Design and testing of a tilting-pad journal bearing with additive manufacturing cooled pads

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1. Introduction

Tilting-pads journal bearings are widely used for rotating machinery. Although they are characterised by higher cost than sleeve bearings, they guarantee greater margin of stability, especially when the rotating machine operates at high rotational speeds. In general, in oil-film bearings, the higher the load capacity the lower the temperature of the pads and of the oil-film. Therefore, given the same size of the bearings, the possibility to reduce the temperature of the oil is an interesting aspect to increase the performances. In this paper, both the development of special pads, made by additive manufacturing (AM), specifically designed to reduce the temperature of the pads and of the oil, thanks to cooling circuit, and the experimental results obtained on a test-rig are described.

2. Methods

In a previous study, using CFD simulations, Chatterton et al. in [1] have analysed, in a simple flat pad, which were the effects of different cross-sections and cooling circuit paths.

The results of the simulation were compared with pads having the same geometry, but without cooling channels: the lower temperature is obtained by increasing the cooling fluid inlet flow rate and by adopting a multi-channel cross-section for the cooling circuit. The same authors have proposed to solve the problems of making the "cooled pad", due to the complex cross sections of the cooling circuit, by means of AM.

Further steps have been obtained in this study, in which a three-dimensional thermo-elasto-hydrodynamic model of the entire TPJB, equipped with cooled pads, is considered.

Figure 1 shows the geometry of the cooling circuit inside of one or the considered cooled pads, which equip a TPJB with 5 pads.

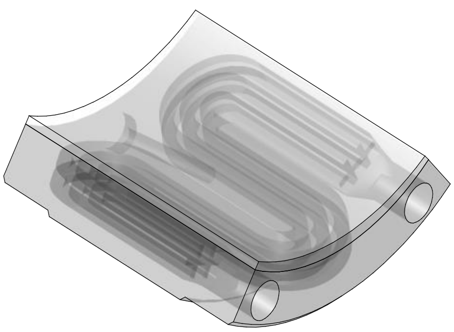

Figure 1: Six-squares cross-section cooling circuit inside the bearing pad.

Figure 2 shows a close-up of the section of the cooling circuit that has been made using AM. The 3D printed pad was made by using AISI 316L stainless steel. A standard finishing process has been used for the pad, by coating the surface in contact with the oil by ECKA Tegostar babbitt material.

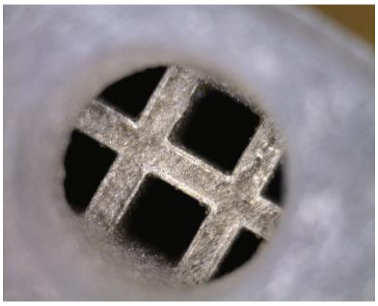

Figure 2: Close-up of the six-squares cross-section cooling circuit made by means of AM.

The simulation of the bearing behaviour has been performed by means of several sub-models, which consider:

- full 3D thermal model;
- oil mixing model;
- turbulence mode;
- full 3D elastic model;
- full 3D hydrodynamic model.

The sub-models have been implemented in a co-simulation environment using ANSYS-Fluent and Matlab software.

As an example, Figure 3 shows the temperature distribution on pad external surfaces and on a cross section, considering a six-squares cross-section cooling circuit.

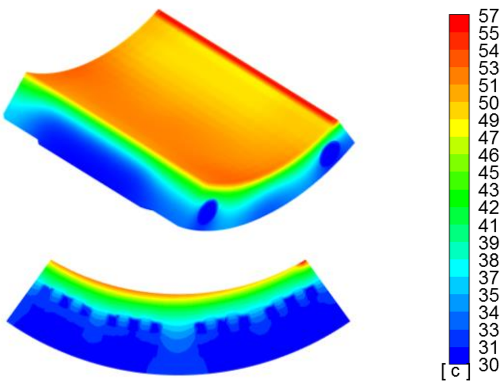

Figure 3: Temperature distribution in the cooled pad calculated by using ANSYS Fluent and Matlab co-simulation.

The experimental tests have been performed by installing the cooled pads on the test-rig of Department of Mechanical Engineering of Politecnico di Milano. The test-rig is described in detail in [2-3].

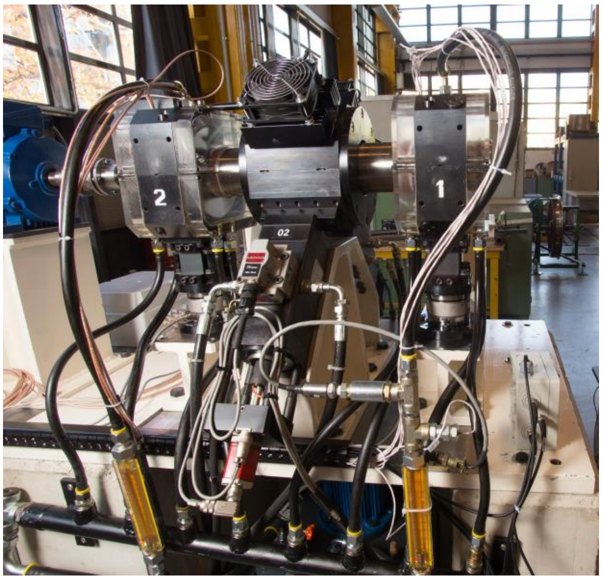

Figure 4: Test-rig of Dept. of Mechanical Engineering Politecnico di Milano.

Different oil flow rates and rotational speeds have been considered. Some results are summarized in Figure 5.

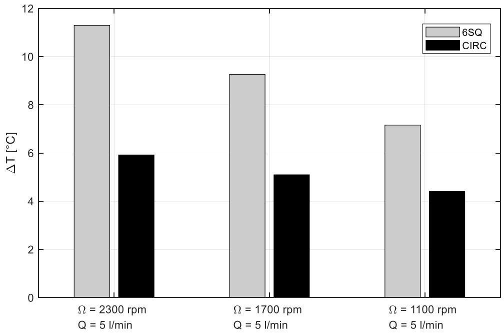

Figure 5: Average pad temperature reduction with respect to non-cooled pads, given the same operating conditions. 6SQ: six-squares cross section, CIRC: circular cross section for the cooling circuit.

3. Conclusions

This paper shows the results obtained with a special TPJB, equipped with cooled pads. The pads were made by AM and the performances were first simulated by means of a sophisticated numerical model and then experimentally verified in a test-rig.

4. Acknowledgements

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5. References

[1] Chatterton, S., Pennacchi, P., Vania, A. Investigation of cooled pads for tilting-pad bearings. Mechanisms and Machine Science, 60, 505-519 (2019).

[2] Dang, P.V., Chatterton, S., Pennacchi, P., Vania, A. Effect of the load direction on non-nominal five-pad tilting-pad journal bearings. Tribology International, 98, 197-211 (2016).

[3] Chatterton, S., Pennacchi, P., Dang, P.V., Vania, A. A test rig for evaluating tilting-pad journal bearing characteristics. Mechanisms and Machine Science, 21, 921-930 (2015).

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