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INCREASING THE EFFICIENCY OF BRAKING FRICTION PAIRS

Theoretical and experimental studies of narrow friction linings with reduced working surfaces in drum-shoe brake friction pairs have revealed and applied the following.Specific loads are quasi-equalized by significantly reducing the advancing and trailing areas of the lining surfaces.The overall dynamic coefficient of mutual overlap of friction pairs during operation of narrow linings has been increased, stabilizing the temperature and gradients on their surfaces, as well as the dynamic friction coefficients.A new method for fastening narrow linings in friction units significantly reduces the time required to install and remove them from brake shoes.

Key words: *drum-shoe brake, friction pairs, serial and narrow friction linings, operating parameters, lining fastening method.*

Introduction. Wear on the working surfaces of friction linings on vehicle brake pads is uneven. This is due to the fact that brake pads perform self-adjusting and self-release functions, and the lining surfaces have advancing and receding areas.

During frictional interaction between the contact patches of the friction pair macroprotrusions, wear in localized areas depends on the energy levels of the contacts. These are determined by the work function of electrons and ions due to the dynamic and thermal loading of the friction pair macroprotrusions.

Prevent uneven wear of friction linings on vehicle brake pads by reducing their design area and by using a method of fastening them to the brake pad.

Analysis of literary data and problem statement. The study [1] is devoted to reducing friction lining wear in vehicle drum-shoe brake pairs. It is noted in the study that operational experience with drum-lining friction pairs has demonstrated that the design of new friction pairs requires consideration of their microrelief and dynamic and thermal loading.

The study [2] illustrates the uneven wear of brake shoe friction linings on the advancing and trailing surfaces.

The study [3] developed two-dimensional finite element models to study the stress-strain state of a friction lining under specified forces from the side of the drum rim and reactions in the lining-drum rim contact, to establish patterns of specific load distribution in the working contact of the friction lining, and to determine its wear. A numerical modeling technique for lining deformation during wear is based on the linear relationship between the wear of its working surface and the specific load with a stepwise increase in braking duration. Coefficients are proposed for quantitatively assessing the degree of unevenness in the distribution of forces at the friction lining-drum rim interface.

The linings are secured to the brake shoe base with rivets and bolts, depending on the vehicle's load capacity [4].

However, no studies [1-4] have explored how to improve braking efficiency using narrow friction linings.

The aim of the work is to justify the use of narrow friction linings in friction pairs of drum-shoe brakes.

Dynamics of braking by serial friction pairs of brakes. If one end of the brake shoe rests on a pivotally fixed support, and the lining is pressed against the drum surface by a force *F* applied at the other end of the shoe, the specific load diagram depends on the direction of rotation of the brake drum [5-8]. When the drum rotates clockwise (Fig. 1*a*), the end of the shoe to which the closing force *F* is applied will be the advancing end. This is similar to a band-and-shoe brake: the maximum specific load is at the advancing end of the shoe, and the minimum at the trailing end. The specific load distribution along the friction surface obeys Euler's law (Fig. 1*b*). When the brake drum rotates counterclockwise, the specific load distribution becomes more uniform because the end of the shoe to which the closing force F is applied becomes the trailing end. Under the condition $p_{1\max} < p_{\max}$, since the value of $p_{1\max}$ is determined only by the value of the pressing force, and $p_{\max}$ consists of the pressure arising as a result of the action of force *F*, and the pressure, the occurrence of which is associated with the grip of the friction lining surface by the surface of the brake drum running on it.

