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On the dependence of static flat seal efficiency to surface defects

Y. Ledoux [a], D. Lasseux [b,*], H. Favreliere [b], S. Samper [b], J. Grandjean [a]

[a] Université de Bordeaux, I2M, UMR CNRS 5295, Esplanade des Arts et Métiers, 33405 Talence Cedex, France
[b] Laboratoire SYMME, Polytech'Savoie, BP 80439, 74944 Annecy le Vieux Cedex, France

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ABSTRACT

We report on the role of the modal content of surface defects on static flat seal efficiency. The configuration under consideration is an annular contact between two surfaces, one holding all the defects, the other being assumed flat and infinitely rigid. The analysis is carried out on synthetic "turned-like" surfaces generated by combinations of the first 50 vibrational eigen modes determined from modal discrete decomposition. The transmissivity of the contact, that fully characterizes the seal efficiency, is computed on the basis of a Reynolds model for incompressible flow. The dependence of the transmissivity upon the modal content of the surface defects is analyzed on a contact pressure range of common use employing a simplified deformation algorithm. Impact of the defects modal content is investigated statistically through a pair of experimental designs. It is shown that, i) the uncertainty on transmissivity, while considering a series of parts, can be drastically reduced if defect modes are well selected; ii) the transmissivity itself can be very significantly decreased when the defects modal content is conveniently controlled. While clearly indicating that the common surface roughness specification is generally not a relevant one to ensure a required seal performance, this work opens wide perspectives on the seal improvement by surface defects optimization only.

1. Introduction

Static sealing performed by direct metal to metal contact is a common design in many industrial applications in particular when severe thermodynamic conditions prohibit the use of rubber seal and was shown to be an efficient design of bolted joints [1]. Such a situation is encountered in assemblies in nuclear power plants, cryotechnic engines, devices for petroleum recovery and turbomachines like helicopter engines to cite some but a few. With the increasing need of reducing fugitive emissions and saving energy, the improvement of such assemblies is a crucial issue. Beyond the management of the assembly [2] tightness efficiency depends on many intrinsic parameters such as the material of the surfaces [3], the contact pressure [4,5] the nature and thermodynamic conditions of the fluid to be sealed, and above all, on the surface defects at many different scales of observation ranging from the sub-micronic scales to body dimension [6–8]. Although these last features are key ones, a thorough characterization of their impact on the contact efficiency and on the associate flow through connected open paths is still at its very beginning. In particular, surface specifications provided on technical drawings are most of the time resulting from pragmatism rather than structured approaches elaborated to fulfill specific seal performance. These specifications are generally restricted to two types of defects, namely form error (*e.g.* flatness, circularity) and arithmetic roughness. However, such specifications are insufficient to correctly assess the geometrical impact of surfaces on the seal performance of an assembly. This was recently proven on the basis of experimental observations showing that defects at intermediate scales (waviness) are of major concern for leakage [9]. In this reference, a simplified reconstruction of a real contact was proposed on the basis of defect measurements at two different scales -roughness and waviness. Numerical predictions of the leak rate dependence on the applied contact pressure were successfully compared to experimental data, confirming the role of waviness.

Clearly, the full control of surface defects at all scales during manufacturing processes is still out of reach. A crucial step toward this end is first a thorough understanding of the complex coupled dynamic behavior of the machine-tool-part system that remains a tricky task and that has been barely addressed in details so far [10–13]. Nevertheless, a detailed investigation on the role of surface defects at all scales on the contact and seal efficiency is equally important in order to help defining the required specifications to be considered during the design. The aim of the present work is to progress toward this goal by presenting an analysis on synthetic surfaces as a preliminary approach before a more

* Corresponding author. Tel.: +33 556 845 403; fax: +33 556 845 436.
E-mail address: didier.lasseux@ensam.eu (D. Lasseux).

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