Characteristics of hydrodynamic plain bearings with bonded coating

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Abstract

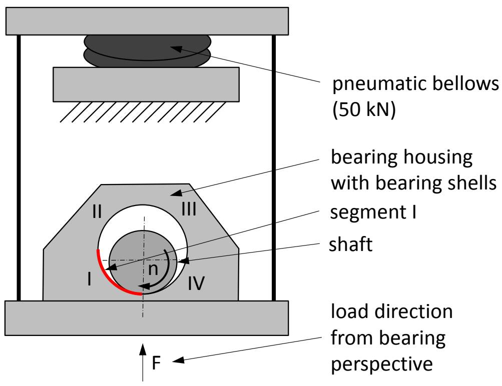
Increasing ecological and economic pressures, as well as increased technical requirements, have given rise to the need for research into alternative wear layers for hydrodynamic plain bearings. Previous investigations have tested and researched the bonded coating GL92. It has been possible to demonstrate that the bonded coating (plastic base) is a viable alternative to a conventional white metal alloy.
However, this coating was not able to address all the issues experienced by industrial users, for example the behaviour of the system (changes to operating properties) during penetration of particles, or behaviour in a mixed friction area. The literature has not – or not sufficiently – answered the questions relating to damage patterns and damage tolerance. Therefore, regardless of the proven benefits, industrial use of this coating is currently not possible or is connected with significant risks.
In the study, tests were carried out in the mixed friction area (start-stop testing, emergency testing without oil, insufficient lubrication tests) as well as in the hydrodynamic area. The comparative tests were performed on different wear layer materials. This paper demonstrates and discusses the results for both a conventional white metal alloy bearing and for the bearing with bonded coating (GL92).
Depending on the operating point, the bearing systems exhibit significant differences at the maximum bearing load, lubricating film pressure distribution and maximum bearing temperature. The investigation has proven that GL92 is a technically useful alternative to conventional wear layers.

Keywords: damage tolerance, changes to operating properties, maximum bearing load, bonded coating

1. INTRODUCTION

All tests were performed on the hydrodynamic plain test bench (GL 110) (Figure 1a). Depending on the planetary gear used, speeds of up to 100 m/s are possible. The maximum load is 50 kN. The rotor has a diameter of 110 mm. Figure 1b shows schematically the loading device with force directions, direction of rotation and the segmentation of the bearing.

a)



b)

Figure 1: a) Test benches; b) Schematic structure of the loading device with segmentation

All tested bearings were multi-surface plain bearings with one of two different coatings. The bearing clearance was set for each variant at 2‰. The following table (table 1) and graphic (figure 1) show the specification of the bearing and the geometry of the bearing surfaces. All bearings were prepared with thermo elements (type K).

Type:	VFL
Nominal diameter:	110 mm
B/D	0.74
Sliding surfaces eccentricity	0.5 mm
Bearing clearance	2 ‰
Coating thickness	white metal 5 mm plastic coating 25 µm

Table 1: Specification of bearings

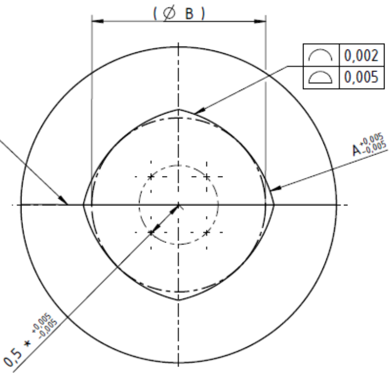


Figure 1: Profile drawing of the multi-surface plain bearing

2. EXPERIMENT

Based on the operational characteristic properties in the mixed friction area, the assessment of damage tolerance was evaluated. The focus was on abrasive wear (localized melting) and on the temperature development or power loss. The tests were divided into two groups; all experiments were performed with a holding temperature of 40 °C.

Start-stop testing:

Figure 2 shows the profile of a start-stop cycle. The shaft was accelerated under a specific bearing load of 1 MPa to a rated speed of 900 rpm. After reaching the rated speed, the specific bearing load increased to 2 MPa or 4 MPa, respectively. Finally, the shaft was decelerated (under load). A test block comprised 10,000 load cycles. The flow rate was 25 l/min.

