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INCREASE OF DYNAMIC STABILITY OF TRAINS DUE TO OPTIMAL TREAD OF WAGONS AND LOCO WHEELS

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Summary:
When making researches aimed at improvement of contact interaction in pair wheel – rail, analysis of entering the wheel sets and vehicles into rail track, friction, creeping and wear-out of contact surfaces, dynamic of their interaction, contact stresses and other factors resulted in developing and implementing new complex – curvilinear profiles of wheel treads of wagons and locomotives of mainline and industrial transport. Theoretical and experimental investigations of areas of deformation have been made both in zone of contact wheel- rail and pre-contact zone which allowed to determine areas of clutch and slippage . Contact stresses in pair wheel- rail for different profiles of tread have been determined. In case of complex – curvilinear profile maximum level of contact stresses was 25% lower than for existing analogues. Theoretical investigations resulted in determination of influence of profile of working tread on deflected mode of wheel in whole.

Key words: rail, contact loads, stresses, complex- curvilinear profile, tread.

At the present time on Railways of CIS countries wear of treads of wagons and loco wheels in zone of ridge considerably increased. A lot of reasons of this occurrence have been mentioned, but one of them, being rather essential, was that functional surface surfaces of main rail, being tracked along mainlines, H65 and standard wheel profiles did not match . There are several direct reasons of ridges wear. They are being revealed during analysis of contact interaction in pair wheel- rail. At high side loads on wheel, considerable contact stresses in ridge area occurred and resulted in plastical deformation of working surface, both wheel and rail. At that two contact zones are being observed: first –on tread and second –in ridge area. If angle of attack is nonzero , ridge contact zone " run" " overshoot" in respect to first zone. Due to this differences of radiuses of tread for these zones essential slippage of wheel surfaces and rails occurred resulting in their detrition.

Procedure of determination of contact zones size and location and also of analysis of stressed state in these zones have been elaborated by means of theory of resilience i.e. plastic deformations were not taken into account. (1-3) has been elaborated. Fig. 1 shows distribution of contact zones at double-zone contact of wheel with standard profile GOST 9036-88 and rail P65.

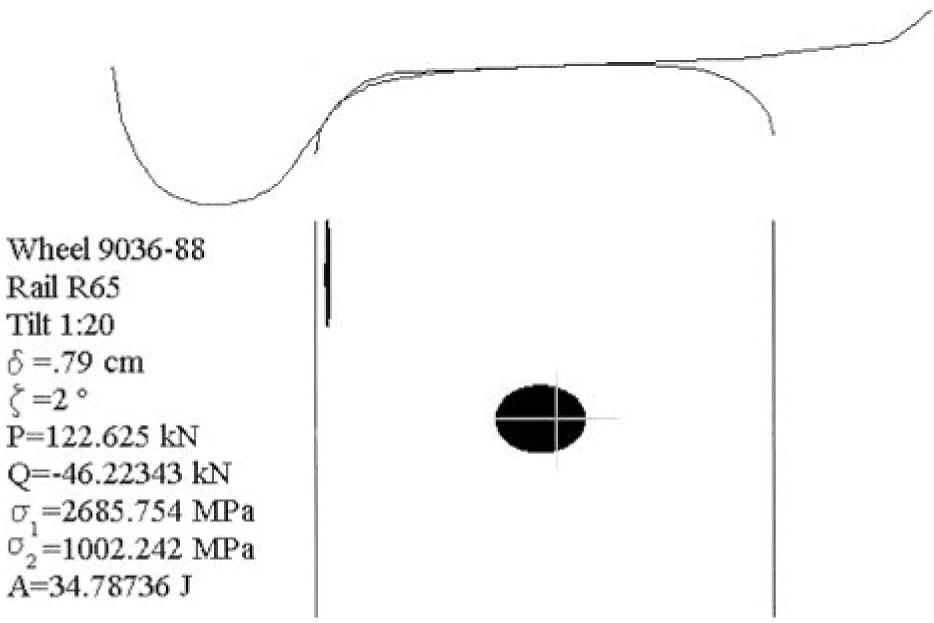
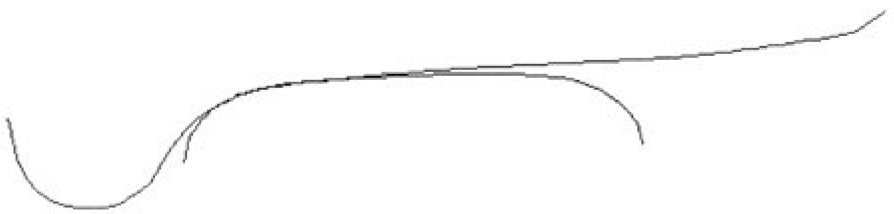


Fig. 1. Contacting in pair wheel- rail for standard profiles at double-zone contact.

