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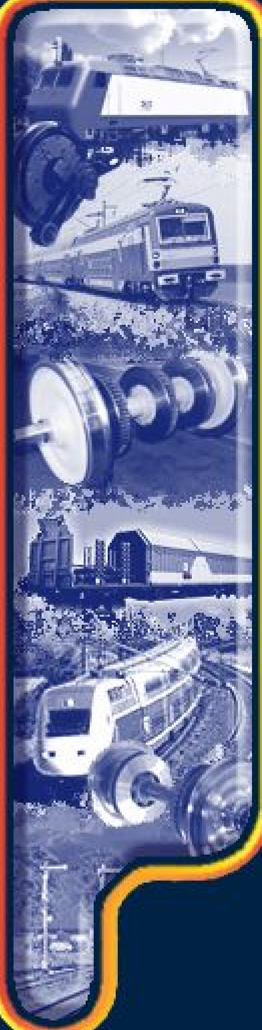

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DEFINITION OF MONTAGE STRESSES IN RAILWAY WHEEL PAIRS

Summary. There was executed the analysis of the stresses in the process of railway wheel pairs forming. Comparison of different wheel constructions was carried out and the influence of the wheel disk shape on stresses allocation in the formed wheel pairs was analyzed.

1. INTRODUCTION

Different aspects of load influence the vehicle wheels during the exploitation process. Among them the most dangerous are the thermal stresses originating at durable or emergency braking, and also the dynamic loads stipulated by different reasons, for example, by transiting of junction deformations (mainly vertical loads) or crossing pieces (side loads). Thus in the wheels there are the original stresses stipulated by production technology of the wheel (residual) or wheel pairs forming. The tension state of the wheels as a whole and, accordingly, their serviceability depend on fields' size of the indicated stresses and their characters. We shall consider the stresses, which arise at a force fit of vehicle wheel during wheel pairs forming, and we shall ask question. How the wheel construction influences allocation of stresses fields and how large are such stresses?

2. RESEARCH OBJECT AND AIMS

The railway wheel pair is one of the most crucial nodes of a carriage rolling stock. It has enough complex construction, is loaded with significant number of external loads of different types, which stipulate its complex tension. Besides, the part of stresses is internal, stipulated by manufacturing techniques of wheel pairs and their constructions. Among such construction technology factors of deflected mode takes the important place, which appears in wheel pairs as a result of wheel press fitting on an axis. Stresses originating during this do not exceed a yield stress of wheel steel, but are significant and should be taken into account during the analysis of the wheels common tension. Such stress magnitude is stipulated by necessity of press connection application of a wheel and an axis. Thus the insufficient tightness in examined connection may lead to crank of the wheel according to the axis, that is inadmissible, and excessive magnitude of tightness may be the reason of wheel corrupting during exploitation.

It stipulates that fact, that wheel pairs forming is enough crucial technological process, which is regulated by a series of old enough normative documents, for example, [1]. Thus the geometry and quality of handling of the hub part of the axis and a hole in the wheel, and also the graph of press fitting effort, which is recorded during forming are the subject of monitoring. The calculations fulfilled with enough simple means usage were based on the strength of materials and theory of elasticity methodologies. They form the basis of the normative documents. They did not take into account the complex geometry of an axis and especially of a wheel. For example, in the indicated instruction magnitude of tightness, which should be in limits of 0,1 - 0,25 mm is stipulated, it means that the lower value of tightness makes 40 % of its maximum magnitude. Thus the range of tightness does not depend on a diameter of hub part of an axis. Magnitude of finite press fitting efforts also is normalized and originally was 366,67 - 539,55 kN on every 100-mm of a diameter of hub part of the axis. In 1987 the Ministry of Railways changed this norm into 382,59 - 568,98 kN. Thus, the lower value of the effort makes 67,2 % of its maximum. It is obvious, that press fitting efforts should match the initial tightness. Therefore the comparison of relative magnitudes of tightness and press fitting effort display a conflict in the normative parameters, which should determine the technique of the wheel pairs forming process.

In paper [2] on the basis of a great quantity of experimental data for different diameter values of hub part of the axis, hub length, wheel rim width we made the attempt to receive functional dependence of finite press fitting force on tightness. On the experimental analysis basis the narrowed down range of tightness for the standard wheel pairs used in the countries of former USSR - 0,14 - 0,19 mm was offered. This range of guaranteed tightness should be the subject of the rigid technological monitoring, first of all careful and precise measurement of hub part of the axis and of a hole in the wheel. Unfortunately, the indicated range also does not depend on wheel and axis geometry. Besides, it was not inserted into departments' practice, executing wheel pairs forming.

