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Manufacturing technologies for slide bushings from powder materials for lever brake systems of vehicles

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Abstract. Slide bushings made of metal powder materials are used in many parts of vehicles. The current trend is to reduce the unit cost of products, increase the durability of components and assemblies, and reduce the harmful effects on the environment. One of these solutions is the use of powder materials. In this article, we consider some manufacturing techniques for sliding bushings of a lever brake system of a rolling stock using one-sided and two-sided pressing, pulse and combined sealing. The areas of their rational use are demonstrated as well.

Key words: metal powder materials, pulsed compaction, slide bushings.

INTRODUCTION

To ensure maximum efficiency and safety when transporting goods by rail, it is necessary to constantly seek and implement innovative solutions. To a large extent, this applies to the technical part, primarily to the mechanisms of rolling stock. Many railway transport nodes operate at high specific loads and significant temperature fluctuations (Kruse et al., 2015), (Ivaskovska & Mihailovs, 2019). Bearing sleeves in articulated joints are subject to particularly intense wear, which requires frequent adjustment and repair.

In nodes of increased dimensions under heavy loads, as well as when working in a humid environment, the plain bearings are the most suitable. The main element of the bearings is an insert (sleeve) made of antifriction material, which is installed between the shaft and the bearing housing (Karpichev, 2000). The disadvantages of such bearings are of higher friction than rolling bearings and the need for relatively expensive antifriction materials.

In railway transport, anti-friction bushings are widely used in lever brake systems, auxiliary and low-speed mechanisms. Characteristic defects in antifriction bushings are caused by friction (abrasive wear) and fatigue failure under the influence of load pulsation. Increased wear or destruction of the slide bushings can lead to both premature destruction of the elements themselves and jamming of the entire structure as a whole. Intensive oscillatory movements are also characteristic features of bearing assemblies of hinge systems of brake mechanisms. This is another serious condition that can lead to accelerated wear on the sleeve. The position at zero speed between each oscillation cycle is the point at which the lubricant will be broken, which leads to increased wear of the material. Self-lubricating bushings are the best choice for oscillatory motion due to the rigid sliding surface, which generates a small amount of wear particles, as well as the presence of internal lubrication.

Modern technology allows the manufacture of bearing bushings of metal powders that meet the most stringent requirements. The criterion for the strength and, consequently, the performance of the sleeve are contact stresses in the friction zone or contact pressure. The estimated contact pressure p can be estimated (Dunajev & Lelikov, 2001).

$$p = N/(ld)\ [p] \tag{1}$$

where N – is the force of the normal shaft pressure on the sleeve (support reaction); l – is the working length of the bearing sleeve; d – is the diameter of the shaft journal; $[p]$ – permissible specific pressure.

One of the main advantages of bushings made of metal powder materials is the presence of pores in them, which contribute to the formation of a stable oil film in the bearing. As a result of the preliminary impregnation of the sleeve in heated oil, a large number of its capillaries are filled with oil. Due to this, a lubricating film is formed on the rubbing surface of the sleeve, which remains for a sufficiently long time. The use of so-called pockets in plain bearings is known. They accumulate oil during parking and low speeds. Then the oil is used when the mechanism is triggered.

Different operating modes require the use of cermet bearings with varying degrees of porosity. In studies (Leitans et al., 2015), it was shown that one of the reasons for increased wear of parts of hinge assemblies is damage to the surface layer of the antifriction sleeve and vertical dynamic forces of an impact nature. In this regard, greater importance should be given to the strength properties of the elements of the system (Ivanovs & Gavrilovs, 2017; Evsejev et al., 2019).

It is possible to increase the strength of sliding bushings made of powder materials by increasing the density of the product and selecting material from the class of high alloy, containing an increased value of chromium, manganese and nickel Oberacker, 2011). However, this increases the cost of parts and makes the use of powder metallurgy unprofitable. The use of low-alloy powder mixtures makes it possible to reduce the cost of production of parts of brake assemblies (Mironovs et al., 2019). But this requires increased attention to the choice of material, porosity and manufacturing technology. For medium loads, a porosity of 20–25% is recommended. In the production of metal-powder products, there are four main stages: the selection and preparation of the powder composition, pressing, sintering to the desired density and additional (finishing) operations after sintering to the final product. Each of these steps is very important to obtain a product with desired properties.

In this paper, a number of technologies for the manufacture of sliding bushings for a lever brake system of a rolling stock from low-alloy powder raw materials using one-sided and two-sided pressing is considered. The use of pulsed and combined seals allows the manufacture of bushings with a wider range of sizes and configurations. The areas of their rational application of technologies are shown.

MATERIALS AND METHODS

Experimental studies have been conducted at the Powder Materials Laboratory of Riga Technical University. The samples of slide bushings with an outer diameter of 25–50, a length of 25 to 120 mm and a wall thickness of 5–15 mm were made.

