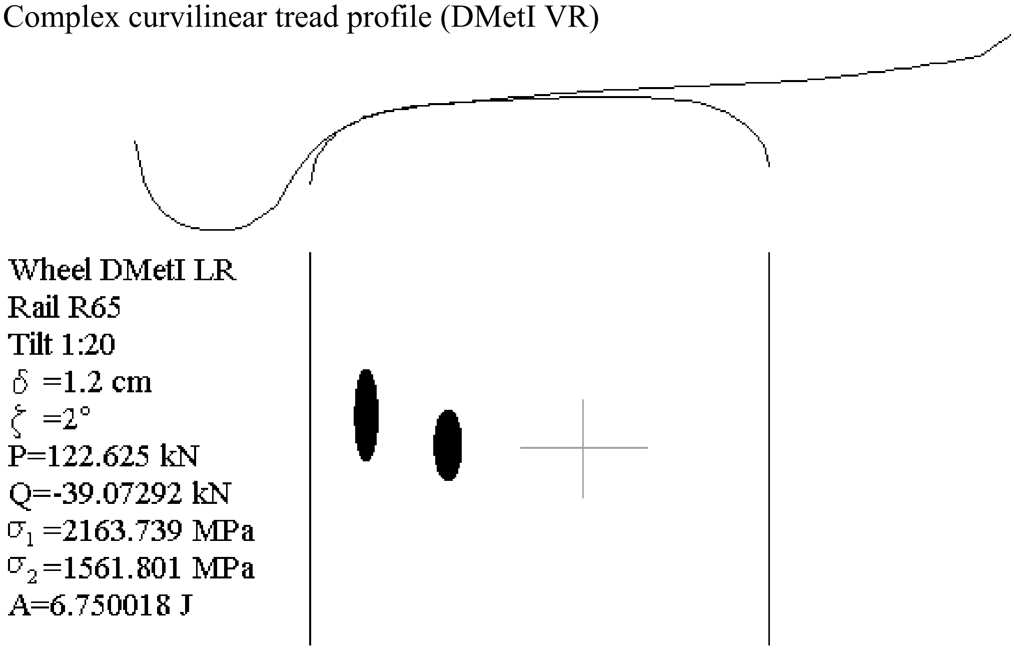


Fig. 3. Interaction in twain wheel-rail for the contact of standard rail P65 with new-profile wheel under two-area contact condition

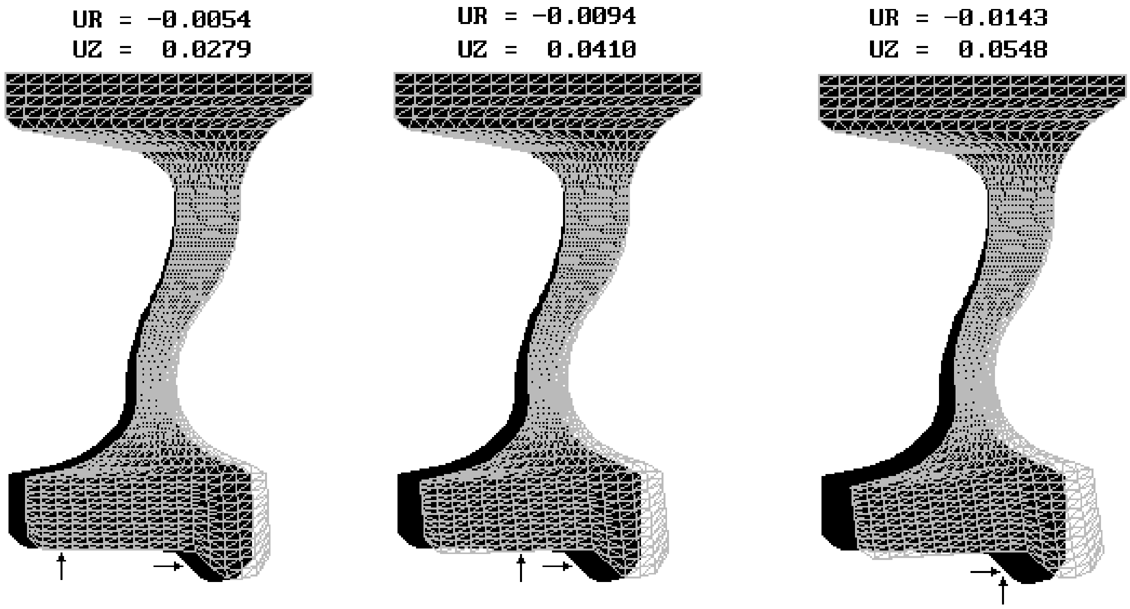


Fig. 4. Influence of the place of vertical and lateral load application over new design wheel strain

