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INVESTIGATION OF INFLUENCE OF FRICTIONAL MATERIAL'S CHARACTERISTICS OF BRAKE BLOCKS OF RAILWAY TRANSPORT ON THEIR FUNCTIONAL THERMAL STATE

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Summary. The results of calculated investigations of overheating pair friction of mechanic brakes of railway rolling-stock made on the basis of numerical solving of no stationary equation of heat exchange have beer presented. The equation of regression in the function of four main factors of influence has beer receiver and offered for using it when calculating heat characteristics of brakes.

Key words: railway transport, mechanic brakes, brake blocks, carbon-carbon (C-C) composite, thermal state, calculation.

INTRODUCTION

Mechanic brakes are irreplaceable brake system for guaranteeing safety conditions of railway rolling-stock movement in the near future. The investigation of this problem shows that increasing effectiveness of mechanic brake system's work (shoes and disc) is possible only at the expense of using on principle new frictional materials with simultaneous increasing of wheels and rails coupling. For the last 15 years the resource of carriage wheels has beer decreased 2.5 … 3 times, and removability of rails as to lateral wear and tear of heads has beer increased 2 … 3 times. It is conditioned by destructing thermic influence of brake energy on contact surfaces of wheels on discs and on the material of brake shoes or lining.

Considerable influence on wheels and rails resource shows brake shoes and their frequent removability with frequent contact of new shoes and wearing and tearing profile of the wheels redoubles our formed situation. Maintenance costs of rolling-stock have been constantly increasing and this scientific problem acquire in addition important economic character.

OBJECTS AND PROBLEMS

When making friction materials with necessary brake (thermo-physical and tribotechnical) characteristics it is necessary to know their required level. It is evident from the investigation of the process of train brake that for defining of functional indices of different friction materials of brake shoes it is necessary to use special program complex [Starchenko'n'o. 2009], and lasting work of the qualified specialists. That's why working out of engineering method for defining of estimating indices which make it possible to preliminary comparative estimation of thermal characteristics, frictional pair of brakes for various shoes materials.

In this way in series used frictional materials namely on Ukrainian rail way grey pig-iron and serial composite materials of joint-stock company "ФРИТЕКС" production and perspective materials of new generation made by original native technology on the basis The modified carbon-carbon (C-C) composites [Starchenko'n'o. 2006], [Starchenko'n'o. 2008]. As have shown results of previous researches, such materials [Starchenko'n'o. 2009], [Bauer 1999 Starchenko'n'o. 2009], [Ehler 2002] are capable to absorb a thermal flow capacity to 400 kW counting on a brake axel of a train.

For serial brake shoes materials coefficient of friction φ_k was defined in accordance of [Rules of... 1985], and for offered materials from C-C composites by empiric dependence

$$\varphi_k = 0.281 - 6.286 \cdot 10^{-4} \cdot v + 1.251 \cdot 10^{-6} \cdot v^2, \qquad (1)$$

where φ - coefficient of a friction brake shoes on a surface of driving of a wheel.

For defining of thermal state of elements of frictional pairs of mechanic brake non stationary differential equation of heat conductivity in two-measured organization in accordance with regional conditions providing synonymous solving has been solved [Starchenko'n'o. 2009]:

$$\frac{\partial \tau}{\partial t} = a \cdot \left(\frac{\partial^2 \tau(x,y,t)}{\partial x^2} + \frac{\partial^2 \tau(x,y,t)}{\partial y^2} \right) + \frac{q_s}{\rho c}, \qquad (2)$$

where: q_s- specific density of heat flow concerning counterbody,
a - coefficient of thermal diffusivity environments of distribution of a thermal wave (material), m^2/s about (tab. 1),
ρ - material density, kg/м^3,
c - a thermal capacity, J/(kg).

Table 1. **Thermo-physical characteristics of frictional materials**

The material name	Material density, kg/м^3	Thermal capacity, J/(kg)	Thermal diffusivity m^2/s
pig-iron	7850	460	$1{,}44 \cdot 10^{-5}$
composite	2200	1172	$3{,}26 \cdot 10^{-7}$
C-C composite	1675	1750	$1{,}16 \cdot 10^{-5}$

Calculation of coefficient of distribution heat α_k with using method offered by professor Inozemtsev V. Y. [Inozemtsev'n'o 1981] makes it possible to define its average calculating value: for grey pig-iron – 0.28; for C-C composite – 0.22; for serial composite – 0.04.

For further investigations binding together with defining the necessary qualitative and quantitative characteristic of frictional materials the case of stop brake on the platform of freight train (4800 ton) with diesel-locomotive 2 ТЭ116 was modeling on basis of solving equation of movement of the train by Euler numerical method with modifications.

Thus, in the result of numerical solution by the equation (2) net method the heat intensity of contact surfaces "shoes-wheel-rail" has been defined.

The maximum temperature overheat at stopping braking has been fixed at settlement researches on a surface of a contact friction under brake shoes in limiting concerning a direction of rotation of a wheel to a contact zone (fig. 1).