It is evident that at angle of attack $\varsigma = 2^o$ ridge (elongated) contact zone run ahead in respect to first zone. During calculations rail canting a rail is tracked with (1:20) has been taken into account. To have above contact realized wheel set is required to obtain displacement in axial direction in respect to rail gauge in process of wobbling being equal to $\delta = 0.79$ см. Quasi- static forces effecting wheel and are equal to P=123 кN and $Q = 46.2$ кN, vertical and lateral respectively. In contact zones maximum stresses being equal to $\sigma_1 = 2686$ MPa for ridge area and $\sigma_2 = 1002$ MPa for contact zone occurred on tread. Apparently level of contact stresses in ridge zone is very high resulting in plastic deforming of wheel ridge in this zone. The important parameters being determined when solving task is energy being consumed for friction in ridge zone $A = 34.8$ J, which is finally determinant for detrition of interacting surfaces.

The mathematical modeling and experimental investigations resulted in developing of some new perspective wheel treads, which found an application for Railways of Ukraine, Russia and other countries. One of complex- curvilinear treads elaborated is shown at fig. 2. Fig. 3 shows contact interaction of rail P65 with new profile being named DmeTI LP.

Fig. 2 Complex- curvilinear profile of tread.



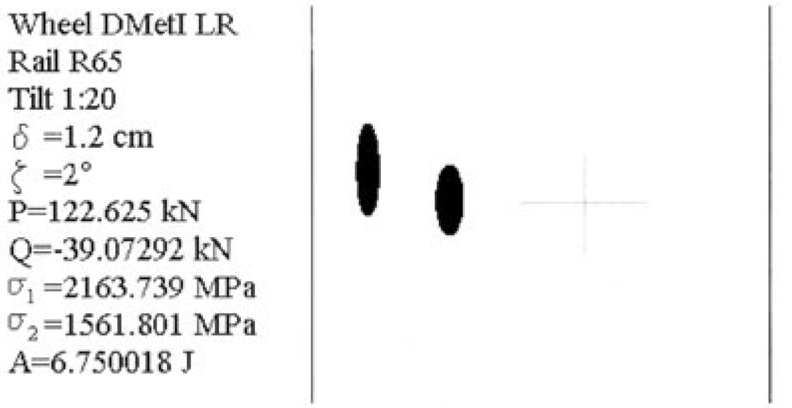


Fig. 3 Interaction in pair wheel- rail for contact of standard rail P65 with wheel, having new profile at double- zone contact.

Evidently, double – zone contact in this case is realized for bigger axial offset of wheel set $\delta = 1.2$ cm, i.e. conditions of inscribing of bogies and rolling stock in whole have been improved. The analysis of lateral force Q arising at that shows that for new profile more smooth growth of it is provided, but at the moment of double- zone contact it has rather lower value in comparison with previous occurrence. Also contact stresses in ridge zone have been considerable decreased $\sigma_1 = 2164$ MPa.

And, finally the greatest effect of new profile application gives change of relative disposition of contact zones. They are disposed essentially closer to each other, runoff of ridge zone decreased and it provides considerable convergence of values of local radiuses of contact zones , resulting in decrease of wear of the surfaces in contact. This fact can be evaluated according to considerable decrease of parameter $A = 6.75$ J.

When analyzing the contact interaction in pair wheel- rail several factors have been taken into account such as elastic release or change of relative disposition of contact wheel surface due to its being deformed under influence of aggregate of loads, applied to it both of force and thermal nature. The last analysis has been made using method of finite elements. Fig. 4 showed enlarged deformation for wheel effected by vertical and side force being applied in different contact zones, influence of vertical and lateral load on deformation of wheel of new construction has been taken into account. Thermal deformations which could tale place in process of braking and considerably exceed those shown on figure, have not been accounted in calculation given, however have been determined at other calculations. As we see, offset of main contact zone off

