THE DEVELOPMENT OF THE LUBRICANTS APPLIED IN THE POROUS BEARINGS

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Abstract

In the article the development process of lubricants applied to the porous sliding bearings is described and characterised. Porous bearings are widely used in mechanical vehicles, household appliances and manufacturing equipment. However their application to tribological pairs is believed to be limited because of their properties and features such as small resistance to edge and dynamic loads, ability to work only at small sliding velocity. For the last twenty years intensive research under the development of the porous bearings has been observed and newly designed porous bearings have occurred. In that process also lubricants were developed. As the result the range of used lubricants is wider and also their chemical constitution was changed from the mineral oils to the synthetic bases giving better resistance on aging process and better rheological characteristics. Each group of lubricants was characterised and the problems of lubricant selection and application were described.

In the article it was also noticed that especially the Polish manufacturers of porous materials do not regard the problem of lubricant selection seriously.

Finally, it was summarised that wider selection of new lubricants for the porous bearings enables proper design of the tribological pair for the future work conditions.

Keywords: *porous bearings, lubricants, selection of lubricants, development*

1. Introduction

The development of the porous bearings is focused on the enhancement of their application. That process can be stimulated by the progress of the porous bearing structure and construction and by the improvement of the lubricant properties or selection of new lubricants.

Design process of the porous bearing is always aimed on the future work conditions of a bearing, i.e. value and character of load, work temperature and atmosphere. Then one chooses materials to design the bearing, what means not only selection of the material of bush and shaft, but it is also connected with the selection of the lubricant. This is in accordance with a general theory of the tribological systems [1], which theory assumes that all the elements of tribological system (mating elements, lubricant and atmosphere of system) are equal and they should be determined as a whole. Different relations and coupling connect every element of this system with all the other elements, but none of these elements is privileged [1,2]. This attitude towards selection of the suitable lubricant to the given tribological pair has basic meaning, not less important than selection of the constructional materials of bush and shaft.

The conventional bearings with a solid bush have different design than the porous bearings. Sintered bush has pores and channels (mainly 15...25% of their volume) filled with lubricant, what guarantees operation of a bearing in the range of the predicted conditions. These bearings can be additionally supplied from external depots, what could enhance area of their operation. However, the lubrication system of the porous bearing is not the same like in conventional one, in which inflow of fresh oil into the bearing gap is more intensive and forced outside of the bush–shaft system. This results in the different lubrication mechanisms of two kinds of bearings and as a consequence in the operating circumstances and practical applications. On the grounds of that sintered porous bearings are regarded as a complement of the wide range of solid sliding bearings, due to their special features (self–lubrication, non–service operation, work under start-stop swinging motion conditions and operation at small sliding velocity speed). However they have also undesirable features such as:

- small resistance to edge and dynamic loads;
- ability to work only at small sliding velocity;
- only small amount of oil closed in the porous structure of the bearing;
- the effects occurring during work of the porous bearing leading to decrease of the lubricant amount and to it's ageing.

Because of that, their application to tribological pairs was limited and the development of the lubricants is focused on the decrease of the undesirable effects and on the enhancement of work conditions (temperature, sliding velocity, friction coefficient). At the same time manufactures try to meet the most important requirements for the porous bearings such as: long lifetime, high load-carrying capacity in the wide range of the sliding velocity. Also if there are some additional needs (i.e.: the food-grade lubricant, work at the low temperatures) the manufacturer should regard them in the process of the lubricant selection.

2. Characteristic of the lubricants used in the porous sliding bearings and their development

The lubricants used in the porous sliding bearings can be divided into three main groups, as follows:

- lubricating oils – commercially produced different kind of oils (engine, machine, gear, hydraulic etc.) having mostly mineral base; however, the new trends are focused on the use of synthetic bases;
- greases – the mixture of base oil, the thickener and appropriate additives (inhibitors of corrosion, antioxidants, lubricity additives etc.);
- the other kinds of the lubricants, mostly solid lubricants (i.e.: graphite, boron nitride); also magnetic fluids; Mikrozella (product of Klüber Lubrication).

