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STRESSED- DEFORMED STATE OF RAILWAY WHEELS OF DIFFERENT DISIGN.

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Summary

National metallurgical academy of Ukraine jointly with JSC " Nizhnedneprovsky tube rolling plant" have been solving problems of development of new details and units of railway engineering for 35 years. During above mentioned period 25 designs of wheels and 6 new treads have been elaborated, which received patents of leading countries of the world and authorship's certificates of USSR. Developments undergone service tests at Pridneprovsk railway, other railways of Ukraine and Russia, as well as at industrial transport. Above developments have been obtained being based on mathematical modeling of interaction in pair wheel- rail, undergone laboratory, bench and service tests in comparison with the best world samples. Strength analysis of wheel design was based on method of finite elements. With purpose to determine stressed – deformed state of wheels of new design with full and minimal rim the package of computer programs has been developed being based on application of semi- analytical MKE.

Also famous packages of applied programs designated for different designs calculation on MKE have been used.

Key words: stressed- deformed state, railway wheel, method of finite elements, service tests.

Important and actual task of mainline and industrial transport in conditions of continuous acceleration of motion speed and axle loads is considered to be an increase of service life of wagon and loco wheels. Effective method of this task solving was development of new wheel designs meeting up-to-date service requirements. Rather complete understanding of stressed state of railway wheels could be obtained when testing wheels, formed into wheel set, under vertical, side and joint, as well as heat loads at fully or ultimately turned rim. Stressed state of wheels of different types to GOST 9036-76 (1) " UIC" (2) and wheels with torodial web (3) (fig. 1a – b) have been investigated on special bench (fig. 1г). Bench tests allowed to make a conclusion that balanced life of web, small value of deflection moment of rim, considerable relief of web during action of combined loads, lower value of compression and tension stresses were an evidence of reliability and perspectiveness of toroidal wheels. (3).

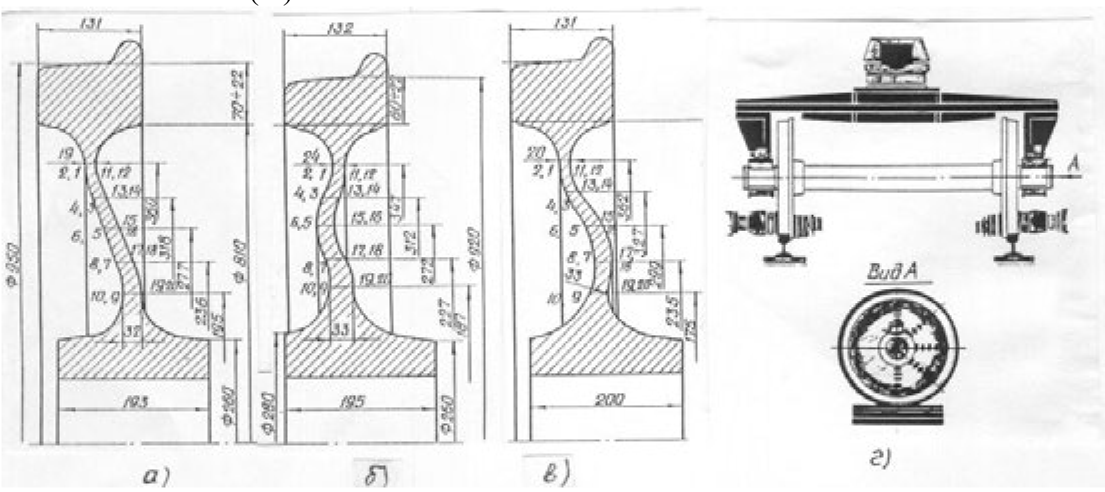


Fig. 1 Wheels of different designs : GOST (a), UIC (b), with toroidal web (в) and test bench (г).

In order to prove the results of bench tests train tests have been performed. Fig. 2a shows change of radial and tangential stresses in wheel webs (1) during the period of continuous braking, which is an evidence of constructive non correspondence of cone-and-plate web to high complex loads. Transition zone from rim to web is especially dangerous , where alternating deflection moment causes fatigue cracks from inside of the wheel. In such exploitation conditions cone-and-plate web operates at the brake point of its constructive capability.

Stressed state of wheels webs " UIC" (2) is characterized by increased alternating radial and tangential stresses (fig. 2b).