Heat strain, which can occur while braking and exceed considerably those specified on the figure, were ignored for the purpose of this calculation, but were evaluated at other calculations. It is clear that displacement of the main contact area from tread to flange causes wheel strain increase. Here axial displacement of points on bevel grows from u_z=0,0279cm to u_z=0,0548 cm. Existence of heat fields, caused by rolling stock braking, results in wheel rim displacement in the opposite direction, which means self-discharging effect for new-design wheels under heat and braking loads exposed integrated.

Figure 5 demonstrates radial σ_{rr} stresses in lower radial section of the above wheel under vertical P=150 kN and lateral Q=50 kN loads applied to various contact areas. Their level varies from $-82.4<\sigma_{rr}<36.3$ MPa for the first case and up to $-100.7<\sigma_{rr}<49.2$ MPa for the third case with transition area between wheel web and hub being whe most stressed.

One of the ways to ensure high railway wheel wearing capacity lies in investigation of structural transformation that occurs in course of operation while rail and wheel interacting near tread being in composite stress state due to combined action of external, non-uniform contact and thermal stresses. Structural transformation cause fatigue nature defects occurrence, which result in rim failure (with flange undercut being very dangerous) and in wheel profile change due to metal layer displacement along the tread. Mechanism of tread wear out constitutes a set of mechanical, thermophysical and chemical attacks and involves formation of wear-out particles and microcracks in areas of intensive plastic strain and in "white layer" zones.

The pattern of plastic process near the tread is in many respects governed by its profile that means also by the pattern and the value of contact stresses. The area of heavy strain has been registered at curvilinear area of wheel 1 of plane-tampered tread profile having incline of 1:20 and 1:7 (figure 6a). Strain is weaker following closer to tread center, however closer to external lateral rim surface strain intensity grows up again (figure 6b). Buildup of metal over rim lateral surface occurs resulting in wheel profile change (Figure 6c). The basic parameters for the layer of intensive metal strain along the rim section are specified on the table 1.

