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# AN INFLUENCE OF GEOMETRICAL CHARACTERISTICS OF FRICTIONAL ELEMENTS ON THE EFFECTIVENESS OF DISK BRAKE

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**Summary.** An influence of physical, technical and design factors on the functional characteristics of friction brake has been considered on the basis of molecular and mechanical theory. The appropriate mechanism has been given.

**Key words:** friction brake, friction coefficient, frictional force, molecular and mechanical theory of friction, contact type, contact area, braking efficiency.

## INTRODUCTION

At present friction brake is oe of the main means of surface transport facilities braking.

The operation of a friction brake is based on the creation of resistance to the relative displacement of brake elements by means of frictional forces. As a result the kinetic energy of transport facilities movement is converted into heat energy.

Friction coefficient is one of the main criteria by means of which the efficiency of the friction brake is evaluated [1, 2]:

$$f = \frac{F}{P}, \tag{1}$$

where: $f$ – friction coefficient,

$F$ – frictional force,

$P$ – normal loading (pressing force of braking elements).

The friction coefficient of friction brake is a variable and first of all depends on the potential frictional properties of friction elements and conditions of their development under the force interaction.

Potential properties of the friction elements are:

- physical and mechanical properties of the materials and their compatibility,
- geometrical and microgeometrical characteristics of friction surfaces,
- physical and chemical properties of friction surfaces.

The development conditions of potential frictional properties are:

- load and speed characteristics of friction elements interaction (the pressing force and the type of its action, relative displacement speed, force interaction duration);
- environmental parameters (temperature, humidity, ingredient content).

The criterium which characterizes potential properties of friction elements is the static friction coefficient.

Taking all that into consideration the main target of the article is a search for the potential properties increase of the frictional brake.

## OBJECTS AND PROBLEMS

Molecular and mechanical friction theory is taken as a leading theory of research and that theory describes the friction processes in the area of frictional contact and is universally recognized at present. Molecular and mechanical friction theory explains the forces of external friction as the sum of resistances to relative displacement of the bodies, stipulated by atom-molecular interaction and deformation of surface layers by means of introduced microroughness. Coming from that fact the friction coefficient at the interaction of two bodies is equal to [2, 3]:

$$f = f_{mol} + f_{mech}; \tag{2}$$

where: $f$ – friction coefficient,

$f_{mol}$ – molecular component of friction coefficient,

$f_{mech}$ – mechanical component of friction coefficient.

According to molecular and mechanical way of friction nature, the general equation for static friction coefficient has the view [3]:

$$f = \frac{\tau_0}{p_r} + \beta + k\sqrt{\frac{h}{r}}, \tag{3}$$

where: – frictional parameters which depend on the work conditions of friction pair;

$p_r$ – actual pressure,

$k$ – Boltsman constant,

$h$ – introduction depth of microroughness,

$r$ – microroughness radius.

While changing force interaction intensity of solid bodies, the given dependence (3) is being modified according to the deformation nature of microroughness of the surface (types of contact). There are elastic nonsaturated, elastic saturated, plastic nonsaturated and plastic saturated contact types [2].

As an example showing marked positions, there have been considered interaction of rail track disk brake. In accordance with the criteria presented in the paper [2], interaction of friction elements of a disk brake is carried out under the conditions of elastic nonsaturated contact.

The static friction coefficient for elastic nonsaturated contact is determined by the expression [2, 3]:

$$f = \frac{2,4\tau_0\left(1-\mu^2\right)^{4/5}}{p_c^{1/5}\Delta^{2/5}E^{4/5}} + \beta + 0,24\alpha_{eff}\,p_c^{1/5}\Delta^{2/5}\left(\frac{1-\mu^2}{E}\right)^{1/5}. \tag{4}$$

The formula (4) determines interconnection between the friction coefficient $f$ and effecting parameters.

The formula includes:
$p_a$ – nominal pressure,
$\tau_0$ – molecular shear strength,
$R_{max}$ – maximum height of microroughness,
$R$ – curve radius of microroughness peak,
$v,b$ – parameters of degree approximation of initial part of support curve,
$k_1$ – integration constant depending on $v$,
$A_c$ – contact contour area,
$\beta$ – piezocoefficient of molecular bond,
$p_c$ – contour pressure,
$\mu$ – Puasson coefficient,
$E$ – modulus of elasticity,
$\Delta$ – complex criteria of roughness,
$a_{eff}$ – the coefficient of hysteresis losses.

Contour pressure $p_c$ in the area of contact of a disk brake friction elements are defined in the supposed localization of force interaction of microroughness on the wave peaks in accordance with the dependences presented in the paper [2].

On the basis of dependence (4) an influence of some factors is determined on the static friction coefficient. The above factors characterize the peculiarities of interaction of friction elements such as contour pressure $p_c$, surface roughness $\Delta$, modulus of elasticity $E$ and nominal contact area $A$ too.

Nominal contact area is taken into account in the dependence (4) by means of nominal pressure . Figures 1 – 4 show the obtained dependences.

