EXPERIMENTAL ANALYSIS OF THE OPTIMUM LUBRICATION CONDITIONS FOR MECHANICAL SEALS

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ABSTRACT

This paper deals with an experimental study of the interface lubrication conditions and of the dynamic behavior for low pressure mechanical seals. Two test cells, equipped with the same carbon rotor, have been developed. The first cell is extensively instrumented with electrical transducers and the second cell is devoted to optical methods. Two main lubrication regimes are demonstrated:

- Large geometrical defects induce pure hydrodynamic regime with no wear and possible appearance of leakage.
- Low geometrical defects leads to a combination of contact on the low pressure border and hydrodynamic film in the rest of the interface.

Soft contact associated with appropriate thermoelastic distortions leads to zero leakage and acceptable wear.

INTRODUCTION

Numerous experimental studies have been devoted to the phenomena involved in the functioning of mechanical seals. Although they are now well indentified their complex interdependance is not always well understood.

In the early 60's, by measuring pressure and film thickness in the interface, authors (1, 2) have pointed out that the opening force can be hydrodynamically generated in the lubricant film. It has been shown afterwards, in many experimental works (3 to 7) that waviness, misalignment and vibrations of the faces are responsible of the wedge and squeeze effects generating hydrodynamic pressure in the film. The gaz cavities, which appear in such cases, in the low pressure zones of the lubricant film were experimentally studied and their role in the pumping effect was analysed (4, 8 to 10).

The axial load of the lubricant film, and thus, the equilibrium of the floating element, is greatly dependent on the radial profile of the faces. This profile is governed by the mechanical and thermal distortions of the seal faces (11 to 13). In the case of several elements assemblies, performance hysteresis has been found to be due to friction and slip...
between elements (14, 15).

If the typical "dynamic tracking" seems to be the suitable dynamic behaviour (6), cases where the floating element wobles at twice the shaft frequency have also been observed (3).

It is often accepted that face seals operate in hydrodynamic lubrication mode and numerical programs have been established in order to determine the critical values of the main parameters avoiding hard face contact (16 to 19). Nevertheless, it has been found that, under certain conditions, mechanical seals also operate with mixed friction (20, 21). Very few modelisation have been developped in this last case (22 to 24).

Most of the studies reviewed here are concerned with high or medium pressure seals. This paper deals with low pressure seals which have been less explored. In order to satisfy the two following antagonistic requirements:

- low leakage which implies very thin lubricant film or face contact
- low friction and wear which require the presence of a lubricant film thick enough

The questions are:

- do the low pressure seals operate under hydrodynamic or mixed lubrication regime or under a combination of both?
- what are the mechanisms of the transition between this modes?

The study reported in this paper, which is the extension of previous works (25 to 27) is intended to answer these questions in order to give realistic hypothesis for developping numerical modelisations.

TEST RIG WITH INSTRUMENTED SEAL

Description of the test rig

Figure 1 shows a photograph of the test rig. Major features are:

- a vertical precision shaft driven by a 3.7 kw motor through a variable speed drive capable of speeds from 250 to 5000 r.p.m.
- a hydraulic power pack which supplies fluid at controlled flowrate and temperature, and controlled pressure in the range 0 to 0.1 MPa
- a test housing equiped with electrical transducers
- a computerized data acquisition system.

A drawing of the test seal and housing is presented in figure 2. The rotor consists of a ring of metal-impregnated carbon assembled in a copper alloy carrier. The stator is made of steel. The mean diameter of the seal faces is 70 mm and the face width 4 mm.

The oil is fed to the inside of the seal, the outside of the seals is in the atmospheric air. The secondary seal between the floating stator and its carrier is an elastometric O-ring whose active diameter is 74 mm.