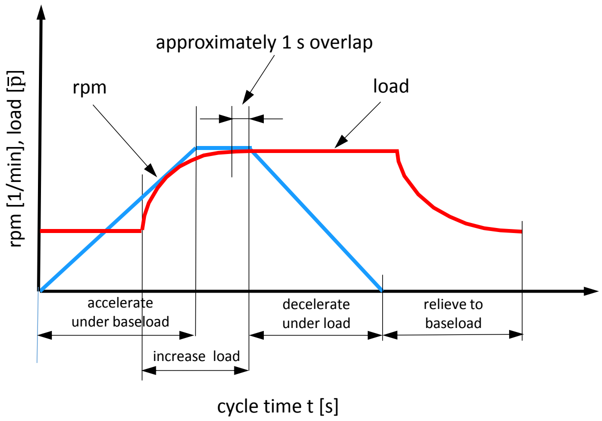
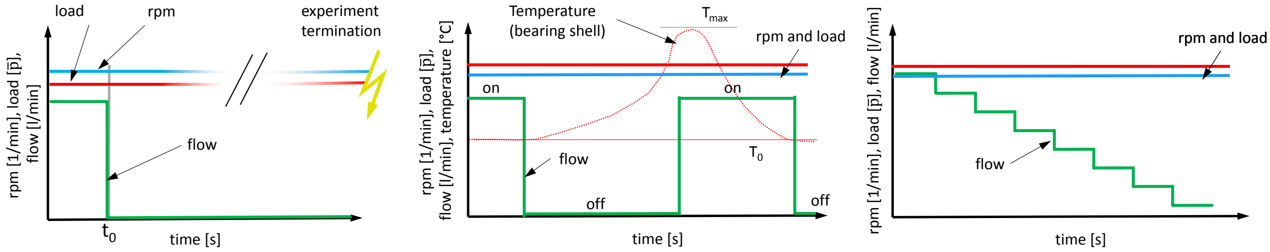


Figure 2: Schematic representation of a start-stop cycle

Emergency testing:

Emergency testing, which represents the most extreme application conditions, was carried out in different variations. Figure 3a shows the first variant. Specific bearing load and speed were kept constant in all variants. In variant a), the oil supply was interrupted at time t_0. The abort criterion was the complete failure of the wear layer. In contrast to test procedure a), in procedure b) the oil supply was turned on again just before complete failure of the wear layer. This cycle was repeated 500 times. The third variant involved the stepwise reduction of the oil supply (Figure 3c) at constant load and speed.



a) Emergency testing with complete interruption of the oil supply

b) Emergency testing with cyclical interruption of the oil supply

c) Emergency testing with stepwise reduction of the oil supply

Figure 3: Schematic representation of the different kinds of emergency test

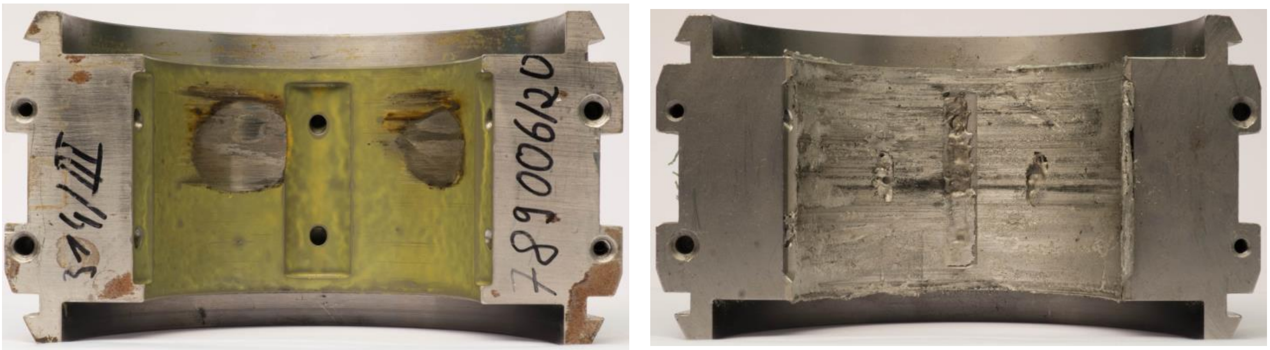
3. RESULTS AND DISCUSSION

Start-stop testing:

In the first test series, the bearing variants were tested at 2 MPa (10,000 load changes). None of the bearings incurred significant wear [1]. In further tests, the load was increased to 4 MPa. The experiments with increased load were performed exclusively on the bearings with plastic coating. It was possible to demonstrate that, at increased load, the GL92 coated bearings again exhibited no significant wear.