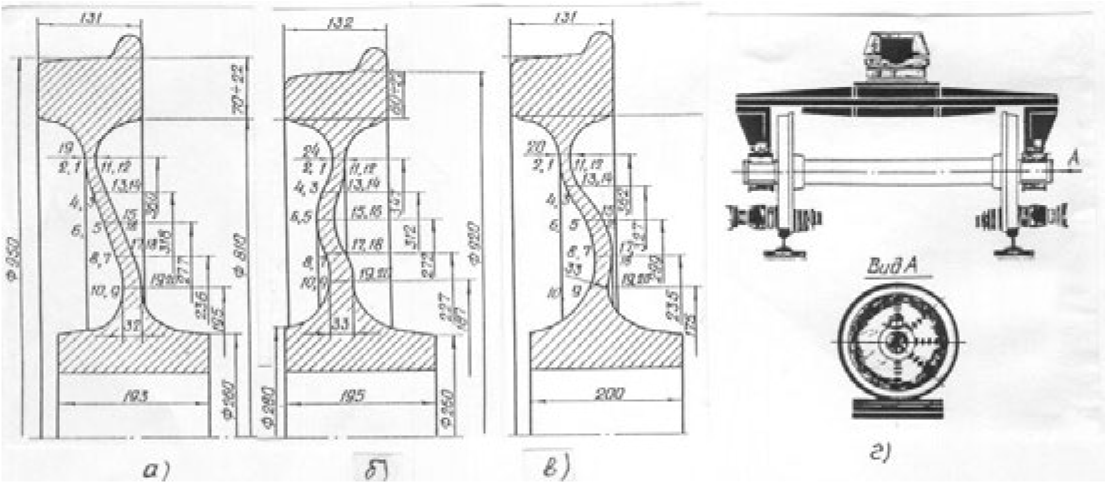


Fig. 2 Wheels of different designs : GOST (a), UIC (б), with torodial web (в) and test bench (г)/

Three stressed zones are evident in places of transition of web into rim and hub and in the center of web, where tangential stresses increased 2,1 – 6 times. Coincidence of radial and tangential stresses on mark from inside and outside is evidence of complex-stressed state of wheel web “ UIC” (2) during operation. Analysis of radial and tangential stresses from complex loads along torodial web (3) showed their relative stability (fig. 3).

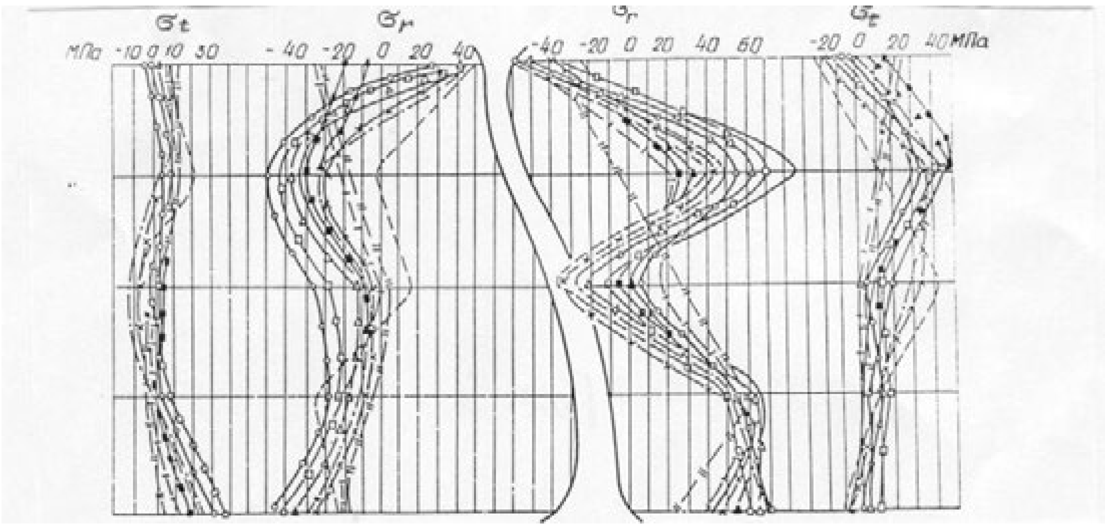


Fig. 3. Change of radial and tangential stresses in webs of torodial wheels.