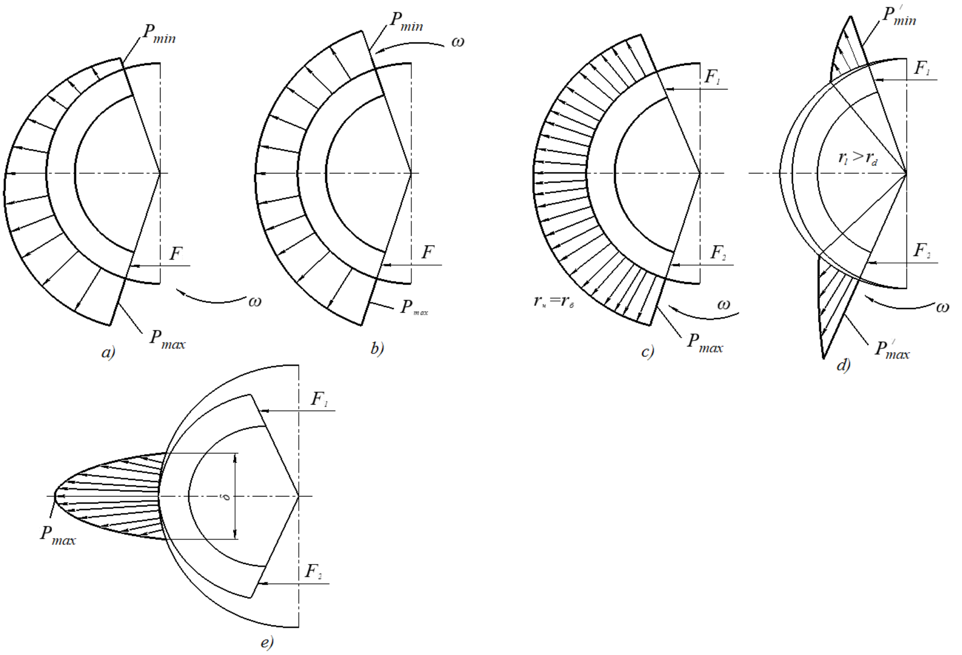

Fig. 1. Diagrams of specific loads in friction pairs of a drum-shoe brake of a vehicle under the condition ($r_l = r_d$ – *a*, *b*, *c*; $r_l > r_d$ – *d*; $r_l < r_d$ – *e*) of squeezing with force *F* one (*a*, *b*) and two (*c*, *d*, *e*) ends

If the shoe is located in the brake mechanism in such a way that the closing forces are pplied to both of its ends (Fig. 1 *c*, *d*), then the distribution specific loads becomes even more uniform, and the difference $p_{2\max} - p_{1\max}$ at $F_1 = F_2$ is due solely to the process of gripping the approaching surface of the lining by the working surface of the brake drum. It follows from this statement that by varying the values of forces F_1 and F_2, it is possible to achieve uniform loading of the brake friction pairs when the brake drum rotates in different directions, provided that the radii of curvature of the friction surfaces of the linings and the drum are equal. However, during braking, the braking energy is converted into heat, which accumulates primarily in the body of the brake drum. The latter is made of metal, has a high thermal conductivity coefficient, and absorbs more heat than the friction linings, the material of which is essentially an insulator. Thus, the temperature of the drum becomes higher than the temperature of the friction linings. Heating of the bodies causes their thermal expansion, and the coefficient of thermal expansion of the metal α_m is an order of magnitude higher than α_f of the friction material.

Due to thermal expansion, the radius of curvature of the friction surface of the brake drum decreases, and that of the friction lining increases, i.e. $r_l > r_d$.

$r_d = r - \Delta h_d = r - h_d \cdot \alpha_{id} \cdot \Delta t$; (1) $r_l = r + \Delta h_l = r + h_l \cdot \alpha_{il} \cdot \Delta t$, (2)

where r is the initial (technological) radius of the friction surfaces of the brake drum and friction lining; α_d, α_l are the coefficients of thermal expansion of the materials of the friction lining and drum; Δt is the change in temperature during heating.

Due to changes in the dimensions of the friction surfaces of the mating parts, a redistribution of the specific loads occurs (see Fig. 1*b*). At $r_l > r_d$, contact between the brake drum surfaces and the friction lining occurs along the edges of the latter, located along its ends. It should be noted that initially, the advancing end of the lining is more heavily loaded, but over time, as the drum surface approaches this end of the lining, the latter is deformed (crumpled), and its curvature increases. This leads to an increase in the contact area, and therefore to a decrease in the specific load. The trailing end of the lining, conversely, as a result of interaction with the drum surface, becomes more gently sloping, which also predetermines an increase in the contact area in this section of the lining and a decrease in the specific loads on it. Thus, with certain ratios F_1 and F_2, it is possible to achieve equal contact areas at the ends of the lining and equal specific loads on them. It's clear that as the difference between r_l and r_d increases, the interface between the friction lining and the drum narrows, the contact area decreases, and the specific load in these areas increases. The difference between r_l and r_d increases with increasing temperature of the contacting surfaces. These conditions are the most unfavorable in terms of the dynamic and thermal performance of the brake's friction components, negatively impacting the longevity of the friction pairs.