For comparison we can use the Polish norm [3], where it is stipulated, that tightness magnitude is defined from the relation $W = Da/1000$, where W - tightness (mm), a - the coefficient of tightness in range of 0,9 - 1,25. Here the geometry of contacting parts is partly taken into consideration. The geometrical parameter diameter of axis hub part (mm), which has maximum influence on tightness magnitude, goes into the formula. Taking into consideration the fact that on Polish railways the wheels with symmetric and asymmetric [4] rim location concerning a hub are used, the indicated distinction of geometry also should be reflected in the normative documents, describing wheel pairs formation. However, it is not done.

3. RESEARCH METHODS

For computer modeling of the wheel pairs forming process the finite element method was used. It allows taking into account complex geometry of the wheel, as well as different force and thermal factors affecting the wheel. Nowadays there is enough wide range of application packages realizing FEM, for example, NASTRAN, ANSYS, MARC, and COSMOS. With their help calculations of new railway wheels constructions are made, and besides, in conditions of different tenders finite - element calculation of the wheel is taken as the mandatory requirement.

Earlier in papers [5, 6] influence of built-up on a common wheel tension was considered. Thus the axisymmetric task of Lame about a common strain of two cylinders was solved: one of which was solid, modeling an axis, and hollow, modeling the wheel hub, which was set with the determined tightness. Such approach was lawful as the first approximation;

however, it is necessary to take into account real geometry of the wheel and axis, thus deciding the contact task about their common deformation during wheel built-up on the axis.

This task analytical solving is not obviously possible, however FEM application allows finding its solution. In particular, for its executing we used the application package MSC/NASTRAN for Windows release 4.0.1. The examined process of wheel pair forming can be realized in program with GAP – elements usage. Thus the task will be solved with usage of algorithms of nonlinear static in three-dimensional setting. We can, certainly, with the help of two radial sections cut any layer and consider contact interaction of axis and wheel for layer elements. However it considerably complicates setting, for which sequentially it is necessary to solve a set of contact interaction in wheel-axis pair tasks for their different relative positions during press fitting. The new technique, founded on the axisymmetric calculated scheme application was developed.

We shall consider all over again the task about stresses allocation and, in particular, contact stresses in formed wheel pairs. For this purpose we solve with the help of NASTRAN the axisymmetric task about common deformation of wheel and axis at preset tightness. For the first we assume that the friction coefficient between contacted surfaces of the wheel and axis is infinite. It means that in such a way it is possible to model a complete adhesion that takes place after durable maintenance of wheel pair.

During FE-model creation we used three-nodal axisymmetric finite elements which total quantity is equal 1548. Thus there were two finite - element grids created, one for wheel, and another one for an axis. Total quantity of nodes is 962, including 17 contact pairs. At FE - grid choice for wheels the guidelines of paper [7], stipulated by necessity of solution exactitude security, were used. In calculation real properties of wheel steel were included. With regard to constructive reasons for creation of tightness during wheel fitting its diameter of a hole in hub was executed on 0,25 mm less, than a diameter of hub part of axis. In appropriate pair nodes on a contact surface “wheel - axis” it was necessary to set boundary conditions, aspect of which is described in paper [8].

