On improving the operational properties of metal-fluoroplastic plain bearings

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Abstract. The analysis of metal-fluoroplastic materials was carried out. Domestic metal-fluoroplastic materials do not meet the requirements of regulatory and technical documentation adopted in domestic engineering. A review of patents on technologies for the production of metal fluoroplastic materials (MFM) was carried out. Promising methods for producing MFM have been identified. New methods can significantly increase the operational characteristics of fluoroplastic materials. For widespread use of metal-fluoroplastic plain bearings it is necessary to increase their performance. Reducing the linear wear parameter is possible by increasing the nominal area of the metal contact.

1. Introduction
To run without a lubricant, plain bearings made of metal-fluoroplastic materials are used in modern machines. Currently, metal-fluoroplastic bearings are understood as a fairly wide range of products made of metal with polytetrafluoroethylene (PTFE). These include porous metal frames impregnated with fluoroplastic and various tape materials on a steel basis with a porous antifriction surface layer. A porous surface is necessary to hold the fluoroplastic on the surface and in the pores, since it has low adhesive properties to any surfaces. The production of bearings from the MFM was established in the last century [1]. They are used in friction units of modern technical devices – cars, airplanes and marine vessels [2]. The appropriateness of their use is due to their lightness, variability in composition, structure and a wide range of technical properties. Domestic fluoroplastic materials do not fully meet the requirements of regulatory and technical documentation adopted in the domestic aircraft industry [2,3]. Imported IMF products of the DU and DP brands are widely used in various industries and aircraft manufacturing. The lack of these materials with high performance characteristics not inferior to imported counterparts adversely affects the development and production of the northern performance equipment under the state program “Socio-economic development of the Arctic zone of the Russian Federation.” In this regard, it is necessary to identify promising technologies that allow establishing the production of these materials with high performance not inferior to foreign analogues.

2. Literature review
The traditional MFM module, its production method and characteristics have been detailed in [4]. MFMs have high antifriction properties in the temperature range from 73 to 553 K; pV = 1.5 MPa-m s⁻¹. The ultimate wear in such a bearing is concentrated in the surface layer with a thickness of
0.025-0.05 mm. This wear parameter affects the durability of the product as a whole [5]. Low reliability is explained by the insufficient amount of fluoroplastic located in the porous space of bronze particles [6]. The material is used in units operating in the modes of hydrodynamic and mixed friction (in the friction units of pumps for pumping oil, various rotary mechanisms, hydraulic boosters etc.). Metal-fluoroplastic materials and products are produced in the Russian Federation at machine-building enterprises such as Kompozit LLC, Promsnabkomplekt LLC (Kineshma), Ftoroplast LLC (Bugulma).

The enhanced performance of foreign-made MFM plain bearings is conditioned by technology. Abroad, external pressure is used during the heat treatment of the polymer layer in the porous layer [6]. This technology allows the polymer to be fixed in the pores, which cannot be achieved with free sintering in air. It is known that a necessary condition for the performance of plain bearings is the optimal combination of the amount of polymer and metal in the structures [7].

