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Method of determining the parameters of improved railway brake equipment

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Summary. Cooling properties of brake disc are determined by its material, shape and other factors. In the ventilation device of the brake disc during braking there is a significant increase in air temperature, and thus on the internal elements of the drive occurs thermal stress. The highest temperature during braking has a frictional surface of the disc. The removal of thermal energy from the zone of friction contact elements disc brake enhances braking stability characteristics of a mechanical brake. The specified task can only be solved on the basis of new technical solutions in the field of brake equipment which will allow to create a system of forced cooling of the disc brake, which will ensure the effective characteristics of the cooling process, will be of an acceptable weight and dimensions and fire performance and will significantly reduce the dependence of friction coefficient on temperature generated in the contact zone of the working elements during braking. We propose a method of improving the braking equipment that provides the compressed air in frictional contact, and a method of calculating the pressure of the compressed air, and the diameter of the inlet, such that the reaction force from the compressed air does not lead to deterioration of the above listed parameters.

That is, a reasonable quantification of the factors affecting the process of supplying compressed air between the brake disc and the brake pads during braking and the dynamics of their actions.

Key words: railway transport, brake system, brake cooling, compressed air, disc brake, energy efficiency, adhesion coefficient.

INTRODUCTION

High speed train discs must be capable of absorbing large amounts of heat in emergency brake applications from maximum speed. Heat dissipation during braking is low and therefore it is crucial to ensure low initial brake temperatures.

This can only be achieved with good cooling characteristics, since brake mass must be kept to a minimum to ensure low unsprung mass. It must also be taken into consideration that emergency braking from maximum speed is relatively rare, however the brake system must be capable of performing this duty without excessive thermal loading.

Ventilated brake discs are commonly employed for their good cooling qualities, however this type of brake disc can generate substantial pumping losses when rotating at high speed. The effects are very serious because a high number of discs (usually 4 discs per axle) rotating at high speed (up to 2000 min-I) require very high levels of power, just for disc rotation.

This has resulted in the development of numerous 'low loss' ventilated disc designs and the use of solid discs. Obviously, a very fine balance of low pumpIng losses and good cooling characteristics are necessary to satisfy braking and power consumption requirements for all vehicle routes.

OBJECTIVES

The phenomenon of heat dissipation from friction brakes IS very complex and requires carefully planned research, combining detailed literature study and analytical, numerical and experimental techniques [1-9]. It is important to ensure that research results are of a generic nature, applicable to other brake designs and have wider engineering applications. At the same time, analysis must be orientated to finding ways of improving and optimising brake cooling using practically acceptable and economically viable methods.

Thus there is a necessity to determine and recommend to the pressure value of compressed air, and the diameter of the inlet to the reaction force from the compressed air does not lead to deterioration of the above listed parameters.

That is, the numerical determination of the factors that affect the process of supplying compressed air between the brake disc and the brake pads during braking and the dynamics of their actions.

THE MAIN RESULTS OF THE RESEARCH

The flow of liquids and gases play a key role in the workflow of many modern engineering devices. The design of these devices on the necessary parameters is impossible without a reliable prediction of the characteristics of these currents. Since many modern engineering devices are costly and time-consuming to manufacture, physical simulation with the experimental determination of the parameters of their work in different modes, as a rule, requires a lot of time and financial resources.

Moreover, because of the limited capabilities of experimental rimentally sensors and instrumentation the experimental observations do not provide a complete picture of the phenomenon being studied. Because of the very nature of these environments the flow of liquids and gases often occur in quite a complex way, with the formation of non-stationary tools, stagnant zones and vortex structures, and at supersonic speeds - with the formation of shocks and shock waves.

These factors are driving the growing interest in mathematical modeling of flows of liquids and gases, allow prognoza-you are the flow-characteristics and parameters of the device under design, to fabrication in metal. Section of science that solves the problem of simulation of flows with heat and mass transfer in a variety of technical and natural objects, is called computational fluid dynamics, in English literature - CFD (Computational Fluid Dynamics).

The methods then involve the computation of flows of liquids and gases the numerical solution of the Navier - Stokes equations and Neros-revnost describing the most General case of motion of these ceredo very, very (for turbulent flows - Reynolds equations). The corresponding sequence of actions, from the creation of the geometric model and the assignment of boundary conditions to the analysis of the results of the calculation described in [2].