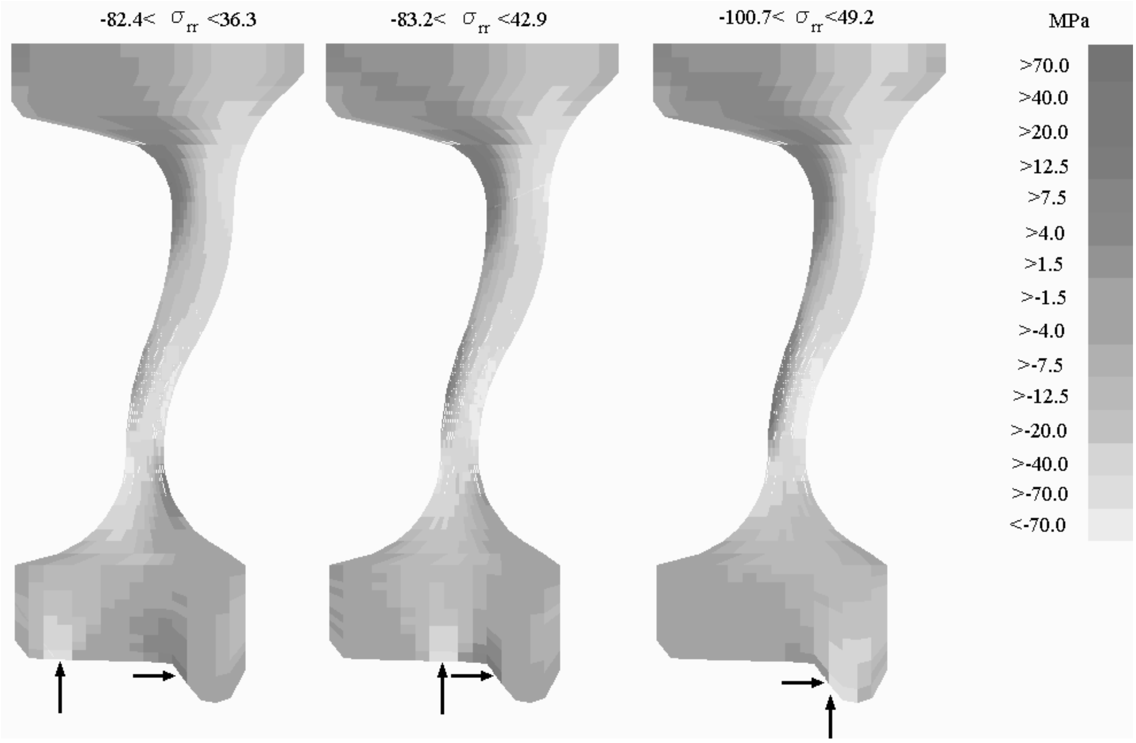


Fig. 5. Pattern of radial stresses in new design wheel under various vertical and lateral loads applied

Tab. 1

Values of strain degree ε, strain area depth h and dislocation density $\rho_{\perp}$ at various tread zones

Wheel number	ε, %			h, mcm			$\rho_{\perp}$, cm^{-2}		
	Выкружка (1)	Середина (2)	Наплыв (3)	(1)	(2)	(3)	(1)	(2)	(3)
1	75	25	90	300	30	600	$9{,}2\cdot10^{11}$	$3{,}7\cdot10^{9}$	$9{,}6\cdot10^{11}$
2	60	10	70	180	20	400	$6{,}5\cdot10^{10}$	$6{,}4\cdot10^{8}$	$8{,}1\cdot10^{11}$

Analysis of worn-out wheels of new design with curvilinear tread has revealed that near surface a zone of plastic displacement was also observed but its pattern parameters differ from those described above. Strain degree and depth of its extension are lower at all tread zones than for the standard wheel 1 (table 1). There have no cracks occurred in the area of curvilinear and practically no overflow of metal from tread center over external lateral rim surface. Wheel profile has not changed since 5 years of operation. Plastic displacement at the wheel 2 of curvilinear tread developed in milder regime, which is connected with lower contact stress values and curvilinear tread profile correspondence with wheel wear pattern under operation. It should be said that “white layer” occurrence is undesirable phenomenon but plastic displacement occurrence in thin layer is not avoidable. Elongated grains are typical for this area, in which cellular or fragmented dislocation substructure originates (figure 6d) resulting in strain strengthening. This works as autostrengthening in course of operation promoting / enabling load aging in twain wheel-rail which enhances total tractive characteristics of rolling stock. Here steel plastic resource and conditions for plastic displacement development are important, which are more favourable at the wheel of complex-curvilinear tread.

