IMPACT OF HIGH SPEED FREIGHT TRAFFIC ON THERMAL LOADING OF WROUGHT WHEELS AT BRAKING

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ABSTRACT

Braking systems on modern freight cars act in a kind of tribological triangle: brake shoe – wheel – rail. Kinetic energy stored by the car during movement at braking due to friction is converted into heat, which is distributed between a brake shoe and a wheel. Numerous studies in recent years have proved that up to 60% heat is generated in the wheel when using iron shoes and up to 95% using composite shoes. During operation the material of the wheel is subjected to thermal impact, the intensity of which depends directly on braking modes and motion parameters of the rolling stock. Repetitive heating and cooling of wrought wheels have a significant effect on the kinetics of their stress-strain state.

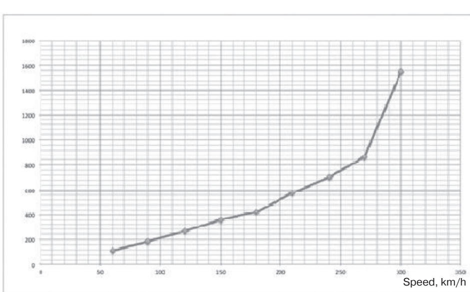
The kinetics of the stress-strain state in operation is determined by the scheme and the level of residual stresses, formed during heat treatment in the manufacture of wheels, as well as stresses and strains associated with mechanical and thermal loading. The level of residual technological stresses in the wheel with which it comes into operation, in some cases, is one of the main indicators of quality, reliability and durability. The combination of stress-strain state with residual technological stresses under adverse conditions, such as low temperature, presence of microdefect or local deviations in the formation of the microstructure can lead to formation of cracks in disc or brittle fracture of wheel that has been repeatedly confirmed by experts.

The objective of the authors is to investigate impact of high speeds on wrought wheels, in particular in case of thermal loading: both heating and cooling. Methods and software developed in MIIT allow computer simulation of the kinetics of thermal, thermal deformation and deformation processes in nonlinear unsteady statement with account of kinetics of the structural state at each step of the solution, which allows to analyze the current state of the structural element using a wide range of technological and operational loadings throughout the life cycle.

Continuing the theme of modeling of wrought wheels thermal loading, described in previous publications, the authors on the basis of the calculation and simulation methodology, developed with their participation in order to determine heat intensity in the system «wheel-brake shoe», clarify the features of influence of high speed of car's movement along the rails on the values of maximum temperatures on the wheel surface during braking. The study confirmed theoretically grounded assumptions that increasing speeds significantly affect the value of the maximum temperature on the surface of wrought wheel at the time of the end of braking, as well as the complex of mechanical properties, kinetics of structures, conditions causing formation of cracks, metal chipping and other defects that endanger the operation of the rolling stock.

<u>Keywords:</u> *railway, roadbed, rolling stock, wrought wheel, brake shoe, high speed, braking, kinetics, thermal loading.*

Background. *Braking systems on modern freight cars act in a kind of tribological triangle: brake shoe – wheel – rail. Kinetic energy stored by the car during movement at braking due to friction is converted into heat, which is distributed between a brake shoe and a wheel. The distribution of heat between a brake shoe and a wheel depends on a type of brake shoes. Numerous studies in recent years have proved that up to 60% heat is generated in the wheel when using iron shoes and up to 95% using composite shoes. During operation the material of the wheel is subjected to thermal impact, the intensity of which depends directly on braking modes and motion parameters of the rolling stock. Repetitive heating and cooling of wrought wheels (hereinafter-WW) have a significant effect on the kinetics of their stress-strain state (hereinafter-SSS).*



Pic. 1. The dependence of maximum heating temperature of the wheel rim on speed at the end of heating.

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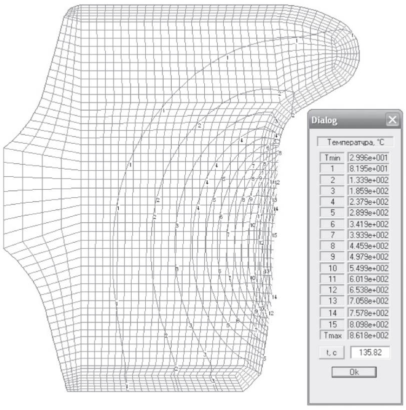
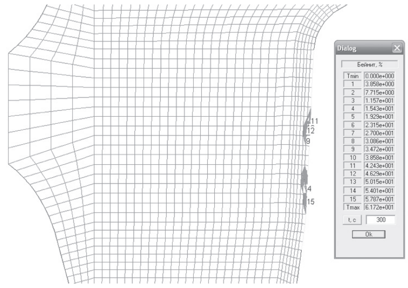
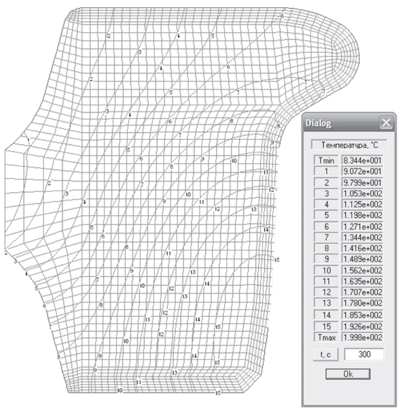


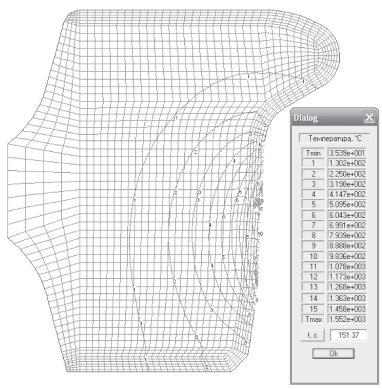
Pic. 2. The temperature distribution in the wheel rim at the end of braking from a speed of 270 km / h.