This is an evidence of the fact that torodial web takes up different service loads stably and relatively uniformly and, what is important, as far as duration of deceleration increases, stresses, mainly, decrease due to self-relief of web, what is a positive constructive value of such wheels. Wheels with torodial form of web (3) have been tested on hydropulsed press . In result of the tests it was stated that fatigue strength of these wheels came to 90 t and fatigue strength of wheels (1) was within 80-90 t.

Mathematical processing of results of train tests of three types of wheels allowed to transform torodial web into curvilinear self- relieving one. Summation of coordinates of points was obtained what helped to obtain curvilinear generatrix of mean surface of web consisting of three sections for conditions of smooth conjugation. It was dictated by particularity of interaction of stresses from mechanical loads with temperature stresses resulting in these stresses compensation from both sides with web being self-relieved.

In order to implement new design of wheels it is required to perform trial analysis of their stressed state for different conditions of loading. Calculation of wheels has been made by means of semi-analytical methods of finite elements based on programs, elaborated in NmetAU. Complex of programs and procedure of calculation are described in literature (1-2). As example we shall adduce investigations of deflected mode and development of new design of wheels for Indian Railway.

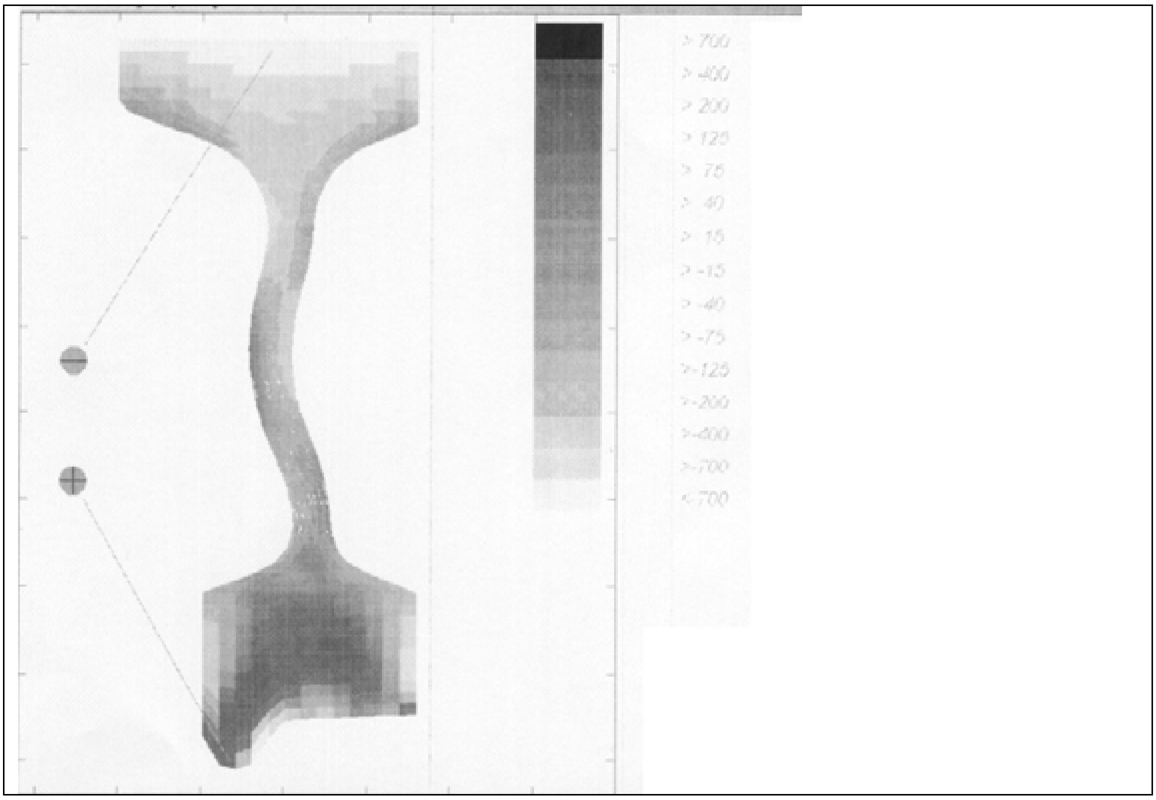
At the present time compound wheel EMU/M-0-1-004 is being used as reference wheel of Indian railway. This is rather massive wheel having wheel center with practically straight web. Calculation of this wheel has been performed by means of above mentioned original programs, and stress fields being stipulated by pressing-on of tyre have been investigated by means of MSC/NASTRAN for Windows.