For the preparation of samples, iron-based powder mixtures were used (Fe – 94%, Ni – 2.5%, Cu–2.0%, Mn – 0.5%, < C – 0.7%) (Mironovs et al., 2019).

The simplest compaction method is single-sided pressing. It is recommended to be used if $0.5d < l < 1.5d$, where d is the diameter of the sleeve and l is its length. Sealing was carried out on a hydraulic press at a pressure of 400 to 600 MPa.

The pressing device (Fig. 1, a) consisted of a die, upper and lower punches, the space between which was filled with pressed powder. The mold matrix was made of carbon steel with a hardness of HRB 58-64. A steel bar was used to form the inner hole. To ensure the specified accuracy of the dimensions of the workpiece, limiters were used. The force was applied to the upper punch. The experiments showed that uniform porosity in height can be obtained provided: $0.5\,d < l < 1.5\,d$.

Double-ended pressing was carried out in the same matrix; however, a compression force was applied to both punches (Fig. 1, b).

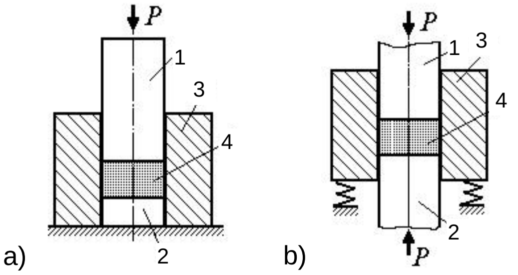

Figure 1. Scheme for powder compaction: 1 – upper punch; 2 – lower punch; 3 – die; 4 – powder.

The following recommendation (German, 2005) was considered here, which indicated that the ratio of the diameter and wall thickness is an important factor in choosing a two-sided pressing method. It is recommended within (2).

$$3 < s/d < 17 \tag{2}$$

where s – wall thickness; d – diameter.

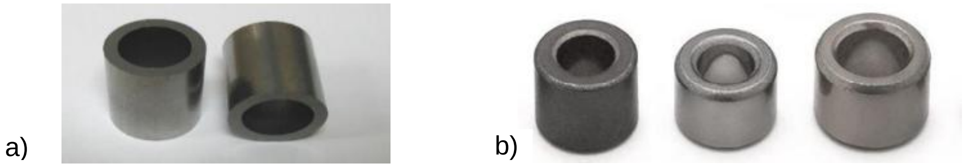
a) b)

Figure 2. Sliding bushings after compaction (a) and after sintering (b).

When the sleeve length was increased to more than 1 ≥1.5 d, the method of magnetic pulse pressing was applied by crimping the powder material in an electrically conductive shell. This method also turns out to be suitable for calibrating the bushings, as well as in the manufacture of bushings of a more complex configuration, for example, in the manufacture of bushings with a shoulder (Fig. 3).

Figure 3. The scheme of magnetic pulse pressing of the bushings (a) and the sample sleeve with a shoulder: 1 – powder; 2 rod; 3 – inductor; 4 – pulse current generator.

To increase the density of products, the combined static-dynamic sealing scheme developed in (Mironovs et al., 2016) is used. In this case, the powder was pre-compacted on a hydraulic press at a pressure of up to 400 MPa, and then subjected to repeated pulsed exposure by applying

To obtain bushings with the ratio 3 d < l < 10 d, combined pressing was used: pulse compaction followed by drawing (Glushenkov et al., 2017).

In the manufacture of powder parts, attention was paid to the basic characteristics of metal powders. The stability of the bulk mass (mass per unit volume of the freely sprinkled powder) provides a more constant shrinkage during sintering. It depends mainly on the shape and size of the powder particles. The presence of protrusions and irregularities on the surface of the particles increase interparticle friction, which complicates their movement relative to each other and leads to a decrease in the bulk density of the powder. The granulometric composition of the powder is of significant importance – with an increase in the content of finer particles, the bulk density of the powder decreased, apparently due to an increase in the friction surface. The fluidity of the powder worsened with decreasing particle size of the powder.

All samples were sintered in a protective atmosphere of endogas at a temperature of 1,120 °C. For 30 minutes.

RESULTS AND DISCUSSION

Changes in the volume of the powder body during compression are the result of ongoing processes during compaction. The density of the workpiece depends on the pressing pressure and the form of its application. In all processes, with an increase in compaction pressure, the specific gravity increased and the porosity decreased. Porosity is evenly distributed throughout the volume (Fig. 4).

