THERMAL AND DEFORMATION PROCESSES IN WROUGHT WHEELS DURING EXTENDED BRAKING

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ABSTRACT

Railway wrought wheels (hereinafter- WW) belong to the most critical elements in the design of rolling stock, the reliability of which largely influences traffic safety. During operation, they are subjected to high thermal effects resulted from braking (system «brake shoe-wheel») and mechanical loading during the interaction of wheel and rail.

Continuing previous publications in World of Transport and Transportation journal (Vol. 12, Iss. 5, pp. 22–37; Vol. 13, Iss. 1, pp. 56–62) the authors analyze the studies that were conducted at MIIT to assess the influence of braking parameters on the kinetics of thermal and deformation processes taking into account the geometry of the wheel disc. Modern technical means and methods do not allow for analysis of the distribution of thermal processes throughout the wheel volume during braking and implementation of direct measurements of deformation of WW elements at the end of the freight car braking.

The objective of the authors was to present an analysis of the influence of the wheel disc geometry on maximum values of deformation of the rim at the end of extended braking. In the paper the authors use analysis, mathematical and engineering methods.

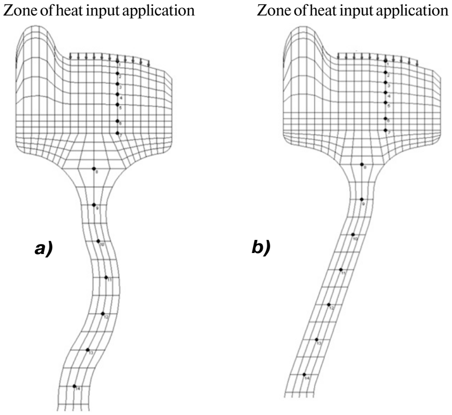
The results were obtained by methodological tools, designed at MIIT, and a software complex SANAK, created on its basis. Computer modeling was carried out using volumetric finite element models of wrought wheels with a diameter of 950 mm with rectilinear and curvilinear shapes of the disc with the size specified in GOST 10791–2011 [1]. The features of interaction in the system «wheel-rail», and wheel wear during its operation were not taken into account (thickness of the rim was 70 mm).

Keywords: *railway, car, wrought wheel, kinetics, heat input, deformation, braking.*

Background. *In determining the level of thermal loads on wheels of a freight car during extended braking the following conditions were accepted for computer simulation:*

- *the use of composite brake shoes implies that 90–95% of heat released during braking in a pair brake shoe-wheel is transmitted to a wheel rim;*
- *the use of composite brake shoes for freight cars with auto mode, switched on in the average mode, provides a calculated value of the coefficient of force pressing brake shoes, which is 0,22 [2];*
- *dimensioning of the heat input into the wheel is oriented according to [3,4] for extended braking on downhill i = 20‰, speed is 70 km / h and duration of brake shoes action on the rim is 1200 s; relative power of heat release:* $q_1^{*av} = 17,7\ W/sm^2$.

Objective. *The objective of the authors is to analyze the influence of the wheel disc geometry on maximum values of deformation of the rim at the end of extended braking.*



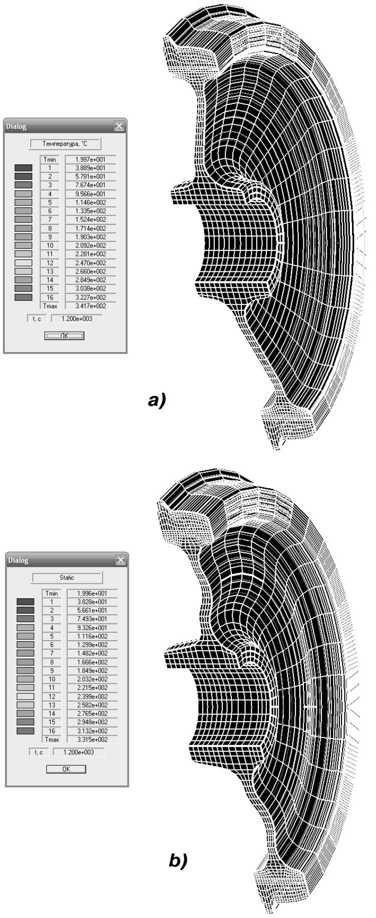
Pic. 1. Scheme of heat loads application by computer simulation on WW: a) with a curvilinear shape of a disc, b) with a rectilinear shape of a disc.