Comparison of deflected mode of wheels being stipulated only by force factors (vertical and side loading, both static and dynamic) showed that reference wheels as well as new design are rather operable. However, recording of thermal stresses arising in process of service both at emergency and sustained braking showed that wheel design suggested had essential priorities in comparison with reference wheel.

Theoretically wheels have been stationed in different conditions. Braking has been modeled within 30 sec, heat flow being given from braking block equal to 0,1 kW/sm2, which was supplied to functional tread of wheel. At rather massive rim distribution of temperatures along wheel section was practically equal. Maximal temperature on rim surface came to 480 ºC.

Fig. 4 showed radial stress fields in wheels of new design at vertical force being equal to 100000N and heat flow on tread being equal to 0.05 kW/sm2,stipulated by braking within 10 sec. At that in lower radial section there was radial stresses field with level from – 118 Mpa to 68 Mpa. The comparison with reference wheel EMU showed that at analogous loading the level of radial stresses of the latter was from – 134 Mpa to 71 Mpa. Considering the fact that at Indian Railway wheels experience multiple cycles of thermal effect when braking (to 250 per day) , the alteration of stresses in webs for wheels EMU is a factor which negatively effects fatigue strength of wheels.

The imperfection of design of wheel EMU is also the fact that it is compound. Having similar thermal stresses the reduction in tyre tension and its turn-over is available. This peculiarity was managed to have been taken into account using application package MSC/NASRTAN for Windows. By means of that the deflected mode of compound wheels (with tyres) was determined. Using package MSC/NASRTAN for Windows the FE- model of above wheel was created .



- 700
- 400 - Wheel in question
- 200 New design
- 125 Vertical force 10000kg
- 75 side force 0 kg
- 40 braking 0 min 10 sec
- 15
- -15 Heat flow 05 kV/cm^2
- -40 Tightness 010 cm
- -75
- -125
- -200
- -400 Extremum of stress field[3]
- -700 max 682.4 kg/cm^2
- -700 min – 1179.5 kg/cm^2
- ghj
- tjh
-

Stresses are investigated in redial section			Upper
			Lower
s	s	Outlet (exit)	

Fig. 4. Stress distribution in wheel of new design at vertical force and heat flow stipulated by braking.

When creating FE- model three-unit axisymmetric finite elements were used. Actual properties of wheel steel were laid into calculation. At that two finite- element nets have been created, one – for wheel center, other – for tyre. On basis of constructive reasons to provide tightness of tyre the outside diameter of wheels center was made 0.69 mm more than internal diameter of tyre. In relative pair units on contact surface center- tyre it was required to create the following boundary conditions :

$u_{r\text{б}}-u_{r\text{ц}}=\Delta,$ (1)

$u_{z\text{б}}=u_{z\text{ц}}$ (2)

Where $u_{r\text{б}}$, - $u_{z\text{б}}$ are radial and axial transitions of tyre contact units,

$u_{r\text{ц}}$, $u_{z\text{ц}}$ analogously for wheel center , Δ- tyre tightness

The distinct imperfection of application package MSC/NASRTAN or processor FEMAP, on our opinion, is the fact that they do not allow to specify boundary conditions of Constraint Equation type (1) , if Δ= *const*. This imperfection was managed to overcome considering the fact that it is required also to specify boundary conditions, limiting transition of wheel as rigid whole towards axis Z. Then for one of the units (with number 1, being on the butt of hole in hub and its internal lateral surface) the boundary condition $u_{z1}=\Delta$ (1) was specified and boundary condition (1) was written as

$u_{r\text{б}} - u_{r\text{ц}} - u_{z1}=0$ (3)

Fig. 5 shows non- deformed FE- meshes of wheel center and tyre as well as their co-deformation. Deformation is given in enlarged scale. We consider retaining ring to be integrated whole with the tyre.

The above loading resulted in creation of additional stresses both in wheel center and tyre. Among them the most characteristic are axisymmetric radial stresses, given on fig. 6. These stresses are within – 399 MPa to 6.51 MPa. As expected when pressing-on the tyres mainly compression stresses occur in wheel center, they do not exceed elastic limit for wheel steel, but should be taken into account at superposition of decisions as their contribution in whole deflected mode of wheel is rather considerable.