The calculation of the flow of liquid or gas in modern software products is performed by numerical solution of the system of equations describing the most General case of motion of a liquid medium. These are the Navier - Stokes equations (1) and continuity (2):

$$\frac{\partial}{\partial t}\left(\rho u_i\right)+\frac{\partial}{\partial x_j}\left(\rho u_i u_j\right)= -\frac{\partial p}{\partial x_i}+\frac{\partial}{\partial x_j}\left[\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)\right]+f_i, \quad (1)$$

$$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x_j}\left(\rho u_j\right)=0. \quad (2)$$

Here we have used a shorthand notation of the equations, i,j=1...,3, we assume summation over the same indices, x_1, x_2, x_3 are coordinate axis. A complete record of these equations in curvilinear coordinates are given, e.g., in [3]. Expression f_i expresses the action of mass forces.

In this system of 4 equations is independent of the unknown parameters are the 3 velocity components (u_1, u_2, u_3) and pressure p. The density ρ of the gas at speeds of approximately up to 0.3 Mach number can be considered constant.

As boundary conditions, as a rule, specify the condition of adhesion in all solid walls (velocity is zero), the distribution of all components of velocity in the inlet section and the equality to zero of the first derivative (in direction of flow) velocity components in the output section. Pressure is included in equation (1) only in the form of first derivatives, and the user needs to specify the pressure only at some one point of the computational domain.

Generally speaking, the development trend of the leading software products is to implement each one of a set of mathematical models (MM), allowing as much as possible to simulate all the physical effects that occur in practice [10, 11, 12].

Computational fluid dynamics is the newest method used to analyze the cooling of the brakes and predict the temperature. This method makes it possible to analyze the flow of air via complex rotating disc geometry and provide values of convective heat transfer coefficients for all brake surfaces.

Study of parameters based on the analysis of the flow of air through the drives. Brake cooling efficiency is determined by the airflow through the disc blades. For scale models. The results show the speed of air flow through the ventilation channels is increased in proportion to the disk inner radius and alternately arranged using two fins of different lengths increase ventilation duct at the entrance to tum a higher speed. The velocity of the air through the blades increases round-shaped blades and short straight shovels, and the results compared with water tank results. It was also found that increasing the number of edges results in a more uniform stress distribution.

Brake systems of modern high-speed trains reach specific energy of 40 MJ. In the absorption of this amount of energy during braking frictional heating elements is 800 – 900 C [10], which causes the instability characteristics of disc brakes and lowers operational characteristics of the rolling stock associated with the need to comply with the stopping distance and the schedules of the trains.

The braking system of railway rolling stock is determined by the conditions under which the friction force in the contact zone of the working elements of the friction disk brake does not exceed (or, at least, equal to the force of friction in the contact zone of the wheel with the rail. In this direction there are many studies that have the purpose of providing the specified dependencies in practice. This is a necessary but insufficient condition for ensuring a consistently high braking of rolling stock. Another condition is to ensure the stable values of the coefficient of friction of the elements of the disc brake.

The problem of the dependence of coefficient of friction of disc brake temperature is solved in different directions: improving the design of the brake system and its management, creation of new principles of braking, the development of algorithms for simultaneous control of various brake systems, development of new materials for brake elements, improving the efficiency of their use, etc.

However, a significant factor of influence on the coefficient of friction is the cooling of the working of the friction elements in disc brakes, so there appears the possibility to significantly reduce its dependence on temperature. Existing designs implement the principle of cooling of the working elements, which is intended for more direction of air flow for more thermally strained surface during rotation of the brake disc, but the effectiveness of these measures is not satisfactory, because with the help of them you can withdraw from the zone of friction only up to 10% of the heat.

It is more efficient forced cooling of the working elements of a friction brake. This method can also be included in the proposed equipment.

The problem of cooling friction pairs, increasing the efficiency of a method for braking a rail vehicle and equipment for its implementation can be solved by efficient use of compressed air, which is discharged from the brake cylinder, and the cooling of the brake pads and the working surface of the wheel, the categorization of products galling to contact "brake disc and pad" [13, 14].

