Conference Program and Proceedings

Published by: Tekniker

Editors: Itziar Alonso, Ana Aranzabe, Javier Barriga, Amaya Igartua

Productor: Tekniker

ISBN: 978-84-932064-7-5

Using Multiphase Conjugate Heat Transfer Analyses to Predict the Contact Temperature of Rotary Shaft Seals

J. Hannss ([1]) J. Grün ([1]), C. Olbrich ([1]), S. Feldmeth ([1]), F. Bauer ([1]),
email: jacqueline.hannss@ima.uni-stuttgart.de

(1) Instite of Machine Components, University of Stuttgart

Rotary shaft seals are used to seal shaft passages and prevent the exchange of fluids. The performance and service life of rotary shaft seals is strongly dependent on the temperature in the contact area between the sealing edge and the rotating shaft. Multiphase conjugate heat-transfer analyses covering different assembly scenarios, for example additional bearings or different shaft geometries, were performed in the software Ansys CFX 2021 R2. A model for predicting the maximum temperature in the sealing contact and for determining the heat dissipation from the sealing contact to the surrounding geometry was developed. This model provides the ability to predict the influence of the design of the surrounding sealing system on the contact temperature. Thus, the surrounding geometry of rotary shaft seals can be optimally designed to reduce the contact temperature between the sealing ring and the shaft as much as possible in order to achieve a longer service life.

1. Introduction

Seals are required in many engineering applications to keep lubricants and operating fluids in and contaminants out of a system. Rotary shaft seals are primarily used to seal unpressurized shaft passages that are subject to splashing or flooding, such as in automotive and mechanical engineering [1, 2]. The rotary shaft seal is a complex tribological system. In addition to the sealing ring, it includes its mating surface, i.e. the shaft surface, and the fluid to be sealed [1]. During operation, the contact area between the sealing edge and the shaft surface is subjected to friction. The more frictional heat generated in the contact area and the less heat can be dissipated from the contact area, the higher the temperature. Overheating of the contact surface is a common cause of the failure of rotary shaft seals and thus of the entire system. To better assess the risk of a temperature-induced failure and to achieve a long service life, it is necessary to know the expected contact temperature during operation as accurately as possible.

The goal of this work is to create a simulation model of the entire sealing system. This will allow the expected contact temperature to be determined without building a prototype. A total of 17 different assembly situations of a rotary shaft seal were considered. One reference configuration and 16 geometric variations. For each configuration a 3-dimensional simulation was performed in the computational fluid dynamics (CFD) software Ansys CFX 2021 R2. The Conjugate Heat Transfer (CHT) method is used because of the heat transfer between the solid and fluid domains in the model. This method calculates the temperature distributions in both the fluids and the solids. The flow in the sealing gap was neglected. A multiphase flow was considered due to the interaction of oil and air in the oil chamber. To validate the results obtained from the simulations, experiments were performed on a test rig at the institute.

2. Simulation model

The rotationally symmetrical geometry model used in the simulations is based on the test rig and consists of a total of nine domains for the reference configuration, Fig.1. In addition to the reference configuration, 16 geometric variations were simulated:

- Variants of the shaft design: air and oil filled hollow shaft with different inner shaft diameters
- Variants with long/short shaft shoulder on the air/oil side
- Variants with different bearings
- Variants with slinger disc or baffle plate in different diameters

To keep the simulation setup as simple as possible the following simplifications were made. For all variants, the same frictional heat generated in the contact area between sealing ring and shaft is given into the simulation model as a boundary condition. This frictional heat is based on the frictional torque measured on the test rig. In the simulation model of the variant with air-filled hollow shaft, the air inside the shaft is not considered and the boundaries to this volume are assumed to be adiabatic. The same geometry model was used for all simulations of variants with bearings. Different pumping effects can be

observed for different bearings. This effect was considered via the initial condition of the oil fill level between the bearing and the sealing ring. In addition, the frictional torque between the bearing and the shaft changes for each bearing.