From the above, it follows that it is necessary to ensure equality of the radii of curvature of the working surfaces of the friction linings and the brake drum in the thermal regime most characteristic of a given brake mechanism. In practice, this can be achieved as follows. Based on experimental data or the results of analytical calculations of the friction surface temperatures of a given brake for specific operating conditions, its operating thermal regime is determined that is, the regime in which the given brake operates for the longest period. Graphs of the change in the friction surface radii for the drum and linings are plotted separately as a function of temperature. Specific values of the friction surface temperatures are specified, and the curve $r_d = f(t)$ is equidistantly transferred to the curve $r_l = f(t)$ so that these curves intersect at the point corresponding to the specified thermal regime of brake operation. The origin of the transferred curve will determine the specific value of the radius of curvature of the friction surface of the lining during its installation in the brake mechanism. For example, the drum-shoe brake of the KrAZ-250 vehicle has a working surface diameter of 440 mm, a drum rim thickness of 22.5 mm, and a lining thickness of 20 mm. It is known a priori that the saturation temperature of the rear brake drum rim is the friction surface temperature of 325°C. Figure 2 shows graphs of the change in the radius of curvature of the friction surfaces of the brake drum and friction lining of this brake.

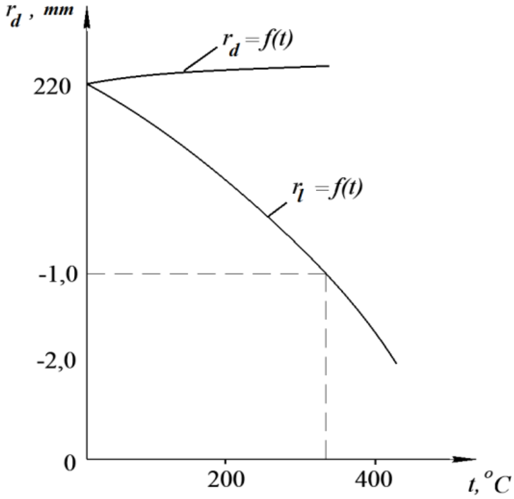

Fig. 2. Patterns of change in the radii of curvature of the friction surfaces of the brake drum rim (r_d) and the friction lining (r_l) from the contact temperature in the brake friction pair

We equidistantly transfer the curve $r_l = f(t)$ and superimpose it on the curve $r_d = f(t)$ so that these curves intersect at a point corresponding to a temperature of 325°C (the brake drum's thermal stabilization point). The intersection of the transferred curve with the ordinate axis determines the initial radius of curvature of the friction surfaces of the friction linings. For the case under consideration, this value is 208.75 mm. Thus, with the initial dimensions of the brake drum working surfaces (r_d = 220 mm) and the friction linings (r_l = 208.75 mm) corresponding to certain values, there is a complete guarantee that the drum-and-shoe brake at a temperature of 325°C will have the most uniform distribution of specific loads along the contact surface, due to the tight fit of the friction surfaces. It should be noted that, with the established dimensions, at the initial stage of braking, the brake will operate in a mode where $r_d > r_l$. With this ratio of the dimensions of the contacting surfaces, the specific load distribution pattern has a peak in the middle section of the friction lining (Fig. 1*e*).

The width of the contact area δ depends on the difference $r_l - r_d$. Reducing this difference results in an increase in the contact area and a corresponding positive distribution of specific pressures.

Therefore, to improve the reliability of the brake assembly, the radius of curvature of the drum working surface must be slightly larger than the radius of the friction surface of the friction linings. The specific ratio of these dimensions depends on the operating mode of the brake mechanism, that is, on its thermal load.

Let us consider the graphical dependencies shown in Fig. 3*a*.

The friction surface temperature increases to 100ºC within 0.6 seconds of braking, after which it gradually decreases. The temperature gradient of the drum rim ($\Delta t/\Delta n_1$, °C/mm) decreases to 5.0°C/mm by the end of braking, while the temperature gradient of the polymer lining surface layer ($\Delta t/\Delta n_2$, °C/mm) decreases to 1.0°C/mm. Moreover, the heat flux distribution coefficients by the end of a single braking session were 0.9 and 0.1 for the drum rim and polymer lining, respectively.