Thus, in order to create modern plain bearings operating without a lubricant, it is necessary to increase the thickness of the polymer working layer, fixing the fluoroplastic coating-lubricant at this should be carried out under pressure. An increase in the thickness of the polymer layer can be achieved due to the larger pore volume. As the porous layers, various matrix materials can be used. However, traditional matrix-filled materials are expensive to obtain the necessary relief on the metal surface of the product [8]. According to the authors of [4, 6] to increase the amount of polymer in the porous space it is promising to use metal meshes from antifriction materials. Methods are known for producing MPM in the form of plates [9-11], where instead of the traditional porous bronze layer of spherical particles, various mesh woven materials are used. Anti-friction nets are specially fixed on a metal surface. The method of obtaining these materials is presented quite in full by [4], and we will not describe it. We will focus only on the process of fixing PTFE in the pores of the mesh space. The process of fixing or monolithization of the polymer in the space of the meshes is carried out during heat treatment of workpieces in a limited volume. In the process of heating the polymer in an enclosed space, pressure arises due to the thermal expansion of the fluoroplastic, resulting in monolithization of PTFE particles due to cohesive interaction. The resulting materials are a metal composites with a heterogeneous structure. The working surface of the bearing is a regularly repeated sections of a solid base (brass mesh) and polymer. The mesh material has a relatively low coefficient of friction. During friction the polymer is capable of forming a protecting from setting intermediate layer in the contact zone. The polymer is evenly distributed throughout the thickness of the mesh. The material has high wear-resistant properties that make it operable in a wide range of temperatures and loads under dry friction at \( pV > 3 \text{ MPa-m s}^{-1} \) [12]. This MFM has not regrettably gained acceptance in friction units. According to the authors of [12], the main drawback of such bearings is that at the initial moment of operation the counter body comes into contact with a minimal contour area. In fact, contact occurs on points. The main load in such a unit is distributed over fragments of a solid surface. It is logical that when a load is applied, intensive wear of the bearing wire will be observed until the compatibility of the assembly is achieved. In most cases, when stable operation of the friction unit is attained, the dimensions of the bearing go beyond the limit value of the linear wear value. In this regard, the bearing fails. For the stable operation of MFM plain bearings with a mesh layer it is necessary to solve the following problems: determine the limits of change in the nominal contact area; find a means of gaining the required area for a particular unit.

3. Experiments and discussion
For experiments a bronze-brass simple weave mesh No. 16 was chosen (the number of wires in the weft per 1 cm is 16, the diameter is 0.25 mm, the number of wires on the basis per 1 cm is 12, the diameter is 0.27 mm). The pore size of rectangular cells is 0.5 and 0.56 mm, respectively (figure 1). When fully filled with polymer, the porosity of the mesh is 70 %.

In [13] a theoretical calculation was made of the change in the contact area depending on the linear wear for a given mesh. The change in the contour area of one weft is shown in figure 2.
The graph shows that the contact area of one weft of the mesh varies over a wide interval with a sharp increase of 1000 times or more. Knowing the area of one mesh weft, we can determine the contour area of the bearing. There is an opinion [6] that the contour contact area of meshes can be changed in several ways:

- by the use of meshes with wires of other diameters;
- by the use of meshes with different types of weaving;
- by machining the surface of the mesh.

The calculations and experiments showed that when using meshes of wires of a smaller diameter, their deformation is observed during pressing in the polymer. When using meshes with wires of a larger diameter, the thickness of the bearing and the fluoroplastic consumption increase with a slight increase in area.

When machining the mesh surface of the finished metal-fluoroplastic bearing, an increase in the contour area of each contacting point is observed. However, after machining no polymer antifriction layer is found on the resulting contact points of an ellipse shape. The absence of a dividing fluoroplastic layer on metal contact areas leads to scuffing of metal surfaces when operating without lubricants. Thus, in this case it is necessary not only to increase the contact area, but also to ensure the presence of antifriction polymer on the contacting surfaces. Machining the inner surface of the bearing to size also requires a special tool and its additional fixation.

4. Conclusion

Domestic traditional technologies for the manufacture of MFM do not allow to obtain materials with high performance properties. The reason has to do with an insufficient amount of polymer lubricant located in the pores of bronze. Promising methods are technologies where anti-friction mesh materials are used as a porous layer. The use of nets allows increasing tens of times the thickness of the working polymer layer in comparison with traditional materials. It was revealed that metal-fluoroplastic plain bearings with an antifriction layer in the form of a mesh material do not realize their potential in the absence of a lubricant. The main disadvantage of such materials is the insignificant nominal area of metal mesh fragments in the initial period of operation. Increasing the nominal area in the finished product by its machining removes a significant part of the polymer layer. A possible way to solve this problem is to improve the methods for producing MFM with a mesh woven layer. The required nominal area on the mesh should be obtained by machining during the manufacture of blanks.
Acknowledgments
The work was carried out as part of the state assignment of Baikal Institute of Nature Management, Siberian Branch of Russian Academy of Sciences, and was supported by the state target of the Ministry of Science and Higher Education of the Russian Federation, project No. 9.7667.2017/8.9, and by the grant “Young Scientists of ESSUTM – 2019”.

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