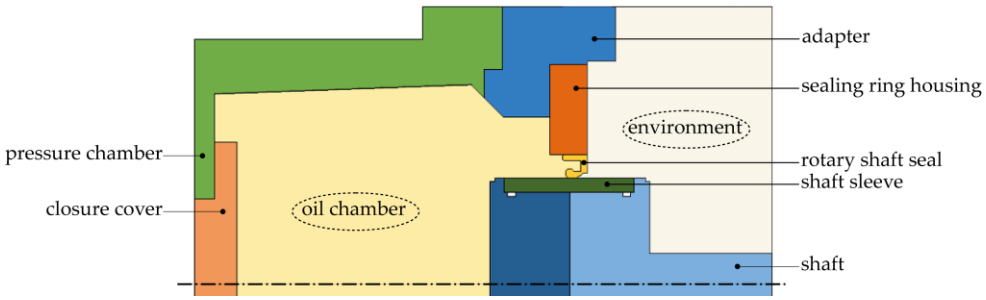

Figure 1: Sectional view of the 3-dimensional simulation model of the reference configuration [3]

3. Results

The higher the shaft speed, the more heat is generated and the higher the temperature in the contact area. In addition, the distribution of the oil in the oil chamber changes for different shaft speeds. The higher the speed, the more oil is dragged against the outer wall of the oil chamber. However, due to gravity, there is still more oil in the lower half of the oil chamber. Since oil conducts heat better than air, the heat generated in the sealing contact is dissipated better in the lower area of the oil chamber. Thus, the temperatures in the lower part are generally slightly lower than the temperatures in the upper part of the oil chanber. To evaluate the contact temperature in axial direction, a horizontal line was defined below the sealing contact. The temperature plot over this line looks like a slightly asymmetric Gaussian distribution curve with the maximum at the position of the sealing contact. The temperature cools down faster toward the oil side than toward the air side.

The temperatures of the hollow shaft variants were almost the same for all variants. The temperatures of the shaft shoulder variants differ only slightly, a higher temperature occurs for the variants with the shaft shoulder on the air side. The temperatures of the variants with cylindrical bearings and ball bearings were almost the same. In the simulation with tapered roller bearings in O-arrangement, there is oil between the seal and the bearing due to the pumping effect of the bearing. In the simulation with tapered roller bearings in X-arrangement, there is pure air on both sides of the sealing ring and the heat generated in the sealing contact can therefore be dissipated less effective. Thus, the tapered roller bearings in X-arrangement resulted in higher temperatures than the tapered roller bearings in O-arrangement. The temperatures of the variants with baffle plate are slightly higher than the temperatures of the variants with slinger disc.

It has been shown that the differences in the geometry of the bearings are negligible and therefore one geometry model is sufficient for modeling all variants with bearings. Despite not considering the air inside the air-filled hollow shaft and assuming that the boundaries of the air-filled hollow shaft are adiabatic to the volume inside, the simulation yielded good results.

4. Conclusion

A simulation model has been created in the Ansys CFX 2021 R2 software that can be used to calculate different variants of the sealing system of rotary shaft seals, such as different geometries or materials. It is now possible to determine the maximum temperatures that occur in the contact area between the shaft and the seaingl ring, as well as the heat dissipation from the sealing contact to the environment. In this way, the surrounding geometry of a sealing ring can be optimally designed without the need for a prototype in order to achieve a longer product life.

References

[1] F. Bauer, “Federvorgespannte-Elastomer-Radial-Wellendichtungen”, Springer Fachmedien Wiesbaden (2021), ISBN 978-3-658-32921-1

[2] ISO 6194-1 “Rotary Shaft Lip-Type Seals Incorporating Elastomeric Sealing Elements - Part 1: Nominal Dimensions and Tolerances” (2007)

[3] J. Hannss, J. Grün et al., “Multiphase Conjugate Heat Transfer Analyses on the Assembly Situation of Rotary Shaft Seals”, Appl. Sci. 13(19):11026 (2023), https://doi.org/10.3390/app131911026