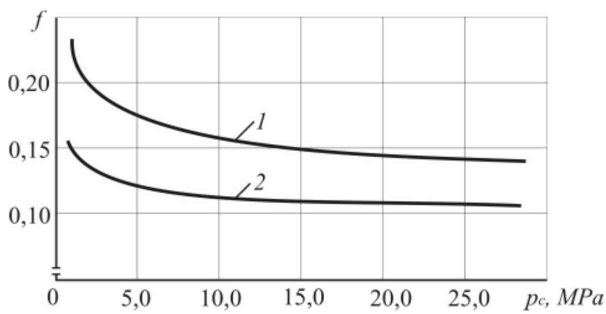


Fig. 1. Dependence of the static friction coefficient on the contour pressure in the contact area of friction elements

1 – block material: grey cast iron ($E$ = 0,8 $\cdot 10^5$ MPa),
2 – block material: high strength cast iron ($E$ = 1,7$\cdot 10^5$ MPa).

The analysis of the dependences shows that while increasing contour pressure $p_c$ , the observed friction coefficient decreases. Taking into consideration the fact that the interaction of friction elements is carried out under conditions of elastic nonsaturated contact it is possible to asume that during further pressure increase in the contact corresponding to plastic nonsaturated contact there will be a tendency friction coefficient’s growth.

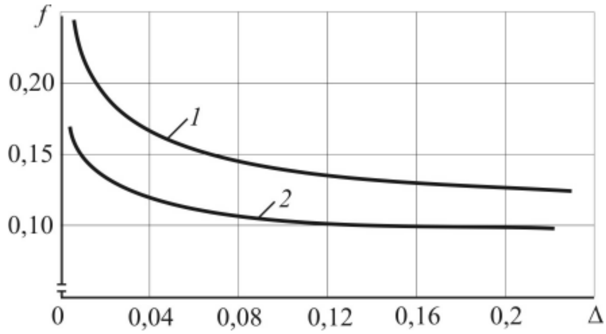


Fig. 2. Friction coefficient change in dependence on surface roughness in nonsaturated elastic contact

1 – block material: grey cast iron ($E$ = 0,8 $\cdot 10^5$ MPa),

2 – block material: high strength cast iron ($E$ = 1,7$\cdot 10^5$ MPa).

The analysis of the dependence (2) shows that roughness level of friction elements may have an influence on static friction coefficient but taking into account an objective process of roughness run in this fact may be effective only at the beginning of brace operation. Later on surface roughness will acquire its optimal values (in this case minimum) due to run in.

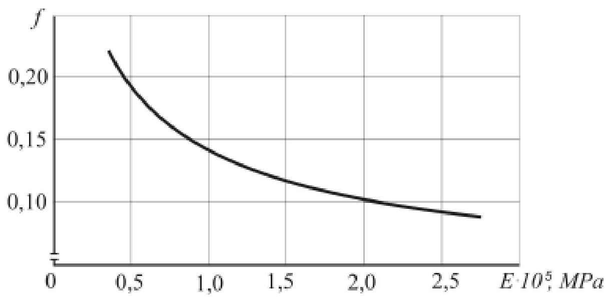


Fig. 3. Dependence of external friction coefficient on modulus of elasticity

The investigation showed that the influence on the friction coefficient by means of the modulus of elasticity is not an effective means (Fig. 3) because it is not possible to modify the modulus of elasticity for a specific material.

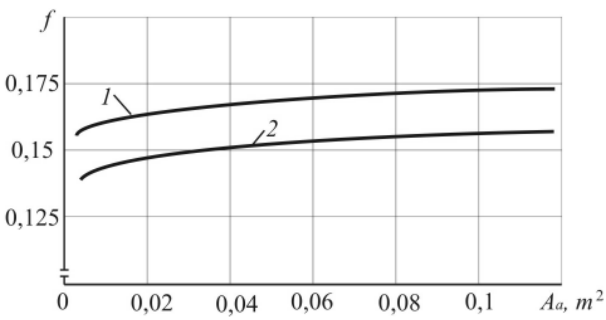


Fig. 4. Dependence of the static friction coefficient on nominal contact area elements

1 – block material: grey cast iron ($E$ = 0,8 $\cdot 10^5$ MPa),
2 – block material: high strength cast iron ($E$ = 1,7$\cdot 10^5$ MPa).

As it can be seen in Fig. 4, the simplest way of friction coefficient rise of block brake is an increase of contact area of interacting elements. It is determined that while increasing contact area 1,5 times it becomes possible to increase the friction coefficient by 2,2 %.

## CONCLUSION

1. Braking efficiency increase of frictional disk brake due to an increase of pressure in the contact area is not a prospective method, because together with pressure growth in the contact area there can be observed a decrease of friction coefficient.
2. An increase of surface roughness level of friction elements promotes an increase of friction coefficient but it may be effective only at the beginning of brake operation.
3. An influence of the modulus of elasticity of friction material elements on the static friction coefficient of frictional brake is rather low.
4. The most effective way of friction coefficient increase of frictional brake is an increase of contact area of interacting elements which ensures a decrease of pressure in the contact area.

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## WPŁYW WŁAŚCIWOŚCI GEOMETRYCZNYCH ELEMENTÓW TRĄCYCH NA EFEKTYWNOŚĆ HAMULCA

**Streszczenie.** W oparciu o teorię molekularną i mechaniczną rozważono wpływ czynników fizycznych, technicznych i projektowych na funkcjonalność hamulca trącego . Przedstawiono odpowiedni mechanizm.

**Słowa kluczowe:** hamulec trący, współczynnik tarcia, siła tarcia, molekularna i mechaniczna teoria tarcia, typ kontaktu, powierzchnia kontaktu, skuteczność hamowania.