

## Friction Unit of a Disc Brake Based on a Combination of Friction Materials

Yu. I. Osenin<sup>a</sup>, I. I. Sosnov<sup>b</sup>, A. V. Chesnokov<sup>c</sup>, \* , L. I. Antoshkina<sup>a</sup>, and Yu. Yu. Osenin<sup>a</sup>

<sup>a</sup>*Berdyansk University of Management and Business, Berdyansk, 71118 Ukraine*

<sup>b</sup>*National Technical University Kharkiv Polytechnic Institute, Kharkov, 61002 Ukraine*

<sup>c</sup>*University of Technology, Korolev, Moscow oblast, 141070 Russia*

\**e-mail: ec\_ut@bk.ru*

Received December 21, 2018; revised April 20, 2019; accepted May 2, 2019

**Abstract**—The design of the disc brake friction unit is proposed, the basis for the creation of which is a combination of friction materials with different properties. As a criterion for the structural formation of a friction unit of a disc brake, it is proposed to use the initial equality of linear wear rates for all brake linings made of friction materials with different properties. It is shown that the use of a friction unit based on combined friction materials makes it possible to achieve new disc brake characteristics, compared to its traditional design. It is concluded that the proposed solution is promising.

**Keywords:** disc brake, brake shoe, brake lining, friction material, combination of friction materials, linear wear rate

**DOI:** 10.3103/S1068366619040093

### INTRODUCTION

The disc brake is the most common design of friction brakes and is successfully used in road and rail transport, as well as in aviation for aircraft braking during landing. There are currently no more reliable, efficient, simple, or cheaper alternatives to disc brakes [1]. Increasing vehicle speeds and payloads assume further improvement in the performance characteristics of disc brakes [2].

The main direction of research, ensuring compliance with modern requirements, is the development of new friction materials with desired properties. However, given that the requirements are, in many respects, contradictory and mutually exclusive, the creation of a friction material with specified properties for disc brakes that would fully meet all the requirements remains an extremely difficult and unresolved task.

Therefore, of interest is a promising method aimed at achieving the required disc brakes characteristics via the combination of several friction materials with different properties in a friction unit [3]. Further improvement of this method, as well as the development of design and technological solutions for its implementation, is an urgent task.

**Objective:** To develop a criterion for the structural formation of the friction unit of a disc brake based on a combination of friction materials; to assess the influ-

ence of combined friction materials on the coefficient of friction of disc brakes.

**Friction unit based on combined friction materials** (further, CFM friction unit). A conventional disc brake friction unit contains two friction materials: a brake disc material and brake lining material. Despite the fact that the main purpose of friction materials is to achieve high performance characteristics of the disc brake, the requirements for the brake disc materials and lining differ significantly. The main difference is that the brake disc material, in addition to the friction properties, have requirements related to ensuring high structural strength.

In addition, the properties of existing friction materials for brake linings ambiguously manifest themselves in different weather and climatic conditions, load-rate characteristics, and temperature in the contact area. All this significantly reduces the design and technological capabilities to achieve the initially set disc brake properties [4–7].

Given that the creation of a friction material that would satisfy all the requirements is currently problematic, a CFM friction unit based is proposed. The main purpose of creating a CFM friction unit is the selective influence on the disc brake characteristics due to the combination of friction materials acting as brake linings. As a result, using various friction materials, it is possible to create integral properties of the friction unit as a whole.

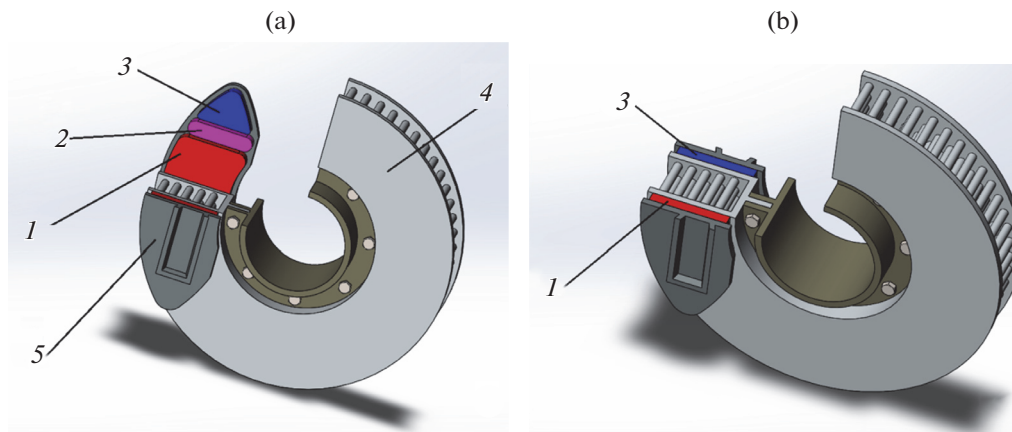


Fig. 1. Variants of CFM friction unit of disc brake: (1–3) brake linings; (4) brake disc; (5) brake shoe.