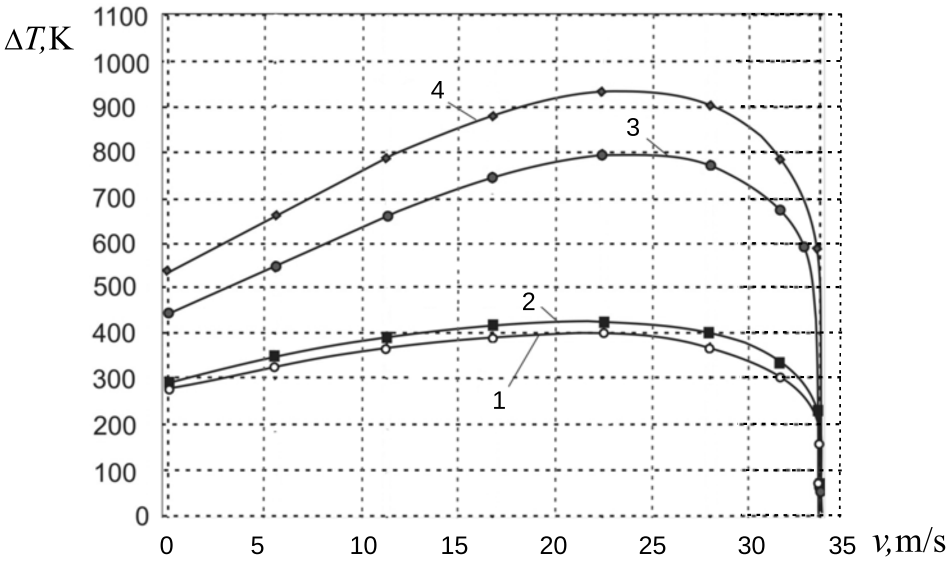


Fig. 1. Dependence of the maximum overheat of a surface brake shoes from speed of movement at stopping braking in a mode of emergency braking of a train: 4 - serial composite brake shoes; 3 - C-C composite; 2 - pig-iron with the raised maintenance of phosphorus; 1 – gray pig-iron

Calculation performance has allowed to receive levels of the temperatures, which characterize influence of a material brake shoes at their functioning at the set mode of movement and weight indicators of a train on the corresponding overheat of interfaced surfaces of a contact friction.

From the analysis of the graphic dependences presented on fig. 1, follows, that in the course of stopping braking of a train since speed of 33,3 km/s (120km/h) the greatest maximum overheat is reached at decrease in the specified parameter on 20... 25 %. The given law is logically consistent and caused by essential relative decrease in power of braking, especially considerable in the end of movement. Quantitative thermal indicators of braking also correspond to realities of operation and confirm actual inability serial composite shoes (the curve 4) to provide steady brake indicators at extreme modes of movement. It is necessary to note also thermal stability offered modified C-C composites even in at such thermal mode of braking.

Using shoes with a serial composite material was accompanied by a corresponding overheat 930K (maximum) in the course of movement with braking and 540K (in the end of braking).

Modified C-C composites were characterized by following levels of temperatures: - 795K (maximum) and 445K (in the end of braking).

For serial pig-iron shoes with the raised maintenance of phosphorus following values of temperatures have been received: - 425K (maximum) and 290K (in the end of braking), and for serial, executed from grey pig-iron accordingly - 400K (maximum) and 280K (in the end of braking).

The maximum overheat of a surface of a contact friction shoes, interfaced to a wheel, (740 … 930K) corresponded to braking serial composite shoes, the least - serial pig-iron - 330 … 400 K. Experienced C-C shoes were characterized by an overheat at level 655 – 795K, that on 85 … 135K to less in comparison with serial composite shoes.

A number of test calculations allowed to define the main factors which greatly influence the functional thermal conditions of breaking friction sets: $\varphi_к$; $\alpha_к$; v and a. The following pressure forcers of breaking shoes are given: to the diesel-locomotive wheels of 40 kN and relatively to the wheels of the train cars of 30 kN at different initial speed of movement: 11.1 … 33.3 m/s (40 … 120 km/h).

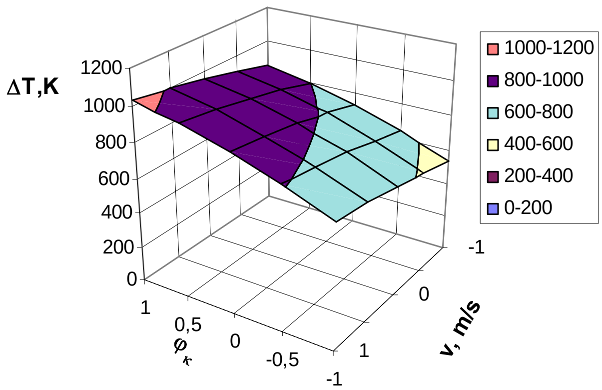
The planed four factors three leveled mathematical experiment (fig. 2) carried out according to the above mentioned calculated methods in the limits of varying actual variables relatively $\varphi_к$ from 0.18 till 0.45; $\alpha_к$ from 0.28 till 0.04; v from 11.1 till 33.3 m/s and a from $3\cdot10^{-7}$ till $1{,}5\cdot10^{-5}$ m^2/s allowed to receive the following equation of regression for the overheating of the friction surfaces (in coded variables):