2.1. Development of lubricating oils

Lubricating oils have been used in the porous bearings from the very beginning of the powder metallurgy. They are mixture of saturated and aromatic hydrocarbon compounds (having the boiling point above 350ºC) and additives. Their application to the porous bearings is limited by the maximum boundary temperature (80ºC). Firstly their chemical constitution was simple and based only on the mineral basic oils with no additives. Very often they were produced from unrefined petroleum. Then the next products were better designed with appropriate additives for the work conditions in the porous bearing. However, it should be pointed out that for many years there were no lubricants intentionally assigned for impregnating of the porous bearings. The lubricating oils were taken from the other different groups of oils (i.e.: engine, machine, hydraulic, gear oils). Originally designed for the porous bearings lubricants have been produced for the last few years (Klüber Lubrication [3, 4], Nakagawa [5]), but they were very seldom used. In Poland the manufactures of the powder metallurgy and petroleum industry do not treat seriously a selection process of the lubricating oils for the porous bearings. Since many years one kind of oil, protective oil Antykol TS120 [6], has been suggested by the manufacturers for impregnation and the customer is left with own choice without any additional information and technical hints about lubricant properties.

Next step in the lubricants development was, as in the other groups of oils, application of synthetic bases because of their better ageing stability, rheological characteristics, and volatility. It was forced out by the main problems occurring during operation of the porous bearing such as:

- leakage and evaporation of oil,
- obliteration of the porous channels by the surface active compounds,
- decrease of the porous bearing permeability,
- ageing of oil.

Leakage of the lubricant from the bearing is a consequence of activity of centrifugal forces. The process is the more intensive the higher sliding velocity and the lower oil viscosity is. Adding to this the loss of oil during evaporation it could lead finally to decreasing of oil amount and worsening of the porous bearing operation. That effect was explained by Korytkowski [7], confirmed by Raman and Babu [8] and also by Krol [9] that the decrease of the saturation rate below 50% results in rapid increasing of coefficient of friction and temperature. The worst characteristics were observed for oils having higher evaporation loss and it was showed by Krol [9] that boundary value for volatility parameter by Noack method [10] is 15%.

Obliteration of the porous channels is strictly connected with the chemical composition of oil and oxidation process of oil during bearing work. Olexa [11] as the first clearly presented that permeability of the porous bearings, which parameter decides about oil circulation in the bearing gap, could be decreased by the active compounds comprised in oil. During process of oxidation in oil occur active surface products, which can improve lubricating properties of oil, but can also easily create boundary layers inside the porous channels diminishing significantly their clearance and making difficult for oil to flow into the bearing gap. Krol [9] noticed, that the porous bearings impregnated with laboratory-aged mineral oils showed the greater decrease of permeability the smaller content of antioxidant was. Furthermore, the porous bearings have worse exchange of heat than the bearings with solid bushes. Accumulated heat, catalyst metal–porous structure and oxygen accelerate oxidation of oil and change of its properties until total blockage of the porous channels. Only few authors [7, 9, 11, 12] turns attention on this problem assuming that this effect of obliteration is probably a reason of loss of porous bearing self–lubricating ability. However, it has not been proved yet in experimental investigations.

Thus, application of the synthetic oils in the porous bearings could be favourable and enables to decrease undesirable effects.

However, not all of the synthetic bases are applied [4]. The smallest viscosity change is observed for silicone oils and they can be used over wide temperature ranges. Silicone oils also show very good oxidation stability, corrosion protection and a good viscosity-temperature behaviour, but they have drawbacks in wear protection, especially at low speeds and high loads in the mixed friction regime. That negative effect was also observed earlier by Zozulia [13]. The best high-temperature and ageing characteristics have oils based on PFPE (perfluorinated polyether) and the authors (4) preferred them for sintered bearings operating at temperatures above 150ºC. However, the most often used and favourable synthetic oils for sintered bearings are believed polyalphaolefins (PAO) and ester oils, because they can be mixed with mineral oils and they show better thermal stability at high temperature up to 160ºC, low friction also at low temperature and ageing stability [4].

Thus, the use of synthetic oils can be profitable, but appropriate complex of oil additives should be prepared for the predicted operating conditions.

2.2. Development of greases

Greases are the next group of lubricants applied for the porous bearings. They are a mixture of:

- base oil (70...90%) – synthetic, mineral or vegetable oils or the mixture of them;
- the thickener (10...25%) – soaps of fatty acids, polymers, solid hydrocarbons and inorganic compounds;
- appropriate additives improving operating properties – inhibitors of corrosion, antioxidants, lubricity additives etc. (1...15%).