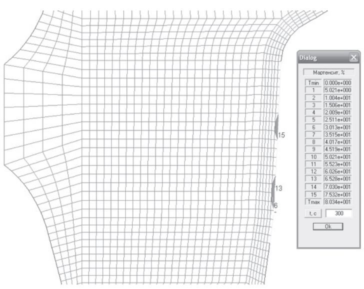
Pic. 5. Distribution of bainite in the wheel rim after braking from a speed of 270 km / h and cooling.



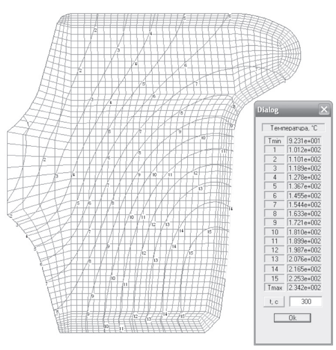
Pic. 3. The temperature distribution in the wheel rim after braking from a speed of 270 km / h and cooling.



Pic. 6. The temperature distribution in the wheel rim at the end of braking from a speed of 300 km / h.



Pic. 4. Distribution of martensite in the wheel rim after braking from a speed of 270 km / h and cooling.



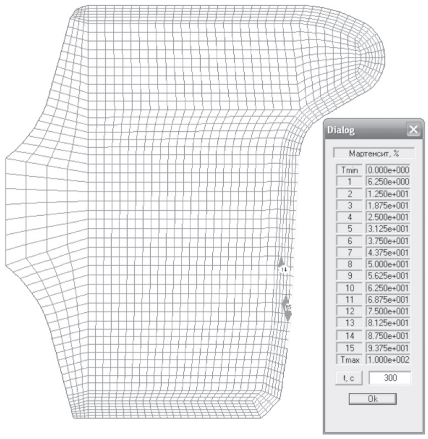
Pic. 7. The temperature distribution in the wheel rim after braking from a speed of 300 km / h and cooling.

tion, which allows to analyze the current state of the structural element using a wide range of technological and operational loadings throughout the life cycle.

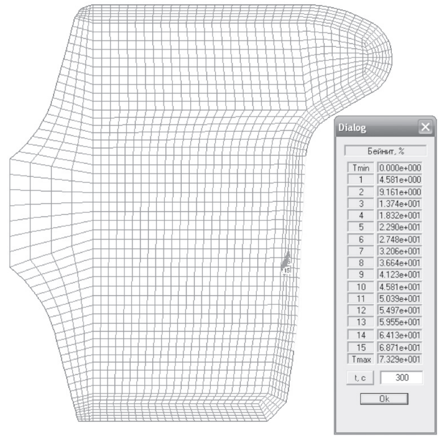
Objective. *The objective of the authors is to investigate impact of high speeds on wrought wheels, in particular in case of thermal loading: both heating and cooling.*

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

Results. *As it is known, the introduction of high-speed freight traffic in the implementation of the braking system increases the level of heat load on the wheel. Studies were conducted in MIIT, including analysis of the temperature distribution over a cross section of the wheel rim and assessment of the impact of a speed of the car at the beginning of emergency braking on the maximum temperature at the rolling surface [1]. In simulation certain parameters of a freight car were considered: the amount of heat generated during braking, was*



Pic. 8. Distribution of martensite in the wheel rim after braking from a speed of 300 km / h and cooling.



Pic. 9. Distribution of bainite in the wheel rim after braking from a speed of 300 km / h and cooling.

determined in accordance with the procedure described in [2].

The results of calculations for determining the maximum temperature on the wheel tread in the speed range of 60–300 km / h are shown in Pic. 1.

The analysis of results shows that at the initial braking speed of 150 km / h the maximum temperature at the wheel tread at the end of braking is 380 ˚C, at 250 km / h it is 702 ˚C, at 270 km / h it is 820 ˚C, at 300 km / h it is 1552 ˚C. It means that, even at speeds of 150–200 km / h maximum temperature at the wheel tread reduces the complex of strength properties in the heating zone by two or more times [3].

Pic. 2–3 show the distribution of temperature in the cross section of the wheel rim at the end of braking from a speed of 270 km / h and after its cooling.

The situation with temperature distribution at the end of braking indicates a high concentration of the maximum temperature in surface layers and a significant gradient across the cross section. It should be emphasized that in a thin surface layer at the end of braking austenitizing of metal structure was marked to a depth of up to 2 mm, which is the basis for the formation of hardening structures after cooling.

The results of kinetic analysis of the structure of the wheel material after cooling are shown in Pic. 4–5.

Obviously, austenitizing of the metal structure at the heating stage resulted after cooling in certain areas of the wheel tread to formation of martensite at a concentration of up to 80% and bainite with a concentration of up to 62%. The formation of such hardening structures in practice, combined with dynamic loading associated with the passage of rail joints and switches by cars, leads to cracking and chipping of metal, which was demonstrated by numerous inspections of WW in operation.

Pic. 6–7 show a temperature distribution in the wheel rim at the end of braking from a speed of 300 km / h and after its cooling.

Pic. 8–9 show the distribution of structural components of martensite and bainite in the wheel rim after its cooling. As it is clear from these data up to 100% martensite and 73% bainite are formed on the wheel tread in local areas of the surface layer, that in combination with dynamic loading again results in cracking and chipping of the wheel metal.

Conclusion. *Thus, this study confirmed theoretically grounded assumptions that increasing speeds significantly affect the value of the maximum temperature on the surface of wrought wheel at the time of the end of braking, as well as complex of mechanical characteristics, kinetics of structures and the creation of conditions for the formation of cracks and chipping of the metal.*

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