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METHODOLOGICAL APPROACH TO THE DEVELOPMENT PROCESS OF SINTERED FRICTION MATERIALS

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Abstract: *The paper presents a conceptual approach to the development of sintered friction materials and friction discs for friction units operating with lubrication. The use of the proposed approach in the developed friction materials is given in terms of powder selection, assessment of the impact on tribotechnical and operational properties. The experience of using the developed friction material compositions in friction units of automotive and tractor equipment in the Republic of Belarus is given.*

Keywords: *Sintered friction material, Friction, Wear, Friction coefficient, Wear resistance, Friction unit, Structure, Counterbody, Powders.*

1. INTRODUCTION

Global growth in extraction and processing of natural resources, exploration of new deposits, development of agriculture and forestry, road construction, industry and communications stimulates an increased demand for motor-tractor, road repair and construction machinery, one of the most important units of which are brake and transmission friction units.

Modern technologies require the creation of machines and mechanisms with higher indicators of their performance characteristics, service life and at the same time to be more economical. Accordingly, the requirements to the performance characteristics of component parts are increasing including friction disks, the performance of which is determined by the properties of friction materials and load and speed modes of their operation. Even one machine may contain several friction disks operating under significantly different conditions and performing different functions. In this connection, the works on creation of friction disks operating at a sliding speed of 5-15 m/s, a pressure of 2-6 MPa, a temperature of 80-150 °C, and the presence or absence of lubrication are becoming more and more actual [1-4].

Currently, friction materials with polymer matrix, on the basis of carbon-carbon composition, ceramic basis, and others are used, and at the same time friction materials on the metal basis (copper, iron, etc.), obtained by powder metallurgy technology – sintered friction materials – are widely used [5-8].

The main advantages of copper-based sintered friction materials, working mainly in friction units in the presence of lubrication, are: a stable value of the friction coefficient; high wear resistance and thermal conductivity; absence of dependence of the friction coefficient on climatic conditions; durability (9000-10000 operating hours); ecological purity of the production process, nondeficiency and low cost of initial powders and the manufacturing process of the friction disc.

Satisfaction of the given operational properties goes on the way of increasing wear resistance and resistance to scuffing, strength, heat resistance, value and stability of friction coefficient by controlling the properties of composite matrix of sintered friction material and modification of its structure by introducing various functional additives, increasing the strength of connection with steel base.

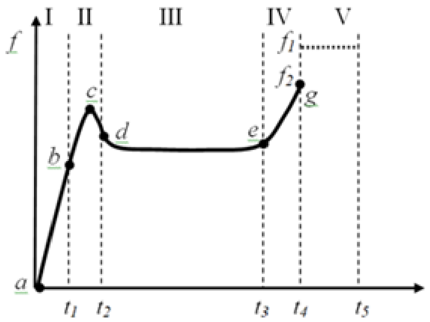
Currently available data on the use of additives in sintered friction materials are scattered and even contradictory. There is no methodological approach to the development of friction disc design, the composition of sintered friction material taking into account the operating modes and the possibility of emergency situations, as well as there is no clear understanding of the criteria for selecting functional additives and assessing their influence on tribotechnical and operational properties.

2. PURPOSE

Development of a conceptual-methodological approach for optimizing the compositions of sintered powder materials of friction units working with lubrication and its implementation in practice.

3. RESULTS AND DISCUSSION

To analyse the features of the process of short-term frictional interaction during the torque transmission in the presence of a sliding (slipping) effect, dynamic models adapted for the inertial test bench are proposed. The quantitative characteristic of the experimental dependence of friction interaction of the friction pair obtained on the inertial test bench is the change of the friction coefficient over time. The dependence reflects the most energy-loaded mode at closing of a friction pair. The dependence is proposed to be considered as a multi-stage process consisting of five phases: lubricant squeezing out, contact of friction surfaces, slipping, switching from dynamic to static mode, and torque transfer phases (Figure 1).



Friction phases: I – lubricant squeezing out; II - contact of the friction surfaces; III-slipping at boundary lubrication; IV-switching from dynamic to static mode (closing of the friction pair); V - torque transfer phase

Figure 1. Diagram of friction coefficient change over time obtained during testing of sintered friction materials on an inertial test bench

In the general case, the character of friction coefficient change in each phase is influenced by the initial microgeometry of the surfaces, the surface layer structure containing adsorbed molecules and modifying inclusions, while controlling the course of dependence in each phase is possible by changing the structure of the composite matrix of friction material and using powders of different nature. For the optimum shape of the dependence of the friction coefficient change in time, the requirements to each phase and position of critical points are established: minimising the period of contact; smoothing of critical points between the periods of lubricant squeezing out and slipping; linear dependence form in the slipping phase; minimum period of transition from dynamic to static mode with the absence of jump-like friction coefficient change. Imperfection of contact areas, heterogeneity of the sintered friction material (SFM) structure leads to fluctuations of the friction coefficient in each phase, which should have a minimum value from the approximated curve, excluding dynamic loads, vibration, and noise. Reducing the fluctuation variation can be achieved by using powders with different physical and mechanical properties and structural characteristics.