Greases have tixotropic properties, what means they have features of solids and liquids simultaneously. Change of the grease structure under small shear rate is reversible, but when the boundary value is exceeded they start to flow as liquids. Application of greases to the porous bearings is also connected with the undesirable effects occurring during bearing operation, described above. The use of greases is favourable because of the following reasons:
- good sealing properties giving protection before the contamination of the bearing by dust;
- small leakage of grease from the bearing during work;
- good characteristics at small sliding velocities and high loads;
- decrease of vibrations and noise during bearing work;
- ability to work in moist atmosphere without a risk of corrosion;
- ability to work in different mounting position of the bearing.

From the very beginning their use was thought to be limited because of difficulty with impregnation of porous structure. However, as Giemza and Kaldonski [14] showed impregnation of the porous bearings by greases is possible and the minimum required saturation rate (95%) can be achieved at higher temperature and duration of the saturation process. Results of investigation of the porous bearings impregnated by greases were published also by Giemza and Kaldonski [15]. They confirmed that lower coefficient of friction and higher load-carrying capacity could be also achieved. Furthermore, the bearings impregnated by greases could work stable at much higher temperatures than the bearings filled with oils (150ºC and more) without the problem of leakage.

The range of greases used in the porous bearings started from pure greases without any additives, what was described by Zozulia [13] and by Krzemiński [16], who proposed the use of vaseline, and by Kaldonski [17, 18], who proposed the use of greases with boron nitride powder. Fully designed and composed greases are produced by Klüber Lubrication [3, 4], but in Poland there are no greases manufactured by petroleum or powder metallurgy plants. If there are some applications of greases they are always produced for order from abroad company and the kind of grease and its chemical composition is unknown.

As each kind of lubricant greases have also some disadvantageous i.e. smaller thermal conductivity than for oils, high viscosity what is very undesirable at higher sliding velocities. As a consequence they cannot be used in all applications and that stimulates a new research.

2.3. Development of the other kinds of lubricants

Development of the other kinds of lubricants is connected firstly with solid lubricants and they can be divided as follows:
- having plate hexagonal structure;
- acting mechanically;
- creating metallic film;
- chemically active.

Solid lubricants having special plate hexagonal structure and anisotropic properties are widely known and often used in the porous bearings, for example: graphite, boron nitride, mica, borax, disulphur of molybdenum and wolfram. It is characteristic for these compounds that under small shearing load the plate crystals could easily move at small friction coefficient.

Lubrication with solids acting mechanically is based on the separation of mating elements. These compounds act as elastic balls scattered on the one surface and covered with the other surface. The examples of this kind of solid lubricants are as follows: perfluorinated polyether

(PTFE) and other solid polymers comprising fluorine, polyethylene (PE), polypropylene (PP), polyurethane (PU), polyamides, polysilicons.

Lubricants creating metallic film cover the surface of mating elements with much softer metal. Metallic film fills the roughness and separates the surfaces of mating elements. The film could be easily created by lead (Pb), copper (Cu), gold (Au), silver (Ag), tin (Sn) and other kinds of metal.

Lubrication mechanism could also be improved by the application of the chemically active solids. They react with the compounds comprised in the friction surface and new chemical substances, having better lubricity properties, are created.

There are also examples of the new solutions of the lubricant starvation during bearing operation. Miller and Tetzlaff [4] presented Mikrozella - the lubrication system produced by Klüber Lubrication. The authors showed that, with the help of Mikrozella lubrication sintered metal plain bearings could attain 10-fold longer running time with use of ester oil in comparison with mineral oil without additional lubrication. These results were also essential because of extreme test conditions the porous bearings were working (bearing temperature was approximately about 150ºC). A special Mikrozella design allowed achieving such meaningful results. It was a plastic oil depot in the form of a sinter bearing oil gel, which served for the additional lubrication (Fig.1).