Emergency tests without oil:

The experiments with different bearing layer material (GL92: Figure 4a; white metal alloy: Figure 4b) show significantly different damage patterns in respect of the cause of damage.



a) Plastic coating GL92, damage to the upper and lower bearing shell

b) White metal bearings, damage to the lower bearing shell (segments 1 and 4), deposits of molten white metal on the upper bearing shell

Figure 4: Damage patterns resulting from emergency testing without oil

Full melting (lower bearing shell) of the wear layer occurred in some areas of the reference bearing with white metal alloy. The upper bearing shell is almost undamaged except for small deposits of molten metal. In contrast, the bearing system with alternative wear layer (GL92) failed as a result of the seizing of the rotor. The damage patterns can be seen on the upper and lower bearing shell. Except for the significant damage (circular clamping points) caused by seizing, the wear layer was undamaged.

A direct comparison of the results is not possible due to the different types of damage. This coating could not be evaluated or compared (application-specific). Due to insufficient results, the test procedure was adapted [Figure 3a → Figure 3b].

Emergency testing with cyclical interruption of the oil supply:
The images in Figure 5 show the types of damage in the experiment with the adapted test procedure.

a) Plastic coating GL92, undamaged upper and lower bearing shell, running-in level visible on the lower shell

b) White metal bearing, damage to the lower bearing shell (segments 1 and 4), deposits of molten white metal on the upper bearing shell

Figure 5: Damage patterns from emergency testing with cyclical interruption of the oil supply

The bearing variant with plastic coating showed no significant damage after 500 load cycles. In contrast, the white metal alloy showed significant damage. For the evaluation of the occurrence of damage, the experiments were interrupted at regular intervals (after 1, 5, 10, 50, 100 and 500 load cycles). It was found that damage had already occurred after the first load cycle: in the contact region, localized melting is visible. This would necessitate a change of the bearing geometry – the bearing cannot be used for a real application.

Emergency tests with stepwise reduction of the oil supply:
Testing with a stepwise reduction of the oil supply was performed exclusively on the plastic-coated bearing (figure 6). Previous studies have shown that, with inadequate lubrication, the bearings with white metal alloy fail very fast.