This design differs from previously known similar structures of the friction disc brake assembly [3] in that brake linings made of different friction materials are located directly on the brake shoe, without intermediate joints.

The design of a disc brake CFM friction unit based is shown in Fig. 1a. Brake linings 1, 2, and 3 made of different friction materials are mounted on brake shoe 5 and interact with brake disc 4.

A special case of a CFM friction unit is a friction unit in which there is one brake lining on the sides of the brake disc (Fig. 1b). The properties of brake linings are different. In this case, the friction unit of the disc brake will consist of three friction materials: brake lining material 1, brake lining material 3, and brake disc material 4.

#### DISCUSSION OF THE DESIGN OF A CFM FRICTION DISC BRAKE

One of the problems in creating a CFM friction unit is to ensure the maximum efficiency of each of the brake linings in relation to the integral coefficient of friction of the disc brake. The main obstacle to this is the wear of the working brake linings, which will be different in each.

As a result, brake linings with a lower wear rate will dominate the force interaction, taking on most of the loading and unloading of the brake linings at a higher wear rate, which obviously leads to a decrease in the potential integral coefficient of disc brake friction.

Therefore, the creation of a CFM friction unit implies compliance with certain criteria. First of all, this refers to the criterion of the initial equality of the linear wear rates of all brake linings located on the brake shoe, which will allow equal engagement with each of them.

Matching of the integral wear rate is possible by varying the contact area of each of the brake linings, since it is known that, other things being equal, it is the

contact area that has a significant effect on the linear wear rate, which in the first approximation is determined by the dependence [6]

$$I_h = \frac{V}{LA_c}, \quad (1)$$

where  $V$  is the volume of material removed in the wear process;  $L$  is the friction path;  $A_c$  is the area of friction contact.

Accordingly, for a brake pad with multiple brake linings, the total linear wear rate will be determined as

$$I_{h\Sigma} = \sum_{i=1}^m \frac{V_i}{L_i A_{ci}},$$

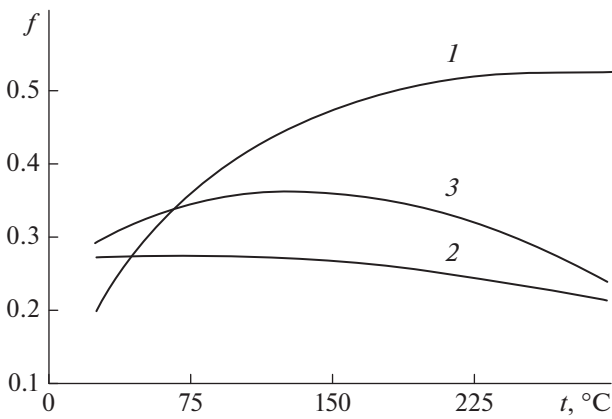
where  $i$  is the index corresponding to a particular brake lining, the total number of which is  $m$ .

Thus, by varying the area of the friction contact of each brake lining, one can determine the area ratios for all brake linings placed on the brake pad, based on the accepted criterion of equality of the original linear wear rate.

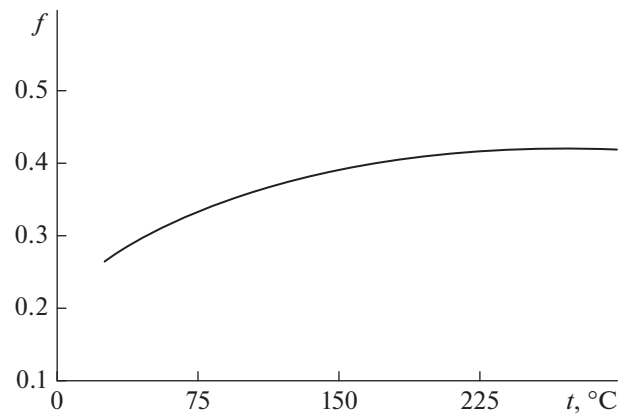
In reality, this is achieved empirically, by obtaining (all else being equal) for each friction material, the dependence of the linear wear rate on the area of friction contact, followed by determining the ratio of areas of friction materials (brake linings) within the real working area of the brake pad.