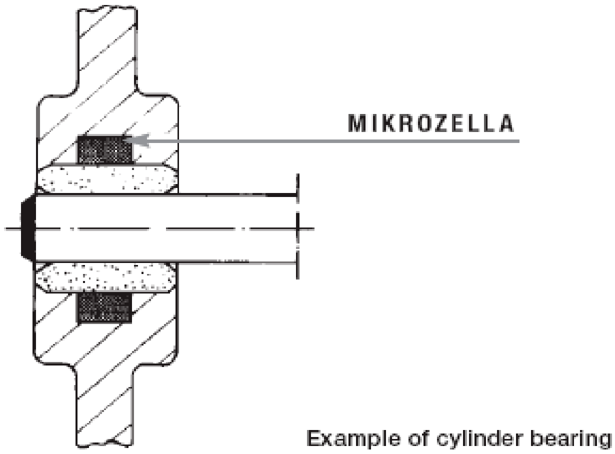

Fig. 1. Recommendation for application of the Mikrozella depot [4]

Moreover, the use of Mikrozella could be also adjusted to the future work conditions by defining oil release of this system especially tuned to the lubrication of sintered bearings.

Miller and Tetzlaff [4] summarised that, Mikrozella is also suitable for series production and could be used in many branches of industry as an additional lubrication system.

Lubrication of the porous bearings could be also achieved by the application of special lubricants. An example of special lubricant is magnetic fluid operating in highly rotating bearings. In the Fig.2 [19] are showed characteristics of motion resistance of porous bearing and in comparison roll bearing both lubricated by magnetic fluid.

Hidekazu and Motohiro [19] presented that the friction moment of the porous bearing lubricated by magnetic fluid is much more stable, than for roll bearing. However, the values achieved for the porous bearing increase with increase of a rotational speed. But friction moment characteristics for porous bearings are more predictable and smaller changes of values were observed, what could have essential meaning regarding future application and stability of work parameters.

Summarising, the application of new lubricants allows reduction of lubricant quantity and enables longer lifetime of the porous bearing. Dry lubrication could give new possibilities i.e. the layers of lubricants covering surface of the bearing could be prepared with higher accuracy to the needed size.

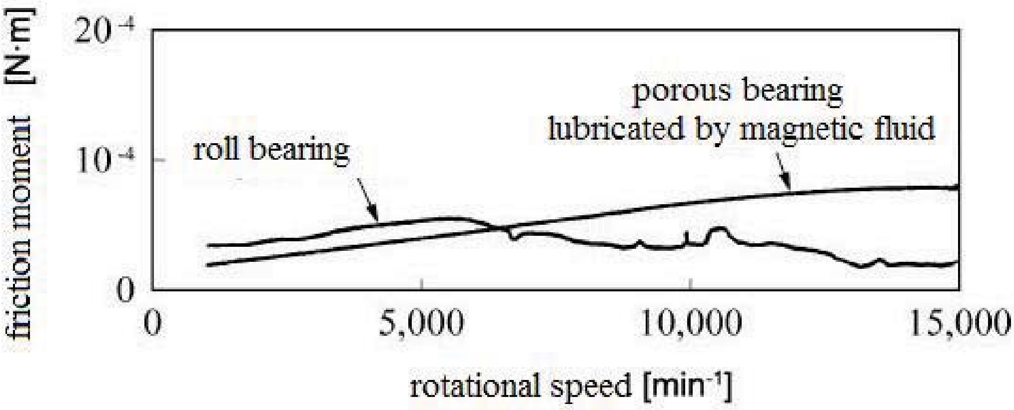

Fig. 2. Friction moment of porous bearing impregnated by magnetic fluid in comparison to friction moment of roll bearing [19]

3. Conclusions

Development of the lubricants used in the porous bearings is firstly focused on the synthetic oils giving better characteristics than mineral oils. But, final composition of the lubricant should be supplemented with pack of the appropriately selected additives regarding the future work conditions.

Greases seem to be very meaningful in the development of the porous bearings and application of greases should be much more wider than nowadays. The investigation results showed, that impregnation process of the porous bearings is possible and work parameters achieved for bearings lubricated with greases are often much better than for oils.

Dry lubricants can be used in combined systems with other kind of lubricant or as the layers bonded to the friction surface. Their use gives also possibility to prepare the bearing dimensions and its surface roughness for future application.

However, is should be pointed out that despite wide range of lubricants to the porous bearings there are no selection rules of that kind of lubricant. The only regarded property of oil is sometimes its viscosity, but other properties are not mentioned (evaporation loss, lubricity, permeability characteristics, resistance to ageing, corrosion activity). The manufacturers and powder metallurgy producers do not have tests checking lubricant properties and these tests are not also specified in the standards of porous bearings.

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