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Material comparison for large sliding thrust bearings in marine environment bases on full scale tribological experiments

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ABSTRACT – The doors of a mitre gate are typically connected to the lock with large sliding bearings. The friction in these bearings influence the torque required to open and close the doors, and determines among others the power of the actuating mechanism. The material selection of the sliding bearings to a large extent influences the frictional behaviour. Selection of the materials should be done based on representative experiments since it is known that tribopairs behave differently on different test scales and conditions. Therefore, we compared different material combinations on a representative full scale tribological test setup.

1. INTRODUCTION

Selecting an appropriate material combination for large components and heavily loaded conditions is important because in that case replacement and downtime are expensive. The application aimed at in this paper are locks in the maritime industry, such as those used on rivers and canals to accommodate water height differences. A common type of door for such a lock is the mitre gate, see Figure 1. Mitre gates are connected to the lock structure by two bearings, a radial bearing at the top of the gate (gudgeon bearing) and a combined axial-radial bearing at the foot of the gate (pintle bearing), which is located under water. Typically, a sliding bearing (lubricated or dry running bronze or an immersed self-lubricating composite) is used for these bearings.

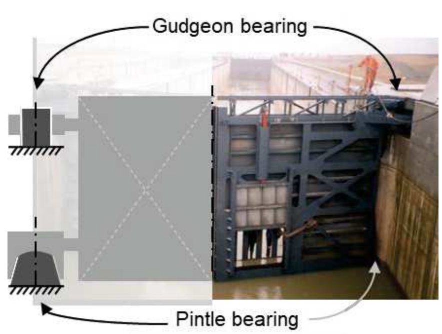

Figure 1 Mitre gate in Enkhuizen (NL) [1].

Selecting a material combination for any tribological application should be done with great care, since it is know that material combinations behave differently at different test scales [2]. Selecting the best material combination for pintle bearings on locks should preferably be based on results obtained from a full scale test rig, such as developed at Soete Lab of Ghent University. This paper focusses only on the axial bearing functionality of a pintle bearing. The radial bearing capacity is not taken into account and is not tested. The results of three material combinations are presented.

2. METHODOLOGY

2.1 Testing principle and test rig

The tribological tests are performed on a full scale pintle bearing assembly consisting of a pin and a bearing, see Figure 2. Notice that only the axial bearing capacity of the pintle bearing is tested. The geometry of the pin and the bearing is given in section 2.2. The pin is rigidly fixed to the test floor. The bearing is positioned on top of the pin and is rotated forth and back around its axis of symmetry (γ) by means of a hydraulically driven lever arm.

A normal force F_N is applied along the symmetry line on top of the bearing by a hydraulic cylinder and loads the bearing on the pin.

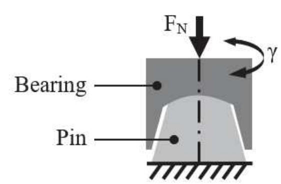

Figure 2 Test principle of the axial sliding bearing tester.

An overview of the test rig is shown in figure 3. The main characteristics of the test rig are given in Table 1.

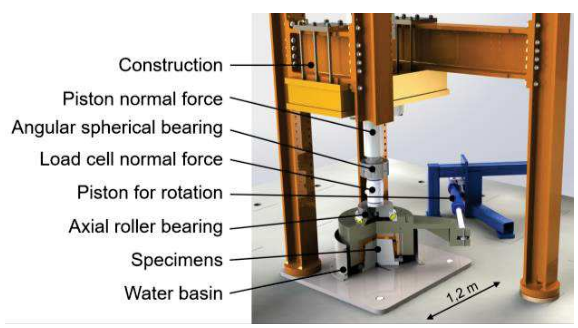

Figure 3 3D view of the axial sliding bearing tester.

2.2 Specimens geometry

The geometry of the pin and the bearing is chosen identical (full scale) to the real application and is shown in Figure 3. The bearing shell is made of two parts: a tapered sleeve and a spherically ended cap. The radius of the spherically ended cap (R = 2050 mm) is slightly larger than the radius of the spherically ended pin (R = 2000 mm).

Table 1 Test rig capacity.

