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Experimental research on water lubricated three layer sliding bearing with lubrication grooves in the upper part of the bush and its comparison with a rubber bearing

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ABSTRACT

One of the more interesting, currently available water lubricated bearing materials is a three layer composite. Each of its layers has an important function. Specially prepared sliding surface ensures minimum resistance. Following running-in its smoothness becomes very high and the bearing may continue working under fluid lubrication regime. NBR layer ensures bearing elasticity, good vibration damping properties and insusceptibility to shaft axis misalignment. The external brass layer makes fitting the bearing easier.

Experiment results of the conducted research were compared with those for a rubber bearing of similar geometry.

1. Introduction

Increased level of environmental awareness and creation of new legislative measures have in recent years stirred a growing interest in environmentally friendly technologies. This trend also applies to propulsion shaft bearings in shipbuilding, hydropower, water pumps and other industrial sectors. The increased interest is especially noticeable in the field of water lubricated bearings and biodegradable lubricating agents.

One example of legislative changes in the area may be a draft regulation entitled “Small Vessel General Permit (sVGP)” prepared by the United States Environmental Protection Agency which states that “environmentally acceptable” lubricants have to be employed on every ship built after 2013. This means that these lubricating agents have to be biodegradable and non-toxic. Environmentally friendly lubricants should also be used on older ships, and if this is not possibility the necessity of employing a regular, standard solution must be clearly documented by the shipowner.

Currently, water lubricated bearings find wide use in numerous areas of technology. Pros and cons of various types of sliding materials have been debated for years (Smith [1], Hother-Lushington [2]). Bearings presently used in shipbuilding and other industries include rubber bearings (Orndorff [3–5], Wang [6], Wang [7]), polymer bearings (Gao [8], Ginzburg [9]; Laskey [10]; Šverko and Šestan [11]), as well as composite bearings (Ford [12]). In addition, there are bearings made of various newly developed multi-layer materials providing custom-made properties (Yamjo [13]). Much scientific research is also conducted on other types of water lubricated bearings. These are mostly ceramic (Nisaka [14], Jahanmir [15], sintered metal alloy (Jun-hong Jia [16], Litwin [17]), and foil bearings (Olszewski [18], Hryniewicz [19]).

Shipbuilding industry is dominated by well-known constructions made of rubber, polymer and composite materials. Rubber and polymer bearings are used in pumps, as are ceramic and various sintered ones. In water turbines one can encounter both polymer and rubber bearings, while ceramic bearings are currently in the implementation-testing phase.

All water lubricated journal bearings may be divided into two basic groups—rigid bearings, in which the bush does not experience any significant deformation resulting from hydrodynamic pressure, and elastic bush bearings. Classified as rigid are all the bearings in which the modulus of volume elasticity is greater than the approximate value of 3000 MPa. This includes all kinds of bronze bearings, ceramic bearings, as well as majority of composite bearings constructed on the basis of epoxide and phenol resins. Other bearing types – rubber, polymer, foil etc. – belong to the group of elastic bearings. Among their fundamental advantages is greater tolerance of work under conditions of shaft misalignment

2. Origin and purpose

Experiment-based research on various types of sliding water-lubricated bearings—including rigid, composite and elastic plastic

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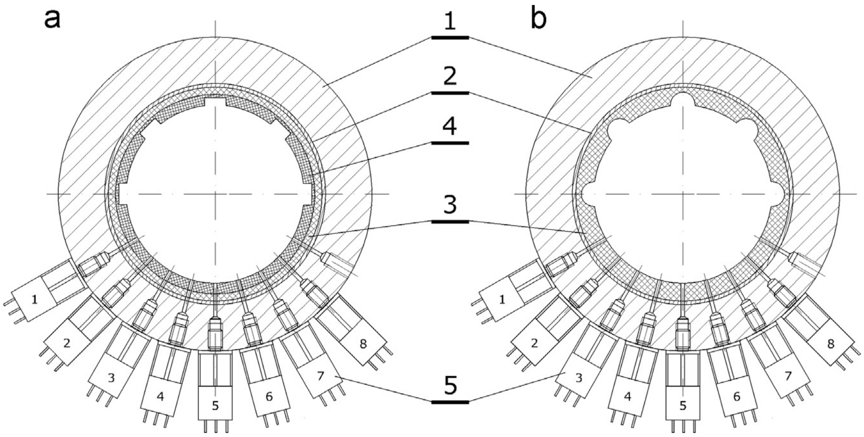

Fig. 1. Tested bearings: (a) three layer bearing, (b) rubber bearing; 1—steel sleeve, 2—bearing steel sleeve, 3—NBR, 4—PTFE layer, 5—pressure sensors installed in steel sleeve.

ones (Litwin [20–22]), has been conducted at the Gdańsk University of Technology in recent years. The research has unequivocally demonstrated that a properly designed hydrodynamic water lubricated journal bearing is capable of working under a fluid lubrication regime at loads and speeds typical of practical applications. Unfortunately, low viscosity of the lubricating agent i.e. water, as well as the absence of effect of increased viscosity as a function of pressure, result in a very low minimum water film thickness, usually not exceeding a few dozen micrometers, despite obtaining full hydrodynamic lubrication.