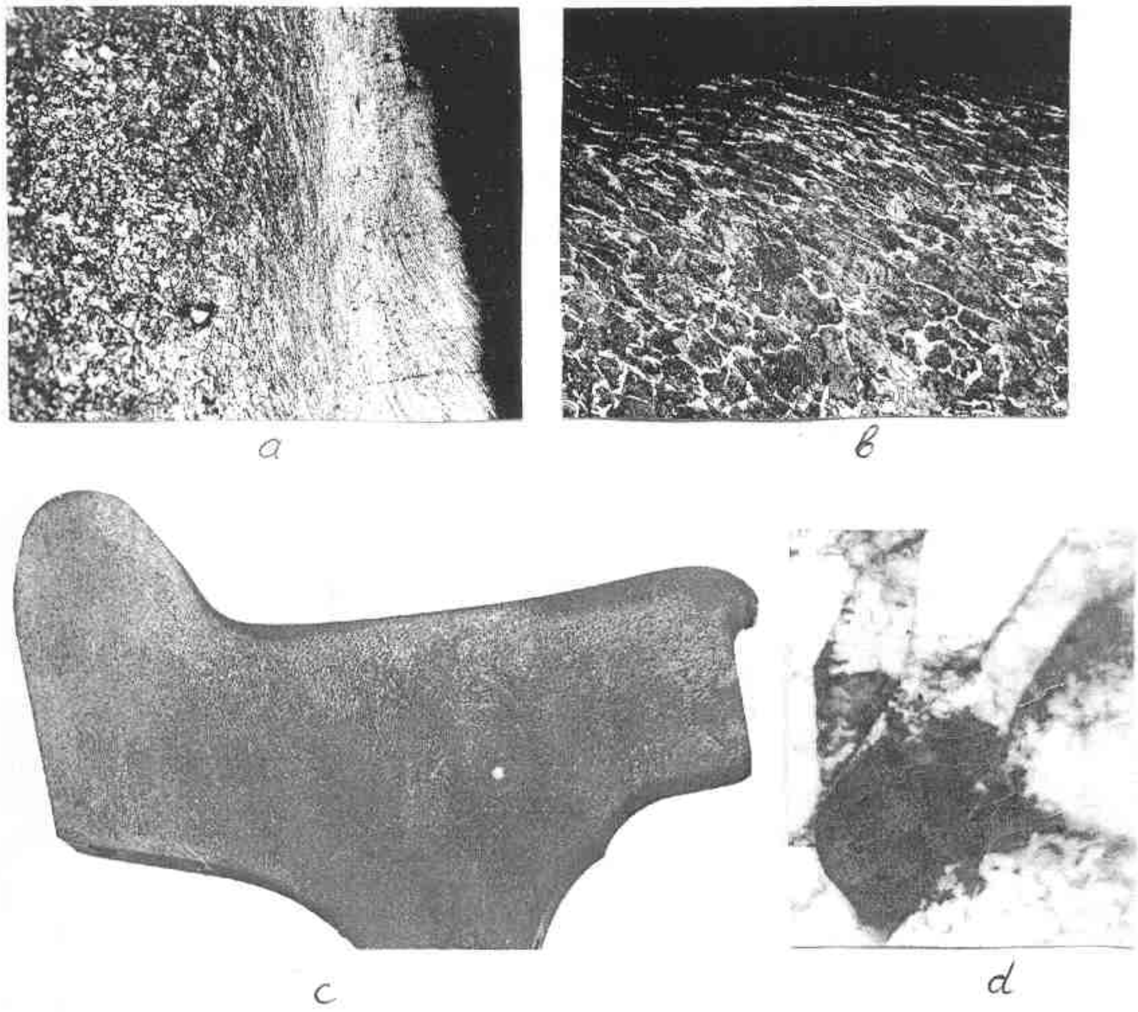


Fig. 6. Tread structure of worn-out wheel; a, b, c- x 200, d – 20000

Hence through the present investigation the new profiles for car and locomotive wheel working surfaces have been developed having enhanced resistibility indexes. Many years' employment of these profiles by railways of Ukraine, Russia and other countries proves their efficiency. Having been developed the techniques can be applied to develop promising wheel designs for railways of world leading countries.

LITERATURE

1. Essaoolov V.P., Sladkovsky A.V. Contact Interaction and Wear Examination of the Wheel-Rail Couple / Proceeding of the International Symposium on the Tribology of Friction Materials.- Yaroslavl, 1991.- Vol.2. - P.288-293.

2. Taran Y., Yessaulov V., Kozlovsky A., Sladkovsky A., Gubenko S. Wear Reduction on Working Surface of Railway Wheels / Boundary Element Technology XIII. - Southampton, Boston: WIT Press, 1999. - P.693-701.
3. Yessaulov V., Kozlovsky A., Taran Y., Sladkovsky A. Studies into Contact Interactions of Elastic Bodies for Improvement of Wheels and Rails / Contact Mechanics IV. - Southampton, Boston: WIT Press, 1999. - P.463-472.

Abstract

При проведении исследований, направленных на совершенствование контактного взаимодействия в паре колесо – рельс, в результате анализа вписывания колесных пар и экипажей в рельсовую колею, трения, проскальзывания и изнашивания контактирующих поверхностей, динамики их взаимодействия, контактных напряжений и других факторов разработаны и внедрены новые комплексно – криволинейные профили поверхности катания колес вагонов и локомотивов магистрального и промышленного транспорта. Проведены теоретические и экспериментальные исследования полей деформаций как в зоне контакта колеса с рельсом, так и в приконтактной зоне, которые позволили определить участки сцепления и проскальзывания. Определены контактные напряжения в паре колесо – рельс для разных профилей поверхности катания. В случае применения комплексно – криволинейного профиля максимальный уровень контактных напряжений на 25% ниже, чем для известных аналогов. В результате проведенных теоретических исследований определено влияние профиля рабочей поверхности катания на напряженно-деформированное состояние колеса в целом.