Analysis of the constructive features of railway brakes and methods of improving the process of their functioning

Nickolay Gorbunov, Ekaterina Kravchenko, Rostislav Demin, Olena Nogenko, Olga Prosvirova

Volodymyr Dahl East-Ukrainian National University,
Molodizhny bl., 20a, Lugansk, 91034, Ukraine, e-mail: kkatherina@ukr.net
Received June 05.2013: accepted July 03.2013

Summary. The article provides the analysis of current situation in railway brake systems and provides new constructive solutions that optimize the use of disc brakes in the traction mode thereby increasing the effective power of the traction vehicle, increase the coefficient of friction for shoe brakes, stabilize the temperature in the tribocontact, reduce the wear of the friction nodes and improve safety.
Key words. Disc brake, shoe brake, shape memory alloy, porophore, pressed air.

INTRODUCTION

Due to the continuous rise of train speeds high requirements are placed to the brake systems. Application of the well-known shoe brake construction that provides interaction between the brake shoe and the surface of the wheels is limited by their allowed heat. The use of disc brakes becomes more common because the required braking power is not achieved with shoe brakes.

In operation, the rolling surface and ridges of wheels that contact with the rails and in case of braking shoe - with pads on the brake axle. Consequently, both the friction pairs mutually affect the process of wheel and rail wear, the formation of the contact zone between them and the arising contact stress level, and therefore the adhesion force, determining the magnitude of traction and braking forces of the rolling stock.

To improve braking efficiency of rail vehicles it is necessary to create adequate braking power for braking devices and provide a stable friction of the wheels and rails. The authors propose new technical solutions that reduce resistance to movement of the vehicle, as well as improving the operational efficiency of frictional brake elements of the rolling stock.

BACKGROUND RESEARCH ANALYSIS

The efficiency of the frictional elements of the brake system of the rolling stock considerably influents traffic safety, the ability to increase the speed and increase of the capacity of the rail lines.

During braking the kinetic energy of the train is converted into other forms of energy, most of which - in the heat. This process is accompanied by a temperature increase of friction elements. Effective deceleration of the train depends on the friction coefficient, which is affected by the temperature changes in tribocontact. Another urgent issue in the operation of rolling stock is to stabilize the temperatures in the zone of interaction of the brake pad and wheel [1, 2, 5, 8, 19, 20].

All the energy that is produced by the traction vehicle is spent on overcoming the resistance forces and the forces of inertia. Annually for train traction a large amount of fuel and electricity is spent, the cost of which significantly affect the the cost of transportation [6-18, 21, 22]. Therefore, resistance reduction is as important as increasing the efficiency of the traction vehicle. Reducing the resistance can increase the weight of the rolling stock or the speed for the same locomotive, reduce wear and repair costs. The problem of reducing resistance of movement is directly related to the need to optimize the aerodynamic of rolling stock [4].

OBJECTIVES AND PROBLEMS

The aim of the article is to develop recommendations and constructive solutions to improve the efficiency of operation of brake frictional elements of the rolling stock, as well as to reduce the resistance to movement of the vehicle by providing a construction of disc brakes with additional elements that allow you to remove the circulation of air in the air ducts on the move.

METHODS AND TECHNICAL SOLUTIONS FOR IMPROVING THE PROCESS OF FUNCTIONING OF THE RAILWAY BRAKES

At high speeds of the vehicle disc brake ventilation vanes creates additional resistance to movement which leads to a certain expense of locomotive power, especially for high-speed locomotives, for which the expense of significant speeds resistance increases. Thus is pumped through the ventilation channels 3000 - 4000 m^3/h of air which cools the disc. This leads to expenditure of a certain power. For example, according to research by Turkov A. [18], for diesel trains of DR-type and electric trains of ER-type in which installed set of eight brake discs at a speed of 200 km /h will spend more than 19.1 kW and 48 kW respectively on the self-venting. For diesel train DR1 total capacity is reduced by 2.6%. Research conducted by the authors, the results of which are presented in Table 1 show that for modern high-speed trains, this amount increases by several times.

The proposed method for reducing the aerodynamic resistance of vehicles is implemented as follows.

To eliminate the self-ventilation of disc brakes, which causes a negative resistance to the movement of the train in the mode of the traction and freewheel, it is proposed to close ventilation holes of disc brakes.