For this purpose, the compressed air from the brake cylinder through the diffuser and check valve venting to the bellows, the next time the brake is actuated modulating valve that connects the brake pad with the bellows, by which the accumulated air on the rubber tubing through is made in the brake shoe openings and channels is fed to the frictional contact, cools it and blows debris into the environment as shown in Fig. 1.

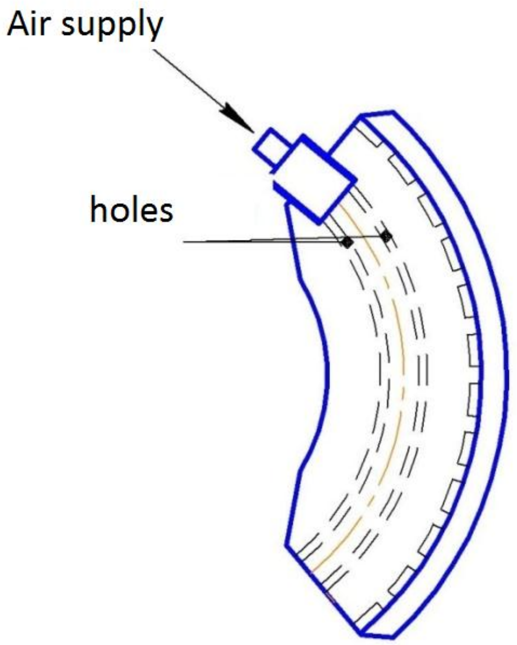

Fig. 1. Bake pad with air supply

The basis of the proposed technical solution the task of increasing the efficiency of the method of braking of the locomotive and equipment for its implementation through effective use of compressed air, which is discharged from the brake cylinder, and the cooling of the brake pad and the working surface of the disk, the categorization of products galling to contact "brake pad and brake disc" [15-18].

The basis of the model the task of increasing the efficiency of the method of braking of the locomotive and equipment for its implementation through effective use of compressed air [19], which is discharged from the brake cylinder, and the cooling of the brake pad and the working surface of the disk, the categorization of products galling to contact "brake pad and brake disc".

The proposed method of braking a rail vehicle and equipment for its implementation is as follows.

The compressor 1 draws in the main reservoir 2, the compressed air that nutritional highway 3 is supplied to the valve 4. Crane operator connects the main tank 2 and the filling line 3 to the brake line 5.

Outbound train brake charge, for which the handle of the valve 4 is put in the vacation position (Fig. 2) in which air from the main reservoir 2 by nourishing highway 3 through the valve 4 flows into the brake line 5 and then through the diffuser 6 is in a spare tank 8. In this case, the brake cylinder 7 through the diffuser 6 and the check valve 10 communicates with the bellows 9, which accumulates compressed air.

The check valve 10 moves of compressed air in one direction only from the brake cylinder to the bellows and prevents the movement of air in the opposite direction.

For braking the handle of the valve 4 is transferred to the brake position, the feed line 3 is disconnected, and the brake line 5 through the valve 4 communicates with the atmosphere. If you lower the pressure in the rail 5, the diffuser 6 comes into effect, disconnects the brake cylinder 7 with bellows 9 and connects it with the spare tank 8 filled with compressed air.

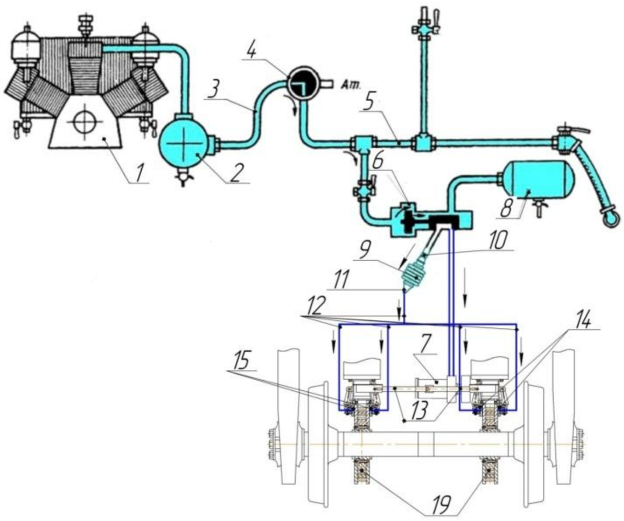

Fig. 2. Developed braking method for disk brakes

When supplying compressed air to the brake cylinder 7, the piston rod moves and transmits braking force through longitudinal traction on 13 tick-borne mechanisms, which press the brake basmati with the brake pad 15 and the brake disc 19. Further actuates the regulating valve 11 of the bellows 9 and compressed, the accumulated air through the rubber tubing 12 is fed under pressure into the holes 16 (Fig. 1) brake pad 15. This contributes to the cooling contact "brake pad and brake disc".