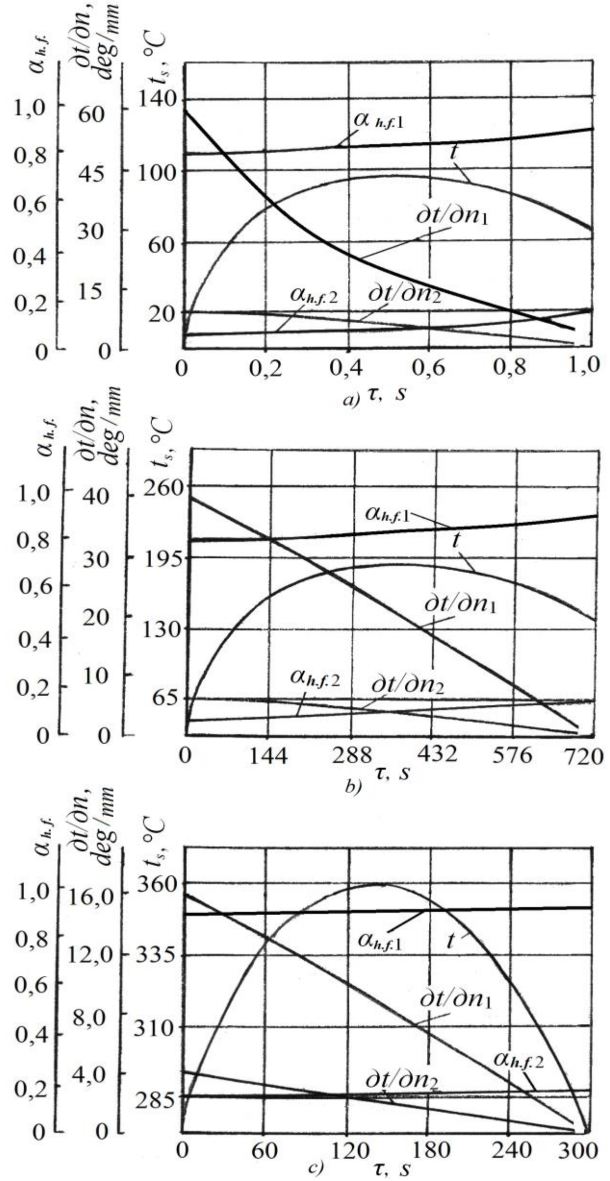

Fig. 3. Energy loading of the friction pairs of the rear drum-shoe brake of the KRAZ-250 vehicle during emergency (V = 60 km/h) (*a*) and long-term braking below (*b*) and above (*c*) the permissible temperature for the lining materials

For continuous braking (Fig. 3*b*), when the friction lining operates at a temperature below the permissible temperature for its materials, the patterns of temperature changes, temperature gradients, and heat flux distribution coefficients do not differ from the behavior of the graphical dependencies in Fig. 3*a*. The difference lies only in the values of the studied parameters, since the temperature gradients ($\Delta t/\Delta n_1$and $\Delta t/\Delta n_2$) were determined over a one-centimeter surface length.

Of particular interest is the operation of the friction lining in the temperature range above the permissible limits for its materials (see Fig. 3*c*). The change in surface temperature is analogous to the flow of a plane electromagnetic wave. The temperature gradients ($\Delta t/\Delta n_1$and $\Delta t/\Delta n_2$) decreased significantly, which is also confirmed by Fig.

3*c*. At the same time, the values of the heat flux distribution coefficients $\alpha_{h.f.1}$ and $\alpha_{h.f.2}$ remain quasi-constant due to the high energy levels of the polymer lining's surface layer, caused by the presence of electrolyte islands with a high electrochemical potential, which is capable of blocking the Fermi energy level of the drum rim's working surface. This polymer lining surface condition causes an inversion of heat flows, which stabilizes the brake drum rim's thermal state with a minimal temperature gradient across its thickness [9-13].

Let's now examine narrow friction linings in brake friction pairs.

Advantages of narrow friction linings in friction pairs. The mounting method for narrow friction linings in drum-shoe brakes is shown in Fig. 4 *a* and *b*.

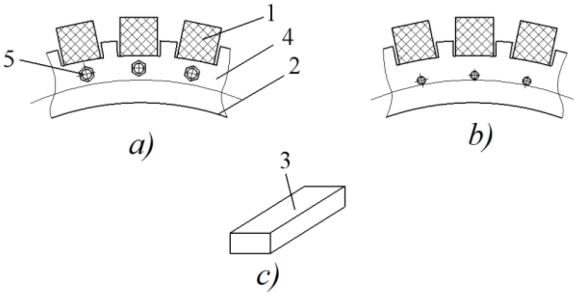

Fig. 4. Fastening of narrow friction linings in the units of the drum-shoe brake with a view of *a*, *b* - the outer and inner sides; *c* - on the limiter bar

A fastening method consisting of narrow linings, equal in length to the width of the shoe base 2, having limiting strips 3 on their surface. The limiting strips are installed at intervals equal to the width of the linings 1, thus forming cells for them. A flange 4 with holes and cutouts is formed on the outer side of the shoe base 2, and a similar flange with threaded holes is formed on the inner side. Threaded bolts 5 are then used to assemble the friction units, which, during operation, improve the wear and friction properties of the friction pairs of drum-shoe brakes.