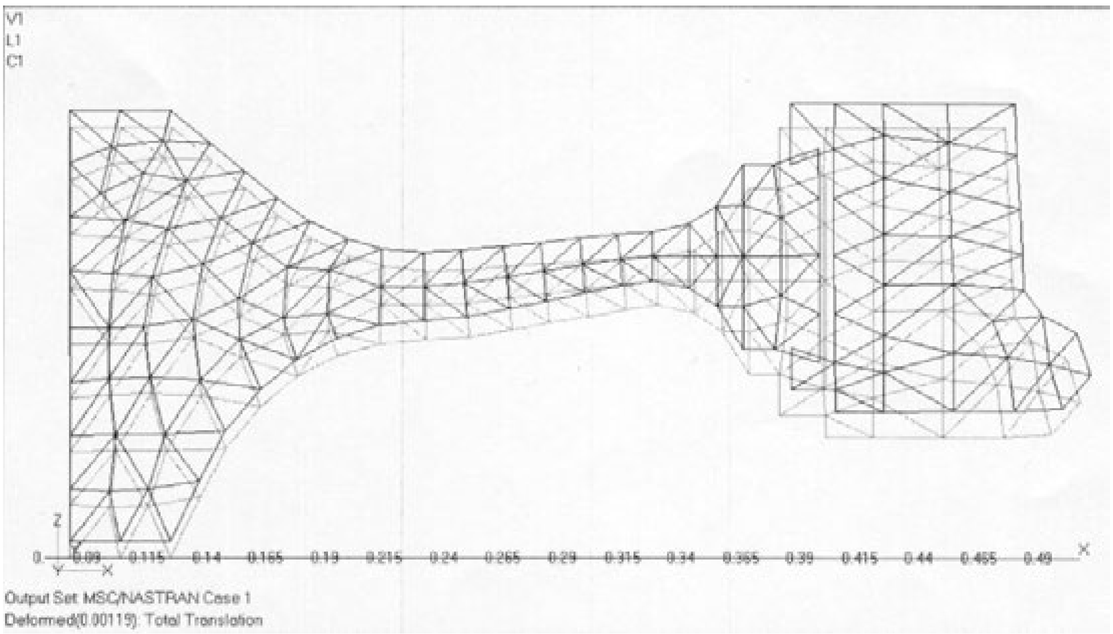


Fig. 5. Deforming of compound wheel EMU/M-0-1-004 due to pressing-on of tyre.

The most loaded are wheel zones being transitional from web to hub and from web to rim. The most complicated loading of wheels is thermal loading, stipulated by interaction of wheel and braking shoes in process of braking.

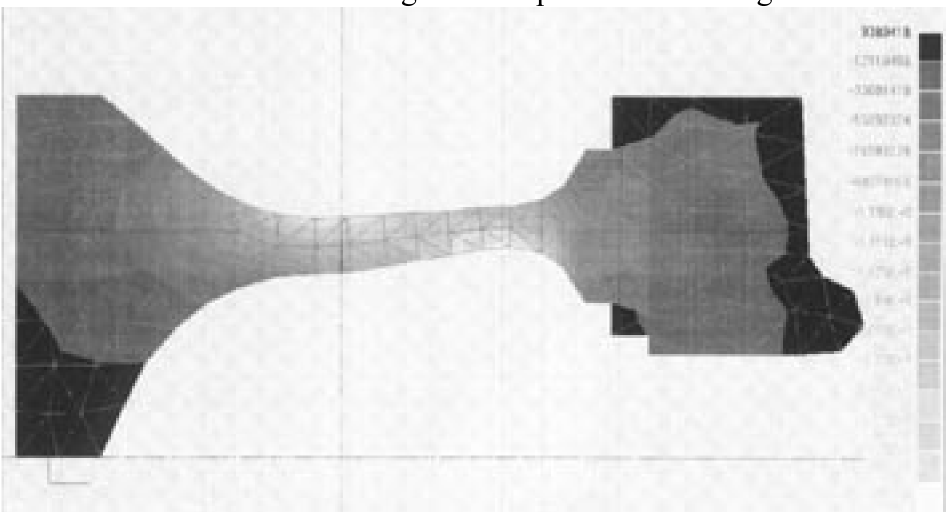


Fig. 6. Radial stresses field in wheel EMU/M-0-1-004 due to pressing-on of tyre.

So, aims were achieved and on example of the above described wheels the procedure of elaboration of some new wheel designs having strength properties exceeding known analogues of leading countries of the world was shown.

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