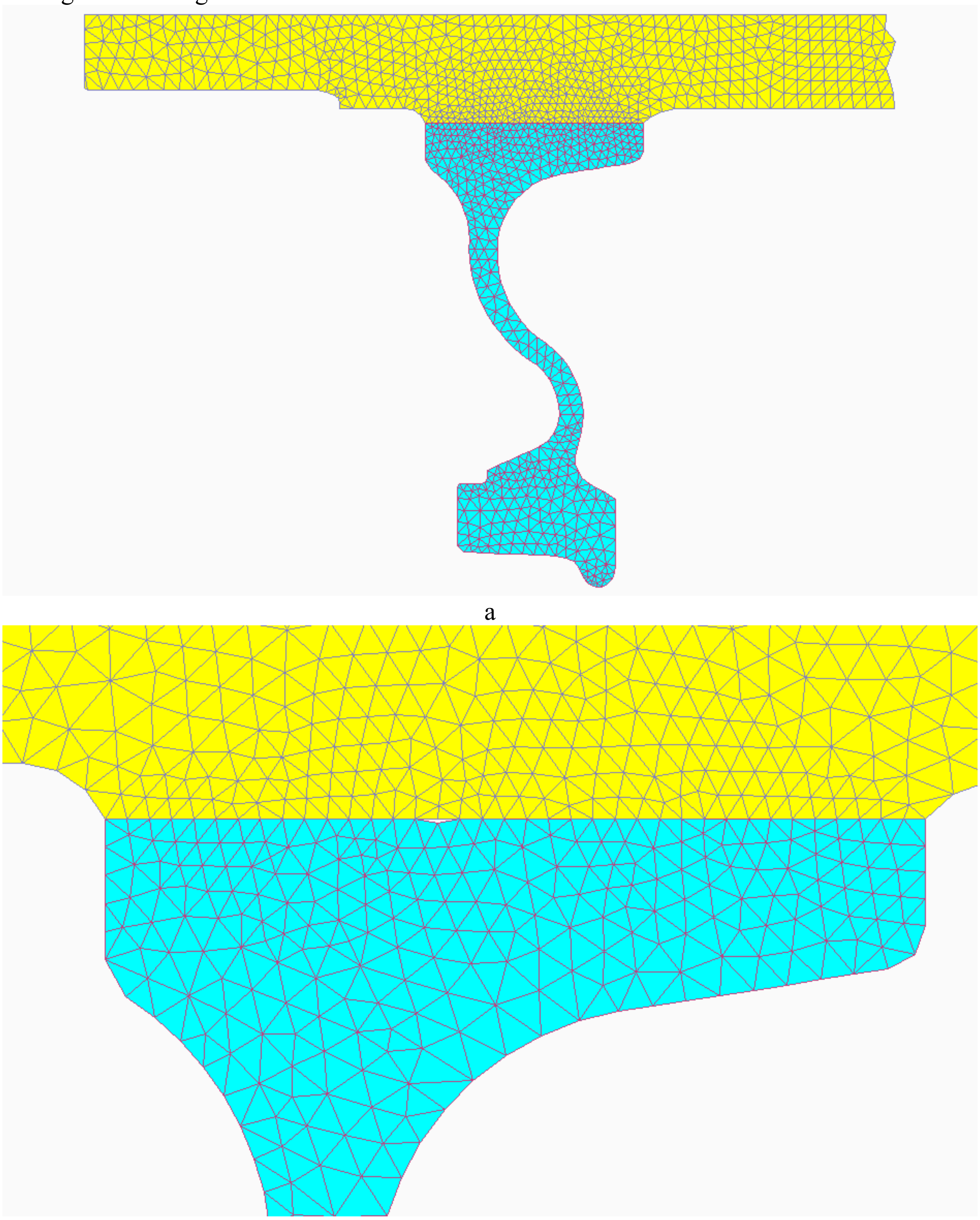
Defined deficiency of NASTRAN or FEMAP preprocessor is the fact, that it does not allow to set boundary conditions such as Constraint Equation if $\Delta = const$. We managed to overcome this deficiency with regard of the necessary to set also the boundary conditions, which bounds the wheel, as the rigid whole, displacement in axis Z direction.

On figure 1 not-deformed FE-grids of an axis and a wheel (fig. 1a), as well as the contact zone in an expanded scale (fig. 1b) is represented. At FE-grids choice the basic principles of paper [7] were used. While using them it was possible to minimize the calculations error, which was stipulated by grid choice, and at its minimum possible amount of nodes (with limitation from the point of view of an error) to provide solution of peak efficiency.

However, as the principal attention in paper is given to contact interaction of the wheel and the axis during wheel pairs forming, it was possible to reduce the elements number on width of the wheel disk. It is still possible to mark, that a series of wheel pair’s constructions have special gnowing-through for wheel pair’s pressing-out FE modeling of this gnowing-through is well seen on the enlarged figure 1b.