There are several methods of supplying and distribution of gas in the gap. Very effective is a sectional system for supplying gas to its distribution in the working gap by mcrainey. Design scheme odnorangovogo straight aerostatico props used in rail width less than 40 mm, as shown in figure 3.

When supplying compressed air between the brake pads and the brake disc during braking, it is possible to identify factors that will influence this process, these are:

• air supply pressure between brake disc and brake pad,

• the diameter of the inlet fittings in brake pads,

• optimum clearance between the brake disc and the brake pads (before the braking process to ensure that the air had time to blow pads).

Parameters that govern the operation of the brake mechanism when supplying compressed air between the brake pads and brake disc are as follows:

• air consumption from receiver,

• the coefficient of friction, coefficient of efficiency and the stability coefficient of the brake mechanism,

• uniform distribution of air over the surface of the friction pad during braking,

• specific braking force.

In the case of forced cooling by compressed air, the surface of the brake pad should be considered as an aerostatic slip resistance. It will serve as the basis of the friction plate with symmetrically arranged relative to the longitudinal axis holes for the supply of compressed air.

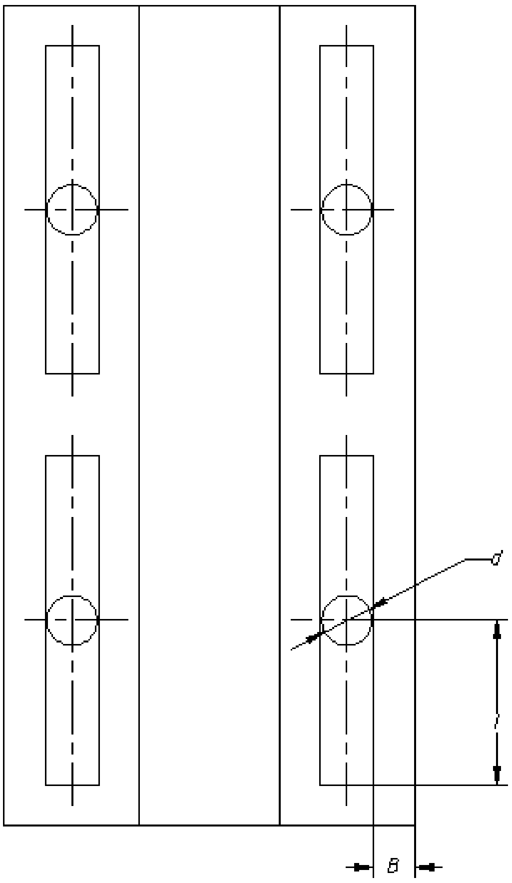

Fig. 3. Bake pad design scheme

Calculation of aerostatic pad made with a numerical method as used in [20]. It is based on the approximation of the pressure field in the gap of differential algebraic equations.

The method takes into account the two-dimensionality of the distribution of gas flow in pads of various configurations and gives results close to real. In each of the points to consider integrated equations using known formulas for approximate calculation of derivatives.

The gas is fed to the pad under pressure. After passing through the hole blowing in, the gas pressure enters screename, moving along the latter, goes through the gap toward the environment. Pipe in conjunction with the fixed part of the pad forms a nutrient capillary channel having a cross section in the shape of an equilateral triangle height (groove depth).

Because of the smallness of the airflow flowing through the lubricating gap, the flow along the capillary can be considered laminar.