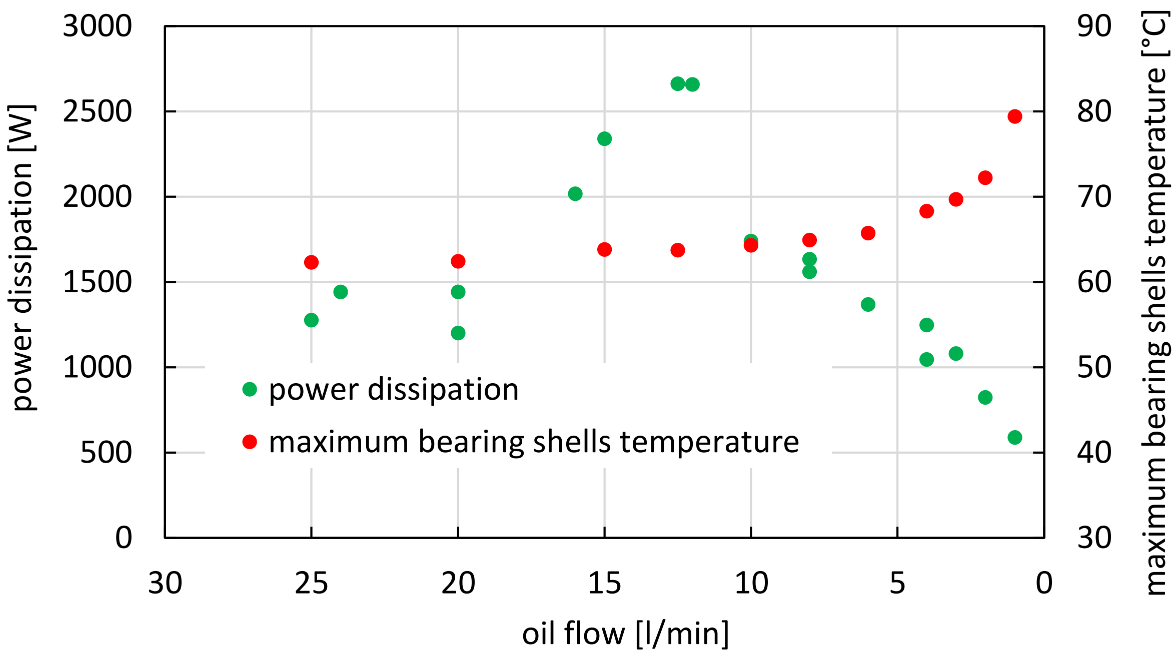


Figure 6: Power dissipation and bearing shell temperature plotted against oil flow

As expected, the bearing shell temperature increased with the reduced oil flow. The oil flow was reduced to 1 l/min (technical limit of the oil supply system). In the configuration used, the bearings showed a significant increase in power dissipation at 12.5 l/min. This may be due to turbulent behaviour. The tests have shown that a reduction in the power loss of up to 75% is possible.

4. SUMMARY

The experiments showed that the chemically bonded coating is a technically useful substitute for the white metal alloy. The tests confirmed the excellent performance of the chemically coupled bonded coating in the mixed friction area.

A general statement as to which is the best wear layer is not possible. This would require a differentiated consideration of the application. Figure 7 attempts to explain selected influencing factors based on selected applications.

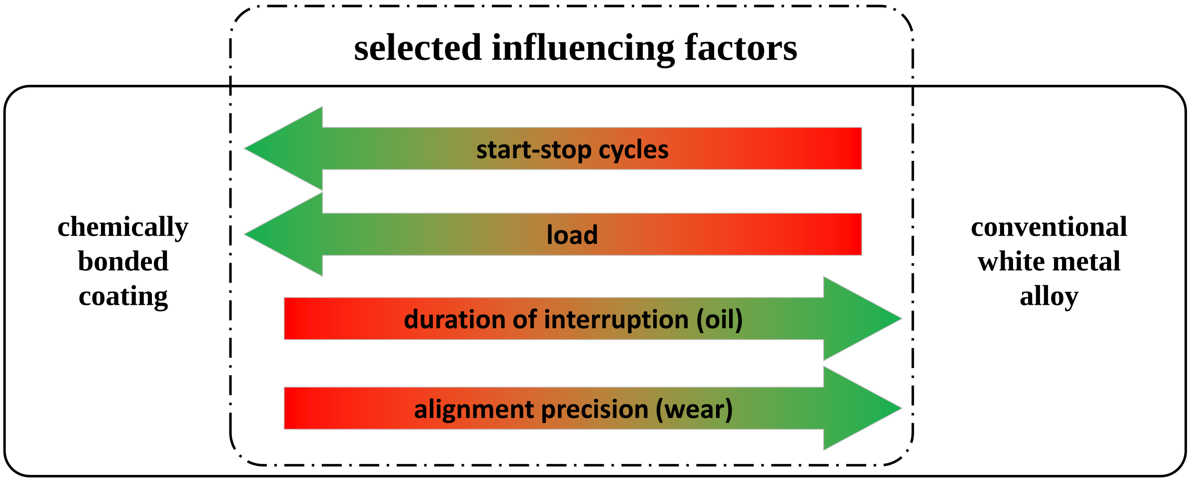


Figure 7: Criteria for an application taking selected influencing factors as an example

As the start-stop testing showed, the chemically bonded coating has a significantly higher load limit and exhibited no significant wear. The bearing would be ideal for the automotive sector, for use in start-stop engines, so that wear could be reduced and the service life could be extended. The problem relates to the damage incurred: during longer dry running, the bearing system seizes (no wear). The extremely sharp braking associated with this can cause considerable damage to the whole system. The coating is therefore only of limited use for large systems.

5. REFERENCES

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