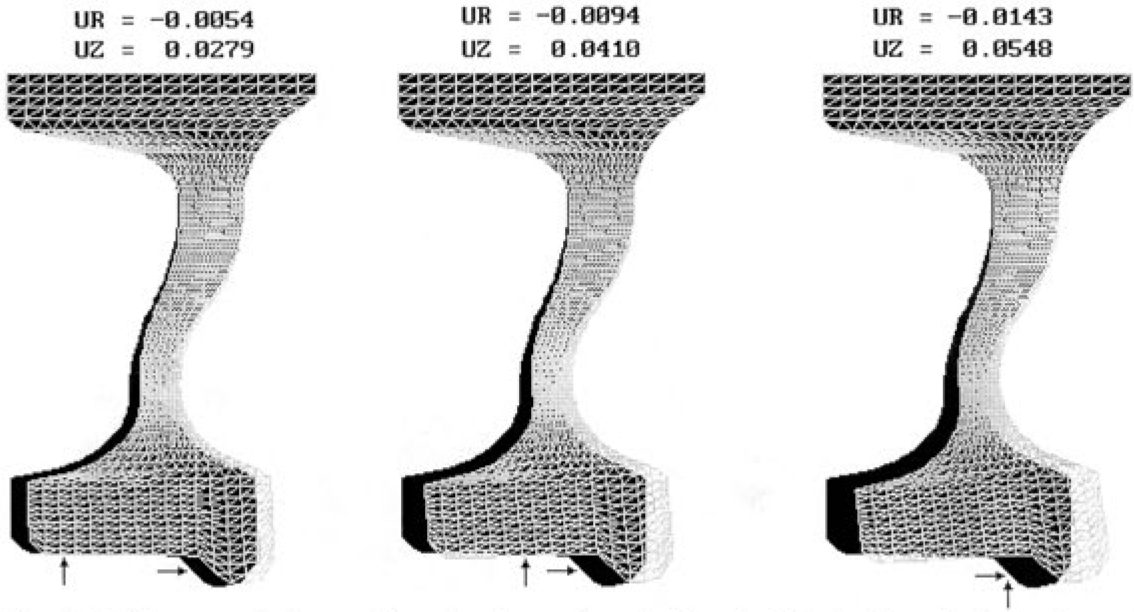


Fig. 4. Influence of place of application of vertical and side load on deformation of wheel of new design

tread to ridge results in increase of wheel deformation. Axial offset of points on bevel being increased from $u_z = 0.0279$ cm to $u_z = 0.0548$ cm. Occurrence of thermal fields, stipulated by deceleration of rolling stock causes displacement of wheel rim in opposite direction, so it is possible to say about presence of effect of self-discharge of wheels of new construction when loads and heat of deceleration being co-acted.

Fig. 5 shows radial σ_{rr} stresses in low radial section of above wheel when applying vertical $P = 150$ кN and side $Q = 50$ кN loads in different contact zones. Their level varied from $-82.4 < \sigma_{rr} < 36.3$ MPa for 1 case, to $-100.7 < \sigma_{rr} < 49.2$ MPa for 3 case and the most loaded is proved to be zone of transition from wheel web to hub.