Research carried out by the author, as well as results available in literature, demonstrate that elastic polymer bush bearings have lower hydrodynamic load capacity than comparable rigid bearings (i.e. made of composite materials), and under identical load values they work at smaller film thicknesses. This is due to local def ormation of bush surface resulting from pressure generated in the lubricating film. As a consequence, the lubrication gap changes its shape within the area of increased pressure. This surface deformation may reach value of theoretical minimum lubrication gap thickness and result in significant limitation of the forming hyd rodynamic pressure, which substantially impacts the bearing's load capacity.

Unfortunately, all of the bearing types employed in practical applications present certain shortcomings. Rigid composite bearings usually have inferior surface quality to comparable polymer bearings and as such may in certain situations have lower hydrodynamic load capacity. They are also more susceptible to shaft misalignment. As a result, they are susceptible to frequent occurrences of local stress concentrations and overheating of composite material resulting in bush delamination. In addition, rigid bush materials offers only limited dampening of vibrations. It is for this very reason that materials of lower modulus of elasticity are so intensively searched for.

Rubber bearings have been employed in shipbuilding as propeller shaft bearings for several decades. In the past, when natural rubber containing sulphur was used, the corrosive environment frequently led to shaft journal destruction. Nitrile rubber (NBR) which has now been employed for years, does not create this problem, however, it does create significant resistance of movement at start-up, which in certain situations results in substantial wear of journal's sliding surface.

The goal of the work was to investigate behavior of a modern, three-layer bearing of an innovative design. Its construction pointed to the possibility of obtaining optimum properties, i.e. low resistance of movement—including at start-up, significant bush elasticity, high surface smoothness and good dampening properties (Fig. 1).

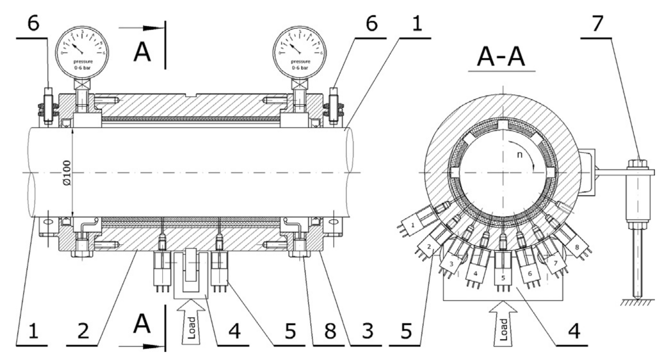

Fig. 2. Test rig – tested bearing unit; 1—main shaft, 2—tested bearing housing with tested bearing located inside, 3—cover (right side) with seal, 4—support with roller bearings – load application location, 5—pressure sensors (in two surfaces, left and right), 6—two pairs of proximity sensors, 7—arm with force sensor for twisting torque measurement.

3. Characteristic of investigated bearings and research methodology

The research object was a three layer bearing. The obtained results were compared with those of a rubber bush bearing of practically identical geometry (Fig. 1). In both bearings, the lubrication grooves were present only in the upper part of the bush which was not under load. This facilitated occurrence of hydrodynamic phenomena.

Geometry of the grooves differed somewhat due to technological reasons at the manufacturing stage. However, it is believed that this fact did not have any significant impact on hydrodynamic phenomena occurring between journal and bush.

Detailed description of the test rig may be found in earlier works (Litwin [20,21]).

The investigated bearing was 100 mm in shaft diameter and 200 mm in bush length (Fig. 2), as such it represented typical proportions of a propeller shaft stern tube bearing. The shaft was made of marine grade stainless steel X10CrNi18-8.

The bearing was placed inside a massive steel housing which was fit with two sets of eight pressure sensors located on two planes, allowing for measuring pressure distribution between the journal and the bush (Fig. 2). The bearing assembly was closed on both sides by covers equipped with seal rings. This allowed for forcing movement of the lubricating agent i.e. water, through the bearing. Two pairs of movement sensors were installed in the covers, allowing for recording of the shaft axis trajectory. The test rig was unique in offering the possibility of recording the boundary journal position in the bush as a function of load defined by the clearance cycle. Radial load was placed on the bush through