During the motion the plates 4 of shape memory material (fig. 2) [3, 4] which are located on each blade 3 venting, ventilation ducts 5 overlap. During braking, rolling stock brake pads are pressed with a certain force to the friction rings 1 (fig. 1) of the brake disc. The result is a braking torque, which is through the friction ring 1 and connected with them with the circlet 3.

Table 1. Power expended by train in motion to overcome the resistance of the working disk brakes

Train	Power of the train, kW	Speed, km/h (m/s)	Ventilation power of brake disc, W	Che total ventilation power of the train brake discs, kW
"Aurora" train (Russia)	609 2	200 (56)	2060	247
TVG (France)	225 00	574,8 (159)	31065	1988
Sapsan (Germany, Russia)	800 0	250 (69,4)	3599	432
Diesel train ADELANTE (ALSTOM)	280 0	200 (56)	2060	99
DR1 (Riga)	736	120 (33,3)	521	19
Fahrgestell Velaro CRH3	550	300 (83)	5731	733

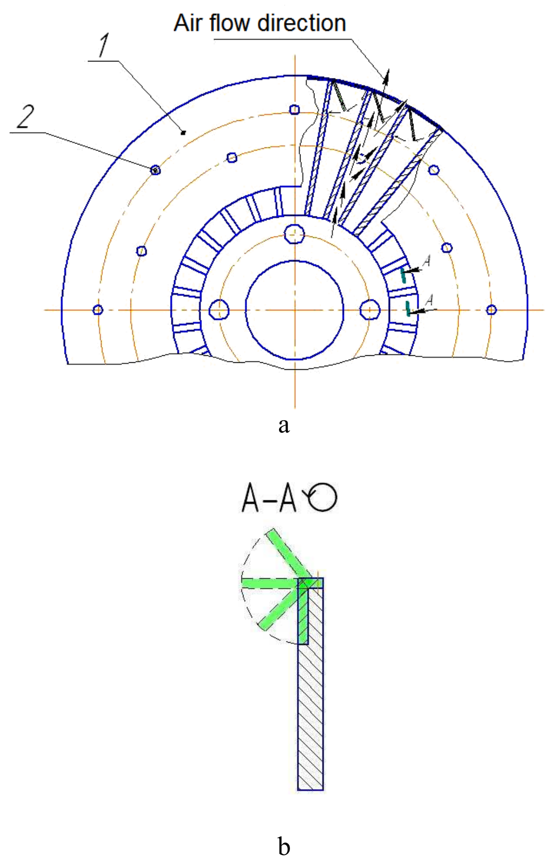

Fig. 1. a – the circulation of air in the brake disc, the plate at the outlet, b – a plate of shape memory material at the inlet

During braking the brake disc temperature increases. Under the influence of high temperature, the material of plate 4 moves from the martensitic state to austenitic (fig. 3). This changes the the crystal lattice and shape of plate 4. Angle of inclination α of plate 4 to the ventilation blade 3 reduces from 90^0 to 0^0 - 5 ventilation ducts open. Under the influence of centrifugal forces the air that is in air ducts 5 moves from the brake disk to the periphery in the radial direction, this produces the ventilation air flow that provide the removal of heat from the disk. The plates may be arranged as at the inlet of brake disc (fig. 1 b, section A-A) as at the outlet (fig. 1 a).

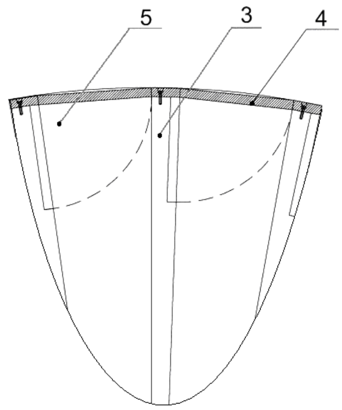

Fig. 2. The constructive scheme of the brake disc

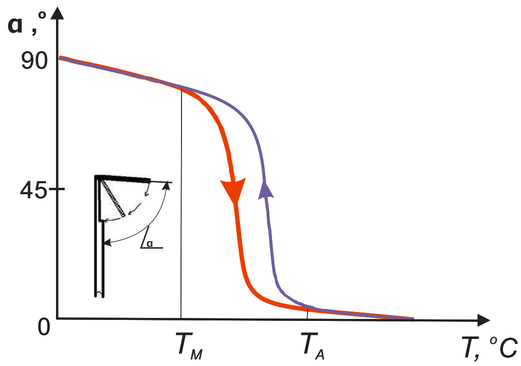

Fig. 3. The dependence of the angle of rotation of the plate relative to the ventilation blade on the temperature of brake disc