When replacing friction linings in a motor transport company, they are machined on a lathe after installation on the brake shoes. In this case, the top polymer layer is removed to a thickness such that the radius of curvature of the outer (working) surface of the linings is equal to the radius of the working surface of the brake drum. This means that even before the brake mechanism is in operation, $r_l = r_d$, eliminating the need for break-in. At the initial stage of braking, when the temperature of the brake friction pairs is uniform and equal to the ambient temperature, full surface contact is observed between the mating surfaces of the friction linings and the brake drum. The distribution of specific loads along the friction surface depends primarily on the brake shoe mounting pattern and the thermal loading of the friction pairs.

How is the wear and friction properties of narrow-lining friction pairs in drum-shoe brakes improved:

- quasi-equalization of specific loads by reducing the areas of the advancing and trailing surfaces, which allows for minimal wear (U);
- an increase in the total dynamic coefficient of mutual overlap of friction pairs ($k_{m.o.}$) during the operation of narrow linings, stabilizing the surface temperatures (θ_S) and gradients ($\partial\theta_S/\partial l$), as well as the dynamic coefficient of friction (f) (Fig. 5).

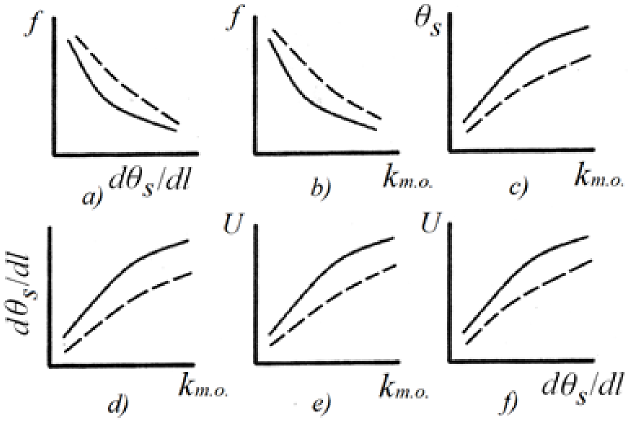

Fig. 5. Patterns of change in the operating parameters of serial (solid line) and narrow (dash-dotted line) friction linings in friction pairs of a drum-shoe brake

Thus, in terms of design and research, narrow linings are a promising direction in solving problems of dynamic and thermal loading.

Discussion of results. Theoretical and experimental studies of narrow friction linings with reduced working areas in drum-shoe brake friction pairs have revealed and applied the following:

- quasi-equalization of specific loads by significantly reducing the advancing and trailing areas of the lining surfaces;
- an increase in the overall dynamic coefficient of mutual overlap of friction pairs during operation of narrow linings, stabilizing the temperature and gradients on their surfaces, as well as the dynamic friction coefficients;
- a new method of fastening narrow linings in friction units significantly reduces the time required to install and remove them from brake shoes.

Conclusions. Thus, a quasi-linear pattern of wear and friction performance parameters in brake systems is ensured by using narrow friction linings with special fastening in their friction pairs.

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ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ПАР ТЕРТЯ ГАЛЬМ

Теоретичні та експериментальні дослідження вузьких фрикційних накладок зі зменшеними робочими площами в парах тертя барабанно-колодкових гальм дозволили встановити таке і застосувати: квазівирівняти питомі навантаження за рахунок помітного зменшення ділянок поверхонь накладок, що набігають і збігають. Досягнуто збільшення сумарного динамічного коефіцієнта взаємного перекриття пар тертя при експлуатації вузьких накладок, стабілізуючи їх поверхнях температури та його градієнти, і навіть динамічні коефіцієнти тертя. Новий спосіб кріплення вузьких накладок у вузлах тертя скорочує помітно час їх монтажу та демонтажу на гальмівні колодки.

Доведено, що використання вузьких фрикційних накладок зі спеціальним кріпленням у фрикційних парах забезпечує квазілінійну залежність параметрів зносу та фрикційних характеристик у гальмівних системах.

Ключові слова: барабанно-колодкове гальмо, пари тертя, серійні та вузькі фрикційні накладки, експлуатаційні параметри, спосіб кріплення накладок.

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