4. RESULTS OF CALCULATIONS

Nowadays there is a great amount of different constructions of solid-rolled vehicle wheels, which are intended for different types of carriage rolling stock. Accordingly, besides the trial function, they execute a series of additional ones, for example, initial damping or lowering of noise. Within the framework of this paper we shall not consider those or other advantages of such wheels. We shall accept, as due already existing constructions. The greatest problem is the requirement to lay down all wheels in identical conditions of wheel pairs forming for analyzing influence of their constructions on their deflected mode. This problem is stipulated by the fact that each wheel is assumed to use its own axis. Thus the wheel hub may be both more widely, and already hub part of an axis. Diameters of holes in hub for different wheels differ among themselves. And, at last, the difference in technology requirements for tightness has a great meaning.



a

b

Fig. 1. FE – discretization of the pair wheel – axis

For unifying such press connections the analysis of different wheel pair's constructions, which are used on railways of different countries of the world and, first of all, on the European railways, was carried out. From all diversity of wheel constructions the most typical were selected and they are shown on fig. 2.

For analysis of wheel construction influence on their deflected mode, stipulated by wheel pairs forming, there were selected the wheels having a diameter of a hole in hub of 185 mm. As the general axis we used the axis with construction, appropriate to Polish standard PN-92/K-91048 of A type. The analysis was done for two tightness values of 0,18 and 0,25 mm, minimum and maximum, accordingly.

The main tendency of modern machine industry is the usage of wheels as an initial elastic unit of a coach, the vertical rigidity decreasing of that promotes lowering of dynamic loads, which are transmitted on sprung masses of a carriage rolling stock. For this purpose on wheel disks there were executed corrugations of different construction in the central part of the disk. The rim location of the wheel concerning a hub may be symmetrical, as for the wheel fulfilled according to Polish standard PN-92/K-91019 920/185s (fig. 2a), or nonsymmetrical 920/185a (fig. 2b). Central corrugations and, accordingly, a vertical rigidity of the wheel may be larger and smaller, compare, for example, the wheel of Huta "Gliwice" S.A. production - drawing TT-2537 (fig. 2c). Enough obsolete construction is the wheels with direct slant disks (conic), for example, the same production - drawing TT-2990/KO (fig. 2d). The wheels of GOST 9036-88 standard, which are used on railways of the former USSR, are similar to above mentioned. The wheels with S-figurative disk of Bonatrans A.S. Bohumin production - drawing 455.0.212.000.12 have more perspective construction (fig. 2e). И, наконец, последнее колесо производства And, at last, the last wheel of Stablimento di Lovere Lucchini production (fig. 2f) has enough original construction with C-figurative disk.

The main results of calculations are also shown in the table, where for the mentioned above tightness values the maximum equivalent stresses are defined according to energy criterion of Von Mises.

The table

Maximum stresses levels in wheels of different constructions for extreme values of tightness

Wheels fig. 2 №	The tight-ness (mm)	Radial stresses σ_r in the wheel disk		Maximum equivalent stresses in the wheel according to Von Mises criterion
		min (MPa)	max (MPa)	
A	0,18	-63,4	18,4	193,7
	0,25	-88,0	25,9	268,8
B	0,18	-56,9	17,5	214,9
	0,25	-79,0	24,2	299,5
C	0,18	-78,8	29,0	190,8
	0,25	-109,4	40,3	265,6
D	0,18	-62,7	12,0	189,1
	0,25	-87,0	16,6	258,5
E	0,18	-45,1	12,6	201,7
	0,25	-62,6	17,5	280,1
F	0,18	-80,5	16,9	192,1
	0,25	-111,8	23,4	266,9

These stresses for all wheels are achieved on an internal surface of the hole in hub. On fig. 2 these places are shown as $\otimes$. Difference of different wheels in this case is only that of transition zone hub-disk symmetric location, these places are also symmetric to axis of hub, transiting through the middle of the hub. At disk displacement, the appropriate zone of maximum stresses displaces on an external part of hub in direction of the disk displacement. Magnitude of such stresses in wheel built-up position does not exceed a yield stress of wheel steel; however, during wheel pair forming it is possible plastic deformations zones creation in zones adjoining to the hole in hub. The latter proves that fact, that if we compare maximum stresses (21,6 MPa) during wheel pairs forming with construction tightness of 0,18 mm fig. 2e and a range of radial stresses for the same wheel in the formed state ($-45{,}1 \le \sigma_r \le 12{,}6$ MPa), we can see, that stresses during forming may be almost two times larger, than for formed wheel pair. Places of localization of the greatest and the least radial stresses in wheel disks, which values are shown in the table, on fig. 1 are marked by signs $\oplus$ and $\ominus$, accordingly.