When the brake disc is cooled the reverse process occurs - the material of plate 4 changes from austenitic to martensitic state. When reaching by plate 4 temperature of martensitic state _ it is unbent, occupying the initial position ($\alpha = 90^0$) - ventilation ducts 5 close (fig. 2, 3), due to this further loss of power because of the circulation of air in the ventilation ducts of brake disc while moving decreases.

Thus, during movement ventilation ducts are closed, during braking - they are open. When reaching the ambient temperature of the plate brake disc returns to the initial position. In this case ventilation ducts close to the next braking.

Let us consider the question of temperature stabilization of frictional contact "brake shoes - the wheel." The existing method of increasing the efficiency and durability of brake pads using the section pad when braking that provides increased contact area of the interacting element and the pressure drop in the contact area, can not sufficiently ensure the effectiveness of braking. This is due to the fact that when braking tribological pair contact is heated and the method of cooling is not provided, thereby decreasing the friction pad possibility and increased wear of the friction pair happens.

Thus, there is the problem of increasing braking efficiency of and reduce brake pad wear.

The assigned task is achieved in that when braking to the contact zone of the friction pair a gaseous active environment is injected formed by reacting brake shoe elements which are provided with porophore and wheel of rolling stock. That is, the design of the brake pad is provided with holes, which have insertions of gas-forming materials - porophore to form between the interacting surfaces of the wheel and the braking pad the gas environment that can cool the contact and reduce wear of the working surfaces (fig. 4).

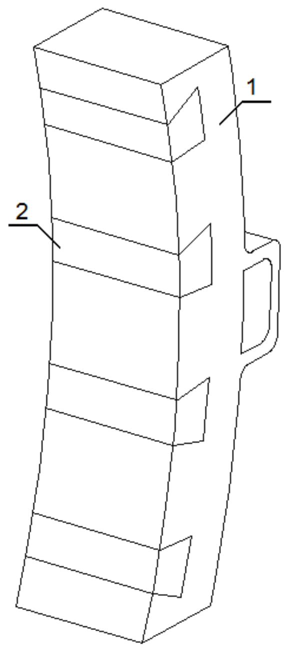

Fig. 4. Brake pad with inserts made of porophore:
1 – bracking pad; 2 – porophore inserts

This solution allows to:

1. reduce the temperature in tribocontact;
2. increase the longevity of the brake pads;
3. increase the coefficient of friction of the interacting working surfaces providing braking efficiency of the vehicle;
4. improve traffic safety.

The proposed method of increasing the efficiency and durability of brake pad works as follows.

During braking rolling stock pads are pressed to wheels or brake disc. The temperature in the friction pair increases. Under the influence of the temperature in the shoe the process of thermal decomposition of porophore pad element begins, which leads to high speed release of significant amounts of gas products. One of the major decomposition products is a gas - nitrogen which reacts with thin surface layers of frictional units. This positively affects the frictional properties of the pair of friction - coefficient of friction increases sharply strengthens and stabilizes the material surface, thereby increasing their durability and wear resistance. Braking efficiency allows to increase safety of the vehicle.

The authors are also tasked with improving the efficiency of the locomotive braking method and constructing equipment for its implementation through the efficient use of compressed air, which is discharged from the brake cylinder and cooling brake pads and working surface of the wheel, placing the products of frictional wear out of the contact "brake shoes - the wheel" (fig. 5).