Methods. *The authors use analysis, mathematical and engineering methods.*

Results. *Schemes of heat loads application in computer simulation are presented in Pic. 1. The total area of the cooling surface in the considered structures of WW is practically the same. The calculations showed: in WW with a rectilinear shape of a disc maximum temperature was 331°C and with curvilinear it was 341°C. Since the maximum temperature difference is less than 3%, it can be concluded that the shape of the disc does not significantly affect the temperature distribution in WW during braking. Pic. 2 shows the temperature contours in the cross section and the side surface of the wheel in the volumetric finite element model.*

Kinetics of thermal processes in WW and the uneven heating of individual elements (rim, disc, spider centre) are responsible for the kinetics of deformation processes in the wheel. Analysis of computer simulation results with the use of volumetric finite element model showed that the highest level of deformation is observed in the wheel disc, and this is a direct consequence of the process of thermal expansion of WW rim.

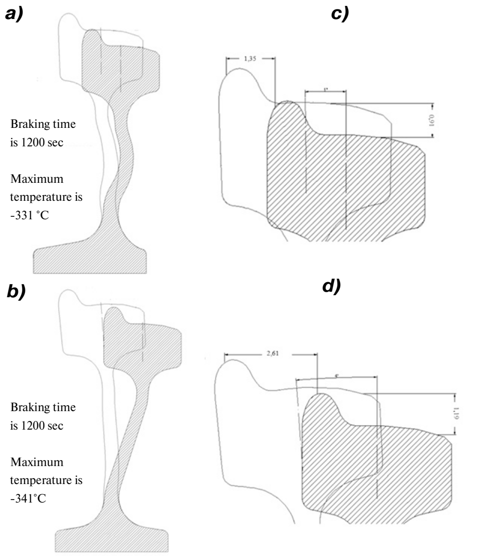
Pic. 3 shows the displacement of the wheel rim with respect to the initial position at the end of extended braking for two considered structures of WW. It is obvious that the heat processes lead to the displacement of the rim in a direction away from the spider centre and toward the adjacent wheel of the wheel set (Pic. 3a, b). The analysis reveals that the maximum displacement of the rim depends on the design of WW. Thus, the maximum displacement of the wheel rim with a rectilinear disc in the axial direction toward the linear disc was 2,61 mm (Pic. 3d), and with a curvilinear disc was 1,35 mm (Pic. 3c). Thus, the total displacement of two wheels of one wheel set for WW with a rectilinear disc was 5,22 mm, with a curvilinear disc was 2,7 mm. Deformations in the radial direction at the end of extended braking for a wheel with a rectilinear disc were 1,19 mm, and with a curvilinear they were 0,91 mm.



Pic. 2. The temperature distribution in the volumetric finite element model of a wrought wheel at the end of extended braking: a) a rectilinear disc; b) a curvilinear disc.

Conclusions.

1. As a result of extended braking maximum temperature on the surface of the wheel reach valueshigher than 300°C. Maximum heat input is in the WW rim.



Pic. 3. Deformations of wrought wheels as a result of thermal loading during extended braking mode, increased 30-fold: a) with a curvilinear shape of a disk; b) with a rectilinear shape of a disc ; c) in the rim (wheel with a curvilinear disc), in mm; d) in the rim (wheel with a rectilinear disc), in mm.

2. The design of the disc does not affect maximum temperature values on the surface of the wheel.

3. Deformation processes in WW at the end of extended braking lead to the displacement of the rim to the wheel set axle and the increase in the wheel diameter. Maximum values of displacement of the rim strongly depend on the design of the wheel disc. The total displacements of the rim with a rectilinear disc are higher than similar displacements of the rim with a curvilinear disc.

4. Displacements in axial direction of the wheel rim result in that the distance between inner surfaces of the wheel flanges of the wheel set reduces from 1440 to 2,7 mm (curvilinear disc) and 5,22 mm (rectilinear disc). In conjunction with the broadening of the track in curved sections of the track it may have an impact on traffic safety.

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