To describe the structure of sintered friction material, a structural classification model has been developed that includes a composite matrix consisting of a metal base, carbon-containing additive and pores, and functional additives of different nature, which allow to vary the physical and mechanical tribotechnical and operational characteristics within wide limits. The metal base of the sintered friction material provides the necessary mechanical, thermophysical properties, adhesion with the steel base of the friction disk. Carbon-containing additive contributes to the increase of friction coefficient, wear resistance and resistance to scoring. Pores provide the supply of gas protective and reducing medium during sintering for the successful implementation of the stages of structure formation, are places of localization of wear products and act as additional sources of lubrication, and being in the structure of friction material, they are dampers.

It is proposed to describe the properties of additives in the friction material composition Aδ by a function depending on structural and quantitative parameters of the matrix type:

$$A_\delta = A_\delta\left(X_i, Y_j, Z_k, \dots\right) \{i, j, k\} = \{1 \div N; \%\} \subset \{\mathrm{N}\} \tag{1}$$

Where:

X, Y, Z,... – are structural-quantitative parameters of the matrix type;

N is a set of integers.

The structural-quantitative parameters of the matrix type contained in dependence (1) can be represented in the form of matrices X={X}, Y={Y}, Z={Z} (Figure 2), containing arrays of quantitative data:

X - physical-mechanical properties: $\{X\} = \begin{bmatrix} HB\ - hardness \\ E\ - modulus\ of\ elasticity \\ \lambda\ - thermal\ conductivity \\ \dots \end{bmatrix}$

Y – dispersed phase state: $\{Y\} = \begin{bmatrix} d\ - \text{ dispersion} \\ \Phi\ - \text{ shape factor} \\ W\ - \text{ phase } composition \\ \dots \end{bmatrix}$

Z – concentration and homogeneity $\{Z\} = \begin{bmatrix} (\mathrm{C})\ - \text{ concentration} \\ (\mathrm{K})\ - \text{ uniformity of distribution} \\ \dots \end{bmatrix}$ (2)

or semantic data:

$$FP\{S\} = \begin{bmatrix} physico\text{-}mechanical \\ tribotechnical \\ economic \\ \dots \end{bmatrix} \tag{3}$$

In practical terms, the use of dependency 1 comes down to the implementation of a table-matrix representation (Figure 2), in which each additive is assigned known properties, and the degree of influence on functional properties is given (based on the results of an analysis of known literature data). Evaluation of the complex influence of the additive on the required functional properties allows to establish the priority of use, the maximum permissible concentration range.

The use of additives in the composition of a friction material should be systematised, for this purpose, as an example, it is proposed to classify additives by the ability to interact with the metal matrix of friction material with the formation of secondary compounds, by hardness, dispersion, composition, and shape. The proposed classification is not final, it can be supplemented in accordance with the requirements to the friction material (for example: by the ability to influence the volumetric changes of the material during sintering, the formation of secondary surface structures after friction, and the ability to influence the thermal conductivity and adhesion strength of the FM layer to the steel base) [9, 10]. [9, 10].