A more exact solution of the problem of laminar lubrication of the pad is associated with great difficulties, because the flow of lubricant through the hole–spatial: the flow rate, in addition to component $\frac{\partial y}{\partial t}$, also has a component $\frac{\partial x}{\partial t}$. These components are proportional to the respective pressure gradients. The pressure gradient $\frac{\partial p}{\partial x}$ along the pore – value is small in comparison with the pressure gradient $\frac{\partial p}{\partial y}$, where it is possible to assume that the flow along the axis of planar and directed perpendicular to the axis y of the capillary. Line current, which confirms the validity of this simplification of the problem.

Consider an element of the lubricating layer of width dx and height h that is a distance x from the inlet. The cost of gas over the cross section of the pores is reduced with x increase for leakage through the gap so $x = l$.

The decrease in mass flow dm_x on a segment dx of the capillary must equal the mass flow rate through the gap (on both sides of the capillary) within the same interval in the y direction. This condition of continuity of flow used to create differential equations pad.

Fig. 4 shows the results of calculating the optimal hole diameter depending on pressure for different values of the length of the groove l.

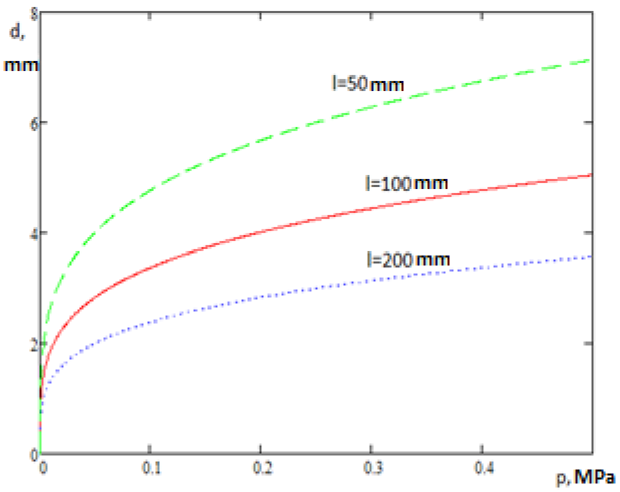

Fig. 4. Plot of the optimal diameter of the holes from the pressure of the air supplied to them for different values of the length of the groove l.

According to the obtained data, with the air pressure, which is supplied into the holes of the brake pads to 0.4 MPa (the pressure in the brake cylinder during braking the car), the calculated hole diameter not exceeding 8 mm.

Also analisys the effect of back pressure is needed, as it is produced when using compressed air for cooling the frictional contact and entrainment wear products. It is calculated by the formula:

$$Q = p_a p_0 B l n K_н, \quad (3)$$

where: $K_н$ – specific force of back pressure. By varying the number of holes n, geometrical parameters of the element aerostatic pads and the pressure one can obtain different values of the force of back pressure Q.

Fig. 5 shows the plot of back pressure force Q dependence on n for one pad. According to a formula it is linear.

Figure 6 shows the dependence of the flow of air from the pressure during braking.

Thus, for $p_0 = 0{,}4$ MPa, $l = 10$ sm, $B = 2$ sm, $p_a = 0{,}1$ MPa the force of the back pressure is 1,44 kN for the two holes in the overlay and 14.4 kN for twenty holes in the cover plate. Depending on the pressing force of the brake pad on the axle and other parameters of the brake system, are determined by the design parameters of brake pad.