$$\Delta T = 831{,}2365 + 162{,}27\, x_1 + 243{,}24\, x_2 + 84{,}6\, x_3 - 321{,}56\, x_4 - 38{,}78\, x_{11} - 127{,}5\, x_{22} - 15{,}31\, x_{33} + 185{,}85\, x_{44} - 10{,}8 x_{12} + 2{,}95 x_{13} + 22{,}44 x_{14} - 1{,}51 x_{23} + 41{,}68 x_{24} + 7{,}72 x_{34} \quad (3)$$

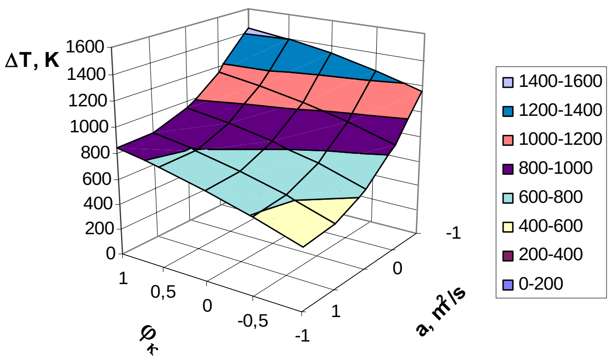
The given dependence approximates the results of a programmed model realization in the range of real combination of sensible - thermo-physical and tribotechnical characteristics of shoes friction materials with a deviation not more than 5%, it is allowed to recommend for using it in preliminary engineering calculations.

The possibilities of the received dependence usage to estimate heat state of friction breaking pairs are illustrated on fig. 2 a, b.

The analysis of the resulted data allows to draw a conclusion, that at the parametres of a train specified above and values of factors of influence accordingly v = 22,2 m/s and $\alpha_к$ = 0,16 use of the frictional materials providing coefficient of a friction at level 0,3... 0,4, coefficient of thermal diffusivity at level $1{,}5\cdot10^{-5}$ m^2/s (fig. 2) is expedient. Such materials must be heat resistance at temperature values till 970 K (700 degrees C).



a



b

Fig. 2. Overheating of friction pair surfaces of mechanical brakes in the function: a) φ_k and v (α_k=0.16; a=$7.65\cdot10^{-6}$); b) φ_k and a (α_k=0.16 and v=22.2 m/s)

As cycle of researches is showed, using grey pig-iron test as a friction material of brake shoes is characterized by the quantity of calculated overheating of friction surfaces till 390-410 K,C-C composites by overheating till 660 - 795 K, and serial composites materials leads to overheating at the level of 820 -945 K under given conditions.

Thus, taking into account maintenance of maximum permissible size of a brake way at sufficient operational reliability of brakes it is expedient to continue the works directed on introduction in frictional knots of system of mechanical braking of a rolling stock of rail transport of materials for brake shoes of new generation on the basis of composites modified carbon-carbon.

CONCLUSIONS

1. Brake shoes, equipped by the overlays executed from a material of new generation on the basis of modified C-C of composites are recommended to certified tests.

2. Influence on an overheat of a contact zone of a friction of frictional brake mechanisms of a railway rolling-stock of parameters of a train and modes of its movement, and also thermo-physical and tribotechnical properties of materials brake shoes is established.

3. For the approached tentative estimation of an overheat of new frictional materials as a part of frictional pair of a friction of executive elements of mechanical brakes depending on parameters of a train, a mode of its movement, definition at their development cycle necessary thermo-physical and tribotechnical characteristics, expediently to use the regress equation (3).

4. The maximum local settlement overheat of a material for shoes mechanical brakes of the rail transport executed on the basis of modified C-C of composites, has left nearly 800K, that does not surpass a limit of thermal stability of the given materials.

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ИССЛЕДОВАНИЕ ВЛИЯНИЯ ХАРАКТЕРИСТИК ФРИКЦИОННЫХ МАТЕРИАЛОВ ТОРМОЗНЫХ КОЛОДОК РЕЛЬСОВОГО ТРАНСПОРТА НА ИХ ФУНКЦИОНАЛЬНОЕ ТЕПЛОВОЕ СОСТОЯНИЕ

Старченко В.Н., Кущенко А.В.

Аннотация. Представлены результаты расчетных исследований перегрева пар трения механических тормозов рельсового подвижного состава, выполненные на основе численного решения нестационарного уравнения теплообмена. Получено и предложено для использования при предварительных расчетах тепловых характеристик тормозов уравнение регрессии в функции четырех основных факторов влияния.

Ключевые слова: железнодорожный транспорт, механические тормоза, тормозная колодка, углерод – углеродные (С – С) композиты, тепловое состояние, расчет.