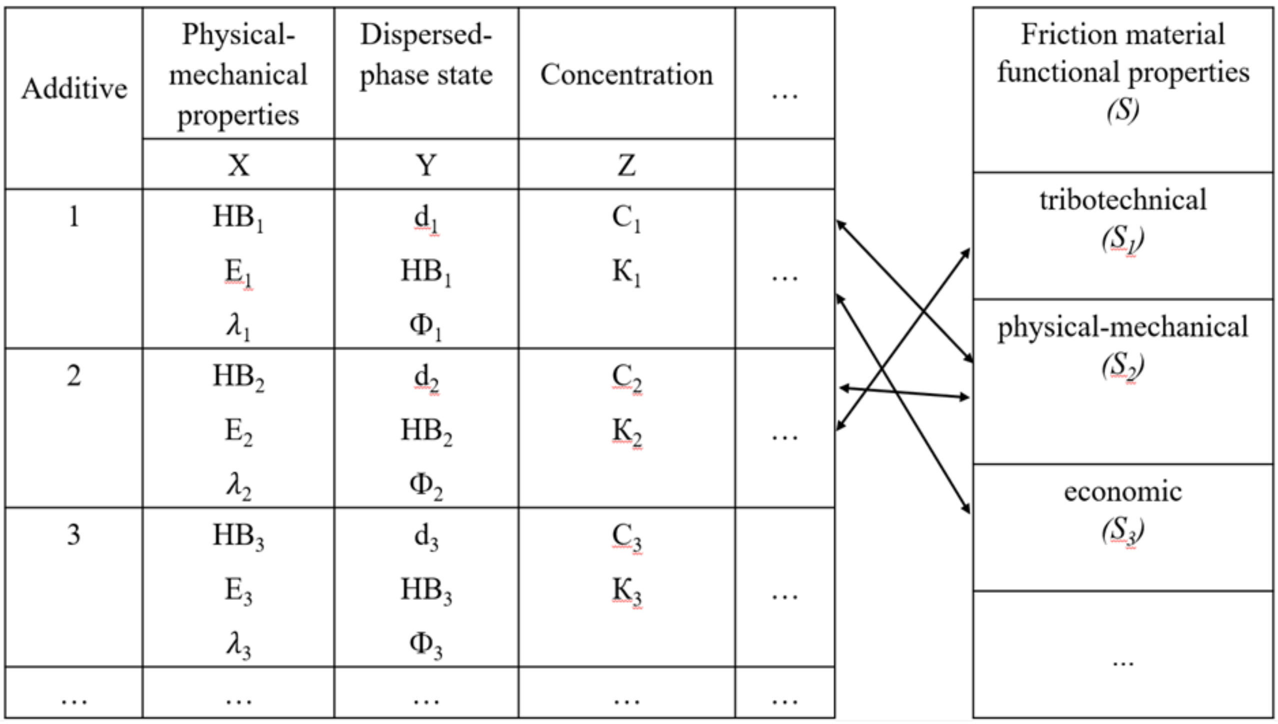


Figure 2. Table-matrix representation of input additives in the composition of sintered friction material

When developing technological processes for manufacturing friction discs, the proposed methodological approach, algorithm for selecting powder additives of the required functional purpose was used, taking into account the data on the influence of bronze matrix, carbon-containing additive, pores, additives of metallic, ceramic powders, and their structural transformations during sintering on physical-mechanical and tribotechnical properties.

The developed technological processes made it possible to manufacture friction discs of hydromechanical gearboxes: BELAZ-7555 dump truck with a lifting capacity of 55-60 tons; MoAZ-40751 loading and delivery vehicle with a lifting capacity of 16 tons designed to operate in underground conditions; BelAZ-74270 airfield tractor designed for towing wide-body aircraft of the fifth category with take-off weight of 400-600 tons; a front loader model BelAZ-78240 with a 4x4 wheel arrangement, designed for delivery of cargoes weighing up to 60 tons, mechanisation of loading and unloading operations of dump trucks, at railway stations, raw materials and materials processing enterprises; Kirovets' hydromechanical gearbox of K-7 series of St. Petersburg Tractor Plant with an articulated frame with engine power from 300 to 460 hp; a hydromechanical gearbox for special-purpose vehicles of Minsk Wheeled Tractor Plant.

Friction discs for oil-cooled brakes of the drive axle of the Amkodor loader; the on-board gearbox of the oil-cooled brake of the Belarus snow-compacting machine MSU-108; clutches of Belarus family tractors have also been produced.

The novelty of the developed friction materials compositions and friction disks designs is confirmed by 19 patents for invention of the Republic of Belarus and Russia.

4. CONCLUSION

The developed compositions and production processes made it possible to produce a friction discs for hydro-mechanical gearboxes: the BELAZ-7555 dump truck with a load capacity of 55-60 tons, the MoAZ-40751 loading and delivery vehicle with a load capacity of 16 tons, designed for work in underground conditions, aircraft tow tractor model BelAZ-74270 designed for towing wide-body aircraft of the fifth category, having a take-off weight of 400-600 tons, a front loader model BelAZ-78240 with 4x4 wheel arrangement, designed for delivery of cargoes weighing up to 60 tons, mechanization of loading and unloading operations of quarry dump trucks, at railway stations, raw materials processing enterprises; a hydro-mechanical gearbox "Kirovets" K-7 series of St. Petersburg Tractor Plant with articulated frame with the power of internal combustion engine from 300 to 460 hp and hydro-mechanical gearbox of special-purpose vehicles of Minsk Wheel Tractor Plant. Friction discs are also produced for oil-cooled brakes of the drive axle of the Amkodor loader; the on-board gearbox of the oil-cooled brake of the snow-compacting machine Belarus MSU-108; the clutch of tractors of the Belarus family.

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