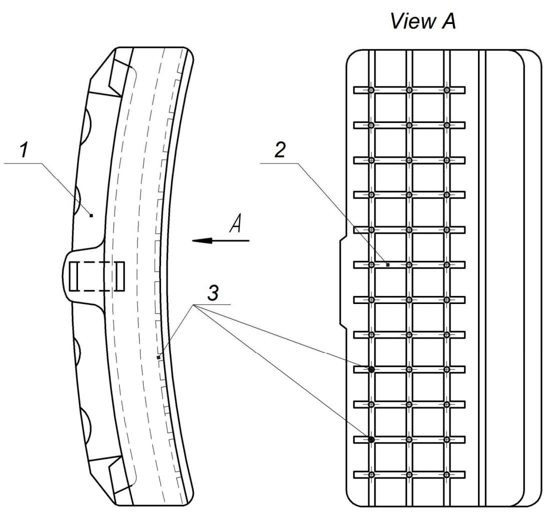

Fig. 5. Brake pad with holes for cooling: 1 – bracking pad 2 – channels, 3 – holes

For this purpose compressed air is discharged from the brake cylinder through the air distributor and a check valve in the bellows assembly, and on the next braking adjustable valve is activated connecting a brake shoe with bellows seal through which accumulated air on the rubber conduit through the holes made in the brake shoe and supplied to the channels to the contact zone "brake shoes - wheel", cools it and blows wear products into the environment.

CONCLUSIONS

Application of the proposed construction of brake disc will reduce the resistance to movement of the vehicle, optimizing the use of disc brakes in the traction mode thereby increasing the effective power of the traction vehicle to reduce the costs of energy and fuel.

The proposed method of increasing the efficiency and durability of the brake pad using the inserts of porophore will increase the coefficient of friction, stabilize the temperature in the tribocontact and reduce the wear of the friction nodes and improve safety.

The use of of the method of the locomotive braking with compressed air and equipping for its implementation will allow the following:

- Efficient use of compressed air, which is discharged from the brake cylinders;
- Cooling the contact zone "brake shoes - wheel"_ by supplying compressed air to the brake pad holes;
- To improve braking efficiency and reduce the intensity of the brake wear through the timely removal of products of frictional wear of the contact zone of the brake pads and the wheel roll surface and improve the temperature conditions of operation of the braking pads;
- Improve traffic safety by increasing the reliability of the braking.

REFERENCES

1. **Golubenko A.L., Tiupalo N.F., Nozhenko Y.S., Mogila V.I., Vasilev I.P., Ignatev O.L., 2009.:** Effect of ozonation on the physical and chemical characteristics of diesel and biodiesel, Lokomotivinform, May-June, 9 -13.
2. **Golubenko A., Mogila V., Nozhenko H., 2007.:** Energy of diesel locomotive's electrodynamic braking for increase of efficiency of diesel locomotive engines, Coll. of scientific labours, Zilina. Issue 69, 163 - 170.
3. **Gorbunov N., 2011.:** Clutch control in the system of "wheel-rail"/ N. Gorbunov, M. Kovtanets, O. Prosvirova, E. Garkushin // Silesian University of