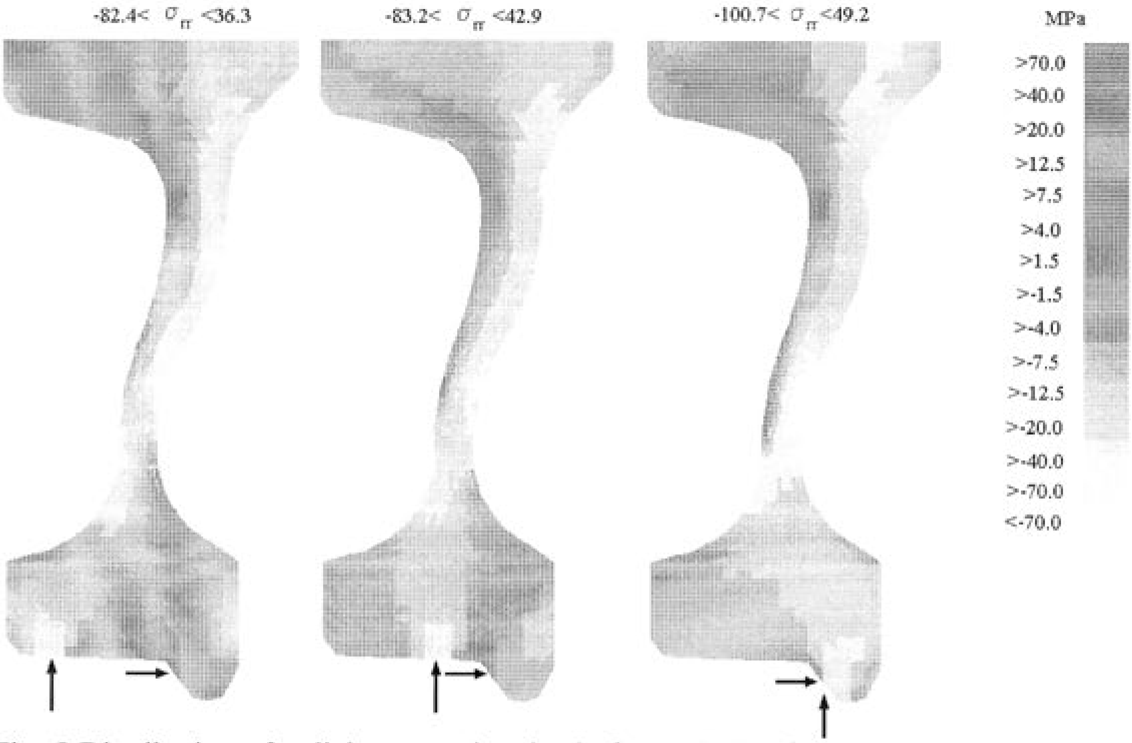


Fig. 5 Distribution of radial stresses in wheel of new design for different application of vertical and side load.

One of methods of high wear-resistance of railway wheel is investigation of structural changes, which occur in process of service when interacting of wheel with rail near tread, which is in complicated stressed state due to combined effect of external, non- uniform contact and thermal stresses. Structural changes cause defects of fatigue origin, which result in rim destruction (very dangerous is undercut of ridge) and change of wheel profile resulted from offset of layers of metal along tread. Mechanism of wear of tread is set of mechanical, thermalphysic and chemical occurrences and is connected with formation of particles of wear and micro cracks in places of intense plastic deformation and in sections of " white layer".

The nature of plastical process near tread is in many respects determined by its profile and so, nature of distribution and value of contact stresses. Wheel 1 with cone-and- plate profile of tread having slopes 1: 20 and 1: 7 showed zone of strong deformation in place of hollow (fig. 6a). When transiting to the middle of tread intensity of deformation is lower, however when approaching to external side surface of rim intensity of deformation again increased. (fig. 6b). Buildup of metal on lateral edges observed, resulting in change of wheel profile (fig. 6b). The main parameters of layer of intense deformation of metal along rim section are shown in table 1.

Таблица 1

Values of degree of deformation ε, , depth of deformation zone h, and dislocation density $\rho_{\perp}$, in different areas of tread

Wheel number	ε, %			h, мкм			$\rho_{\perp}$, см$^{-2}$		
	Hollow (1)	Mid-dle (2)	Buildup) (3)	(1)	(2)	(3)	(1)	(2)	(3)
1	75	25	90	300	30	600	$9{,}2 \cdot 10^{11}$	$3{,}7 \cdot 10^{9}$	$9{,}6 \cdot 10^{11}$
2	60	10	70	180	20	400	$6{,}5 \cdot 10^{10}$	$6{,}4 \cdot 10^{8}$	$8{,}1 \cdot 10^{11}$

Analysis of wheels worn 2 of new design with complex- curvilinear tread showed that near surface zone of plastic offsets is also revealed, however, its nature and parameters are different than those described above. Degree of deformation and depth of its distribution on all the areas of tread is lower than standard wheel 1 (tabl.1). As result cracks in zone of hollow did not occur and practically there are no buildup of metal from the middle of tread to external side edge of rim. Profile of wheel after being used during 5 years did not changed. Plastical offsets of wheel 2 with curvilinear surface have been developed in more mild regime which is connected with lower values of contact stresses and correspondence of profile of curvilinear tread to nature of wear of wheels when being operated. It should be noted that occurrence of " white layer" – is undesirable , but it is impossible to avoid plastical offsets in thin layer of rim. Elongated grains are characteristic for this zone where cellular or fragmented dislocation substructure are formed (fig. 6c) resulting in deformation strengthening. This is – autostrengthening in process of operation, providing run-in in pair wheel- rail, what improves overall thrust power characteristics of rolling stock. Here the most important are resources of steel plasticity and conditions of plastic offset development, which are most favorable for wheel with complex- curvilinear tread.

Fig. 6 Structure of worn wheel tread ; a, b – x 200, r-x 20000.

So, the researches made resulted in development of new profiles of working surfaces of wagon and loco wheels, having improved values of wear resistance. The fact they have been used on Railways of Ukraine , Russia and other countries is a prove of their effectiveness. The procedures elaborated could be used for perspective designs of wheels creation for railway of leading countries of the world.

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