In this case, the braking efficiency of a disc brake with a CFM friction unit can be evaluated by taking into account coefficient of friction, which in the first approximation can be considered equal to the arithmetic average of the coefficient of frictions of all brake linings [3].

Placing several brake linings made of different materials in the CFM friction unit creates prerequisites for selective influence on the characteristics of the disc brake to achieve its specified values.



**Fig. 2.** Dependence of coefficient of friction on temperature for traditional disc brake friction units: (1) SK-07.04—steel; (2) cast iron—steel; (3) retinax B—steel.



**Fig. 3.** Dependence of coefficient of friction on temperature for CFM friction unit: CK-07.04—cast iron—retinax B—steel.

EXPERIMENTAL VERIFICATION

The aim of the experiment is to confirm the possibility of influencing the disc brake coefficient of friction by combining friction linings made of different friction materials in the friction unit.

Experimental studies were carried out on a full-scale laboratory bench, which makes it possible in real time to reproduce the friction interaction processes of the working elements of a tram disc brake, the acting forces, heat fluxes, and sliding rates [8].

The friction materials studied are: gray cast iron (GOST 6921–74); Retinax B (FK-24A)—asbosmol composition (GOST 10851–94); carbon—carbon composition SC-07.04 [9]. The material of the brake disc is steel 20X17H2 (GOST 5632-72). In connection with the goal of experiments, the choice of friction materials was random.

The experiments were carried out with the following parameters of force interaction: pressure—440 kPa; sliding speed—29.4 m/s, ambient temperature—25°C, the temperature in the area of contact of the working elements of the disc brake—250°C.

The experiments were carried out in two stages. At the first stage, the dependences of the coefficient of friction of the disc brake on the temperature in the contact area were determined for traditional friction units: cast iron—steel; Retinax B—steel; CK-07.04—steel. At the second stage, the dependence of the coefficient of friction on temperature for the friction unit was determined based on CFM (SK-07.04—cast iron—retinax B—steel). The working area of the brake linings located on the brake shoe correlated as 0.44 : 0.21 : 0.35 respectively.

The dependence of the coefficient of friction on temperature for traditional friction units (cast iron—steel; retinax B—steel; and CK-07.04—steel is shown in Fig. 2. A similar dependence for the CFM friction unit (CK-07.04—cast iron—retinax B—steel) is shown

in Fig. 3. The boundaries of the confidence intervals correspond to a confidence level of 0.95. The obtained values of the experimental values were checked for the absence of “gross” errors using the Grubbs criterion.

Analysis of the results shows that each of the characteristics of the coefficient of frictions for temperature for traditional disc brake friction units (Fig. 2) has its own individually pronounced features. The dependence of the coefficient of friction on temperature for CFM friction unit QFM (Fig. 3) differs from each of the dependences shown in Fig. 2.

From the analysis of the dependences, it follows that the use of a CFM friction unit eliminates the disadvantage of the SK-07.04—steel friction unit (Fig. 2) and manifests itself in a low coefficient of friction at low temperatures. In addition, due to the use of a CFM friction unit, the disadvantages of cast iron—steel and retinax B—steel are eliminated.

The results confirm the possibility for a CFM friction unit to influence the coefficient of friction of the disc brake compared to traditional friction units. Varying the properties of the friction materials used in the CFM friction unit as linings will make it possible to achieve the specified disc brake characteristics.

CONCLUSIONS

(1) The design of a CFM friction unit is proposed, a distinctive feature of which is the placement of several brake linings made of materials with different friction properties directly on the brake shoe.

A special case of a CFM friction unit is a disc brake friction unit with has one brake lining on each side of the brake disc, and the friction properties of each of them are different.

(2) The design of a CFM friction unit assumes compliance with the criterion of equality of the initial linear wear rates of all brake linings in the friction unit.

Equality of linear wear rates is achieved by varying the nominal contact area of each of the brake linings with subsequent determination of their ratio within the real working area of the brake pad on which they are placed.

(3) The results confirm the possibility (other things being equal) for the CFM friction unit based to influence the coefficient of friction of the disc brake.

Varying the properties of friction materials used as friction unit brake linings will make it possible to achieve the specified disc brake characteristics.

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