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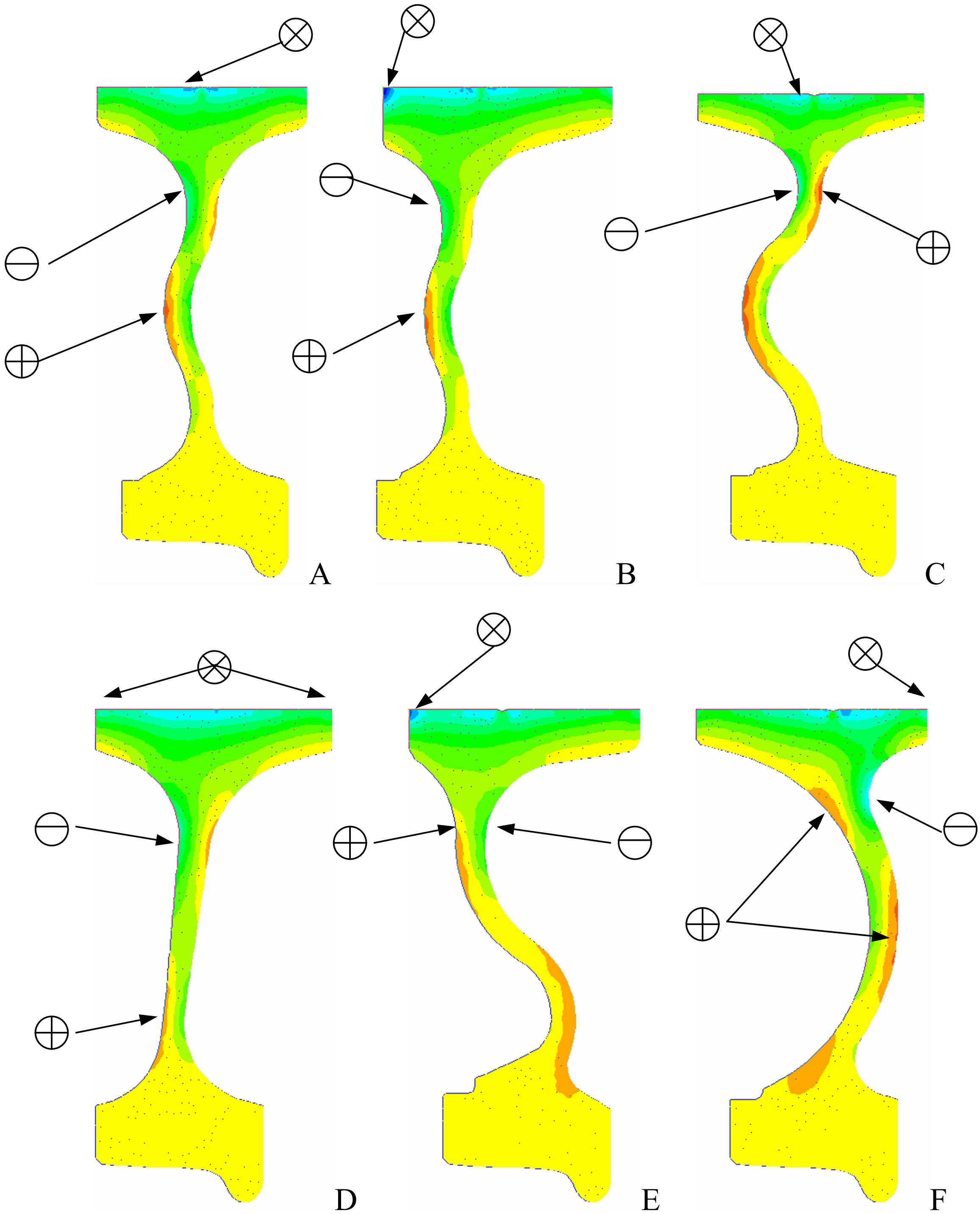

Fig. 2. Radial stress in vehicle wheel of different constructions after wheel pairs forming (description of constructions are in the text)

Abstract

Метод конечных элементов применен для анализа напряженно – деформированного состояния вагонных колес при формировании колесных пар. Проведено сравнение наиболее характерных конструкций цельнокатаных колес, использующихся на железных дорогах различных стран. Определены наиболее нагруженные участки колес в процессе формирования и в уже сформированной колесной паре для различных натягов.