Technology Faculty of Transport(Poland). – Transport Problems 2011, 432-440

4. **Gorbunov N.I., 2011.:** Improving energy efficiency using disc brakes / MI Gorbunov, M. Gorbunov, K. Kravchenko, AV Prosvyrova, VA Korzh / / Proceedings of the 3rd interuniversity scientific conference of teachers, young scientists and students, "Energy-saving technologies and the operation of machinery and equipment" (29-30 November 2011) - Donetsk: DonIZT, 2011. - 97-98.
5. **Gorbunov N.I., Kravchenko E.A., Popov S.V., Kovtanec M.V., Nozhenko V.S., 2009.:** Increasing the technical and economic efficiency of the friction interaction between wheel and rail. Proceedings of the IX International Conference on Tribology and Reliability"", 8 - 10 October, St. Petersburg, PGUPS, 18-29.
6. **Gorbunov N.I., Mogila V.I., Kravchenko E.A., Prosvirova O.V., Skornyakov S.S. 2011.:** Brake disk / Application for Utility Model № u 2011 15061 from 19.12.2011.
7. **Gorbunov M.I., Kravchenko K.O., Kovtanets M.V., 2009.:** The improving of the contact qualities of the diesel locomotives by using the perspective method of purification the surfaces of wheel and rail. II International scientific and practical conference of young scientists and students, 27-29 April. Kyiv, KNUBA, 30-32.
8. **Kazarinov V.M., 1968.:** Teoreticheskie osnovy proektirovanija i jekspluatacii avtotormozov / V.M. Kazarinov, V.G. Inozemcev, V.F. Jasencev – Moskva: Transport, 1968 – 400.
9. **Knothe K. 2008.:** History of wheel/rail contact mechanics: from Redtenbacher to Kalker. // Vehicle System Dynamics, vol. 46(1), 9-26
10. **Martynov A.V. 1976.:** Chto takoe vihrevaja truba? // A.V. Martynov, V.M. Brodjanskij / M., «Jenergija». – 152.
11. **Meli E., Auciello J., Malvezzi M., Papini S., Pugi L., Rindi A. 2008.:** Determination of wheel rail contact points with semi analytic methods.// Multibody System Dynamics, Vol. 20, 327-358.
12. **Mitrofanov A.P. 2012.:** Povyshenie jeffektivnosti shlifovanija putjom impregnirovanija abrazivnogo instrumenta veshhestvami iz klassa poroforov // A.P. Mitrofanov. – Volgograd: 2012. – 16.
13. **Mogila V.I., Nozhenko Y.S., 2007.:** Using wasted energy used for braking of the locomotive efficiency diesel engines, Collected scient. proceedings, Kharkov, UkrDAZT, Vol. 82, 153-157
14. **Mogila V.I., Nozhenko Y.S., 2010.:** Disposal of energy electrodynamic braking, Bulletin of the East-Ukrainian National University named after Volodymyr Dahl, № 3 (145), 237 - 243."
15. Patent na poleznuju model' №95620, kl. B61N7/02. Iznosoustojchivaja tormoznaja kolodka s povyshennym kojefficientom trenija dlja skorostnogo dvizhenija // O.V. Mel'nichenko, E.V. Chuprakov, S.A. Gorbatok/ opubl. 10.07.2010.
16. Shackleton P. and Iwnicki S.D. Comparison of wheel–rail contact codes for railway vehicle simulation: an introduction to the Manchester Contact Benchmark and initial results. // Vehicle System Dynamics, vol.46(1), 2008, 129-149
17. **Stolyarenko G.S., 2000.:** Theoretical foundations of heterophase ozone processes and technology denitrification gas fluxes: diss. ... Doct. Tekhn. Science. Kiev, NTU, 440.
18. **Turkov A. 1982.:** The study, the choice of parameters and the development of the principles of designing a pair of disc brake friction of rolling stock / A. Turkov / dis. Ph.D.: 05.05.01. - Khabarovsk, 1982. - 349.
19. **Vodjannikov Ju.Ja. 2012.:** Raschetno-jeksperimental'nyj metod opredelenija temperatury nagreva kolesa gruzovogo vagona pri tormozhenii // Ju.Ja. Vodjannikov, S.M. Svistun, E.G. Makeeva / Visnik Shidnoukraïns'kogo nacional'nogo universitetu imeni Volodimira Dalja: v 2 - h ch. Ch.1. – Lugans'k: SNU im. V. Dalja, 2012. – № 5(176) – 50-55.
20. **Zili Li 2002.:** Wheel-Rail Rolling Contact & Its Application to Wear Simulation. // Delft University Press, 2002, 67-76.
21. **Gorbunov N. Kostyukevich A., Kravchenko K., 2010.:** Efficiency function for evaluation of the locomotive traction and adhesion qualities // TEKACommission of Motorization and Power Industry in Agriculture V. X, Poland 2010. – 80-86.
22. **Cherneckaya N., Kolodyazhnaya L., 2010.:** Technical and economic calculations in organization of railway transportations. TEKA Commission of Motorization and Power Industry in AgricultureVX.Poland. – 32-37.

АНАЛИЗ КОНСТРУКТИВНЫХ ОСОБЕННОСТЕЙ ЖЕЛЕЗНОДОРОЖНОГО ТОРМОЗА И МЕТОДЫ СОВЕРШЕНСТВОВАНИЯ ПРОЦЕССА ЕГО ФУНКЦИОНИРОВАНИЯ

Николай Горбунов, Ростислав Дёмин, Елена Ноженко, Екатерина Кравченко, Ольга Просвирова

Аннотация. В статье приведен анализ современных железнодорожных тормозов, а также предоставлены новые конструктивные решения, которые позволяют оптимизировать использование дискового тормоза в режиме тяги и выбега, тем самым увеличивая эффективную мощность тягового транспортного средства, повысить коэффициент трения для колодочных тормозов, стабилизировать температуру в трибоконтакте, уменьшить износ узлов трения и повысить безопасность.

Ключевые слова. Дисковый тормоз, тормозная колодка, сплав с памятью формы, порофоры, сжатый воздух.