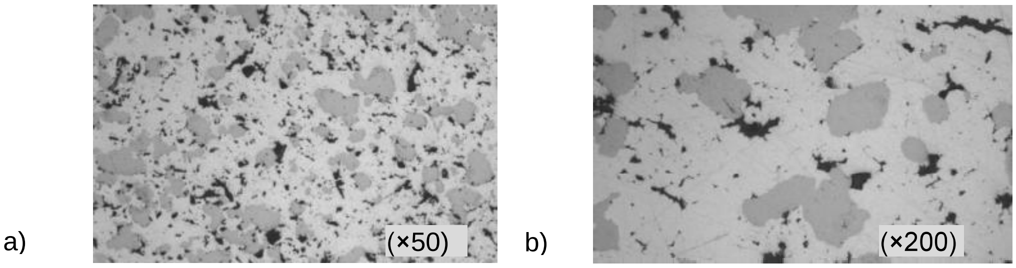

Figure 4. Microstructure of powder sleeves made of low-alloyed iron powder with porosity of 18%.

Particle shape affects bulk density and bulkability. Associated with it is their surface energy, which increases with increasing particle surface (Freeman et al., 2009). Along with the adhesion forces, mechanical factors also act, in particular, jamming of particles and interweaving of the protrusions. The particle size of the powder is one of the factors determining the specific pressure during pressing, necessary to achieve a given porosity, as well as shrinkage during sintering and the mechanical properties of sintered products (Fig. 5). This was especially evident with pulse compaction. Smaller powders were pressed much worse, and some billets cracked during sintering.

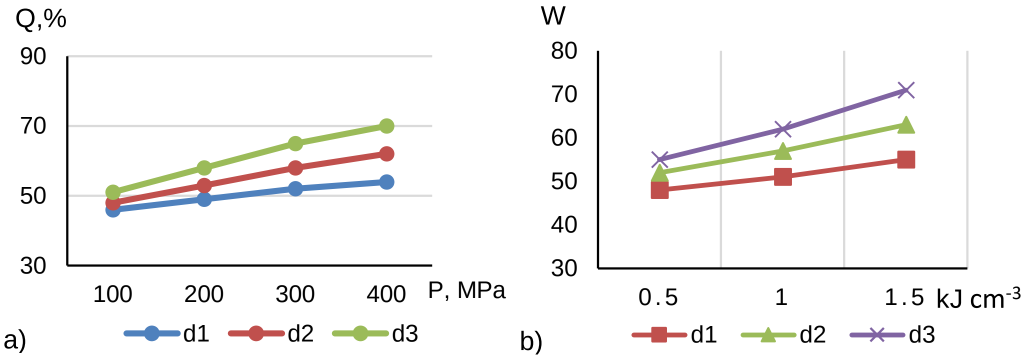

Figure 5. Change in the relative density of iron powder depending on the particle size during static (a) and by impulse pressing (b), $d_1 = 100$, $d_2 = 50$, $d_3 = 20$, – particle size μm; p – pressure; w – specific pulse energy.

Particular attention was paid to the method of manufacturing bushings with side holes (pockets) for subsequent grease retention (Fig. 6, a). A special device has been developed for this purpose (Fig. 6, b).

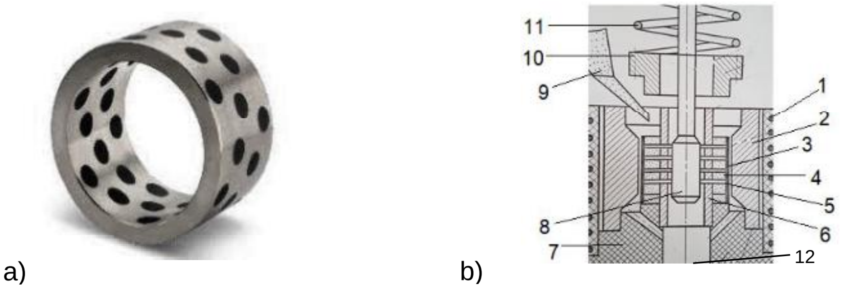

Figure 6. A sleeve with an outer diameter of 50 mm and side holes with a diameter of 3 mm (a) and a device for its manufacture (b), where: 1 – inductor; 2 – hub magnetic field; 3 – metal shell; 4 – powder; 5 – fingers; 6 – sleeve; 7 – base; 8 – stem; 9 – gutter for powder; 10 – cap; 11 – spring; 12 – device for pressing.

The device (Fig. 6, b) is intended for magnetic pulse pressing. It contains a multi-turn inductor 1, a magnetic field concentrator 2, a metal shell 3, a sleeve for forming an internal hole 6, a mandrel with sliding fingers 5 for forming side holes, and also a powder filling mechanism in mold 9 and a device for extruding products 12.

As experiments showed, the device is advisable to use in the manufacture of bushings of large diameter (more than 50 mm).

CONCLUSIONS

1. The technology of manufacturing powder sleeves for railway nodes is constantly being improved. Technologies based on the use of combined static-dynamic compaction methods deserve more and more attention.

2. New technological possibilities for the manufacture of slide bushings with side openings, used as pockets to hold grease, are presented.

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