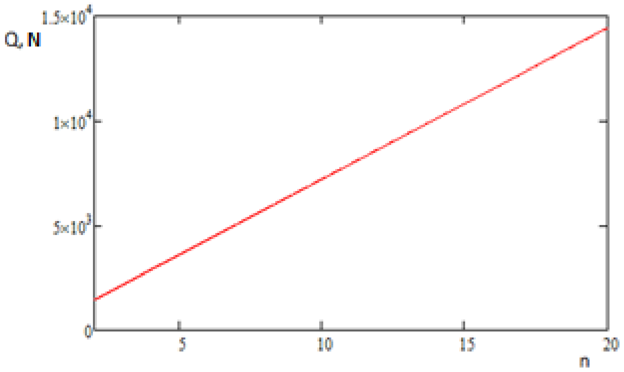

Fig. 5. Back pressure force Q dependence on n

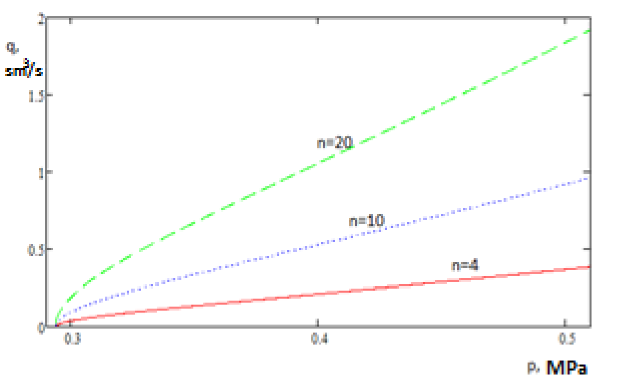

Fig. 6. The dependence of the flow of air from the pressure

The heat transfer coefficient by convection is calculated according to the criteria of Reynolds and Prandle.

CONCLUSIONS

1. Suggested ventilated disc brake for which can reasonably desegment the task of increasing the efficiency of the method of braking of the locomotive and equipment for its implementation through effective use of compressed air, which is discharged from the brake cylinder, and the cooling of the brake pad and the working surface of the disk, the categorization of products galling to contact "brake pad and brake disc".

2. Justified quantification of factors affecting the process of supplying compressed air between the brake disc and the brake pads during braking and the dynamics of their actions.

Consequently, the use of the proposed design will allow:

- effective use of compressed air which is discharged from the brake cylinders,

- cooling the area of frictional contact of the brake pad and brake disc", using the compressed, cooled air into the holes of the brake pads,

to improve braking performance and reduce the intensity of wear of the brake pads due to the timely disposal, the frictional wear of the zone,

- to increase the level of traffic safety of trains by increasing the reliability of the braking.

3. The coefficient of heat transfer by radiation is given depends on the degree of tone color scheme (dark, light) radiating surface

pad, of the absolute temperature of the pad and the ambient temperature. In a modified construction of the pad coefficient of heat transfer by radiation is not considered, because it does not significantly affect the wear pads because organized weak heat removal from the zone of friction of the wheel roll surface and overlay in the environment.

The presence of grooves in the proposed design of pads reduces the intensity of wear, especially at high speeds, through the stabilization of the temperature regime at the expense of increasing the efficiency of heat removal from the zone of friction in the environment. During braking, the cold air that is blown under the cover, heats up and goes effectively in the environment. As a consequence, there is an increase, which reduces the average temperature of the friction of the working surface of the pad, thereby increasing the time to reach the maximum temperature at which there is destruction of the projections of the actual contact. In the overlay model when increasing the initial speed of braking of the intensity of the heat increases.

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Метод обоснования параметров усовершенствованного железнодорожного тормозного оборудования

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Е. Ноженко, М. Ковтанец, С. Мокроусов, С. Кара

Аннотация. Параметры охлаждения тормозного диска определяются его материалом, формой и другими факторами. В вентиляционном аппарате тормозного диска во время торможения происходит значительное повышение температуры воздуха, и, таким образом, на внутренних элементах диска возникает термический стресс. Отвод тепловой энергии из зоны фрикционного контакта элементов дискового тормоза способствует повышению стабильности тормозных характеристик механического тормоза. Указанную задачу возможно выполнить только на основе новых научно-технических решений в области тормозного оборудования, которые позволят создать систему принудительного охлаждения дискового тормоза, которая обеспечит эффективные характеристики процесса охлаждения, будет иметь приемлемые массо-габаритные и противопожарные показатели и существенно уменьшит зависимость коэффициента трения от температуры, генерируемой в зоне контакта рабочих элементов при торможении. В работе предлагается метод совершенствования тормозного оборудования, что предусматривает подачу сжатого воздуха в фрикционный контакт, и метод расчета давления сжатого воздуха, и диаметров входных отверстий, таких, чтобы сила противодействия со стороны сжатого воздуха не приводила к ухудшению выше перечисленных параметров. То есть, обосновано численное определение факторов, которые влияют на процесс подачи сжатого воздуха между тормозным диском и тормозными накладками в процессе торможения и динамику их взаимодействия.

Ключевые слова: железнодорожный транспорт, тормозная система, охлаждение тормозов, сжатый воздух, дисковые тормоза, энергоэффективность, коэффициент сцепления.