Parameter	Maximal value
Normal force	1500 kN
Tangential force	80 kN
Torque	80 kNm
Rotation stroke γ	80°
Rotational speed	135°/min
Diameter contact area	400 mm
Lubrication/environment	Greased or dry/dry or water

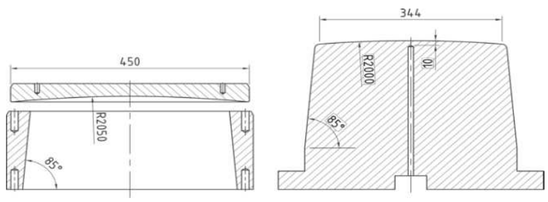

Figure 3 Geometry of the pin and bearing.

2.3 Online measurements

During an experiment the forces and displacements of the two hydraulic cylinders (normal and tangential) are measured. These measurements are used to calculate the angle of rotation (γ) and the torque offline.

2.4 Testing procedure and parameters

The test procedure and parameters are chosen as close as possible to real pintle bearing operating conditions (Zemst lock). The variable of interest is the material combination of pin and bearing.

During testing the pin and bearing are submerged in canal water that is cooled to 15°C. The water is filtered through a screen of 5 µm. The normal load is 1337 kN +/- 1 kN and is kept constant during the test. The bearing is reciprocated around its axis (angular position curve has a saw-tooth profile with an average rotational speed of 38°/min and a rotational total stroke of 77°). The total number of cycles equals 5552. Halfway the test, at 2776 cycles, the test is stopped and the specimens are disassembled and visually inspected.

2.5 Material combinations

Three material combinations are experimentally tested and compared, see table 2. The composite is a glass fibre reinforced epoxy resin matrix with a sliding layer consisting of an epoxy resin filled with solid lubricants.

Table 2 Tested material combinations.

Nr	Pin	Bearing
1	Bronze CuSn10Pb10	Cast steel GE 300
2	Composite Deva.tex.542	Stainless steel AISI 431
3	Brass CuZn35Mn2Al1Fe1	Stainless steel AISI 431

3. RESULTS AND DISCUSSION

For one stroke three characteristic torque values are calculated: The torque at the start of the motion, the averaged torque during half of the stoke and finally the torque at the end of the stroke. The three torque values as a function of the number of cycles are shown in Figure 4.

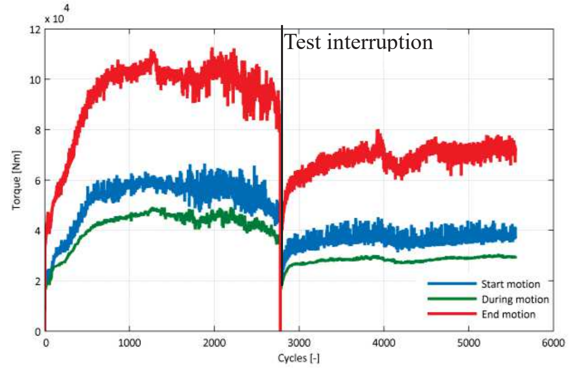

Figure 4 Torque during forward motion.

Comparison of the frictional behaviour of the three material combinations is based on the maximum torque occurring during the entire experiment. The maximum torque is a main design value for the actuating mechanisms. Figure 5 shows the highest torque value for the three material combinations. The material combination composite - stainless steel has a design value that is 47 % lower than the currently used material combination bronze - cast steel. The material combination brass – stainless steel has a design value that is 8.4 % higher than bronze – cast steel.

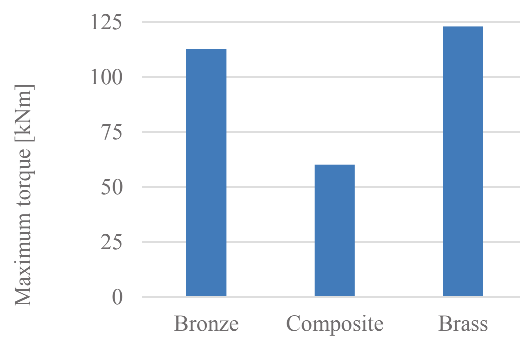

Figure 5 Maximum torque of the material combinations.

4. SUMMARY

At Ghent University a tribological test rig has been constructed to test large scale sliding thrust bearings in marine environment. For a typical pintle bearing of a mitre gate three material combinations were compared. The maximum required torque for the material combination composite – stainless steel is 47 % lower than the currently used material combination.

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