STUDY ON THERMAL DEFORMATIONS OF THE PRIMARY SEALING OF FRONT SEALING

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Abstract: *The thermal phenomena appear at the level of the film within the primary sealing interstitium. An important temperature gradient is performed in the stator and in the rotor, which produces thermoelastic deformations. These deformations are of the order of film width and affect essentially the interstitium geometry. According to the temperature increase direction the repartition in the friction ring is different. The farthest areas from the temperature drops or the nearest to the heat sources will have he highest temperature. These dilate more that the rest of the areas and modify the interstitium form. From the calculation relations it comes out that deformations depend also on certain operating conditions, which can be modified through time (pressure, temperature), the sealing efficiency being thus different in time.*

Keywords:Interstitium, temperature, deformations, sealing.

1.INTRODUCTION

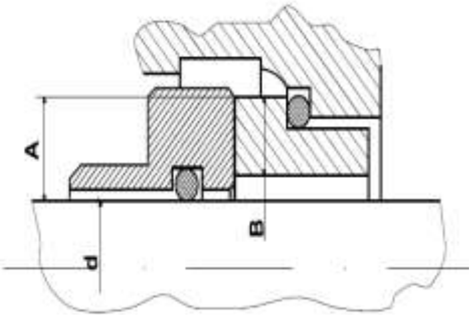
The space between the contact front surfaces represents the most important part of front sealing. An adequate lubrication is required in order to minimize the wear and to provide an accurate sealing (a very small loss debit). This lubrication is provided by the sealed fluid or by the cooling or locking fluid.

Front sealing optimal functioning is ensured if the width of the film separating the two surfaces is of the order of 1-1,2μm. The control of the lubricating film width must be extremely precise, in order to avoid contact areas without lubricant which may lead to a premature wear for the primary sealing and to an inadequate functioning of the device. Nowadays, the industrial target is to be able to create reliable front sealing with a loss debit almost null and with a minimum wear.

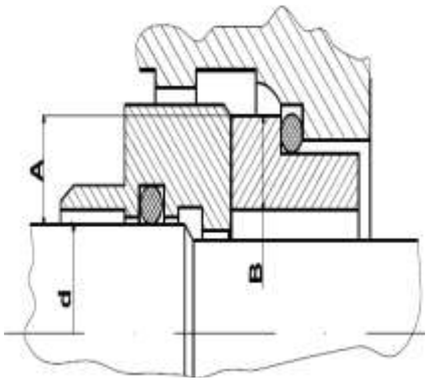
Also, the thermal phenomena appear at the level of the film within the primary sealing interstitium. An important temperature gradient is performed in the stator and in the rotor, which produces thermoelastic deformations. These deformations are of the order of film width and affect essentially the interstitium geometry. Consequently, thermoeasltic deformations play a preponderant role in front sealing stability.

The hydraulic balance term used to face seal is used to specify the relationship between the ambient pressure and the contact pressure sealed to the sealing surface. From the viewpoint of the term hydraulic balance, front seals are classified in "balanced" and "unbalanced". For a balanced face seal contact pressure can be controlled so that it is possible to maintain a lower value hydraulic allowing the formation of a film of greater thickness. For this reason,a balanced face seal has the possibility of handling fluids with higher pressures and difficult operations,than a face seal unbalanced. Normally a balanced face seal is designed to work with the pressure lower sealing surface which practically minimal losses between the surfaces.

Types of outer face seal are illustrated in Figure 1.a, Figure 1.b and Figure 1.c,presents different arrangements of the sealing surface. In this figure, d is the effective diameter sealing, A is the surface on which the sealed fluid pressure acts, and B is the area of contact sealing surface. Force of the spring is ignored in all cases.



a)



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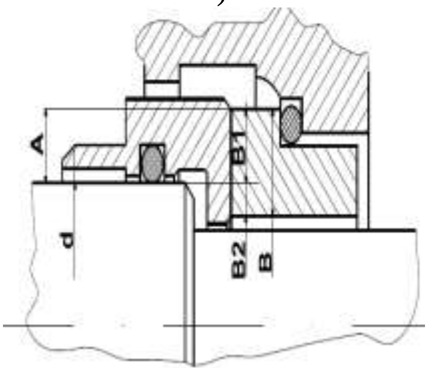

c)

Fig. 1.Different arrangements of the sealing surface.

In Figure 1.a, the entire contact surface B is arranged outside of the effective diameter of sealing "d" and the hydraulic surface area A is equal surface of contact B (A = B). This construction is a condition of 100% imbalance (out of balance), which also indicates that the mean contact pressure will be exactly 100% sealed hydraulic pressure

$$\left(\frac{A}{B} = K = 1\right) \tag{1}$$

In figure 1.b the entire surface of the contact B is disposed outside the effective diameter of sealing "d" and the area of action of the sealing pressure A is greater than a contact area B (A> B). In this case, the face seal is in imbalance, according to the report areas A and B

$$\left(\frac{A}{B} = K\rangle 1\right) \tag{2}$$

Supported by the contact surface pressure is bigger with a report equivalent to the hydraulic pressure which is sealed. This is the condition in most unbalanced front seal.

Figure 1.c shows the relation between the most balanced face seal. Here, a part of the contact surface B is indicated by B1, and is disposed outside the effective sealing diameter "d". The area B1 is therefore equal to the area A. Because the remaining area B2 hydraulic sealing surface is located inside the effective diameter of sealing "d", the total area of the seal B is equal to the sum of B1 and B2. Charging the sealing surface will be less than the pressure sealed, so:

$$\frac{B_1}{B_1 + B_2} = \frac{A}{B} = K\langle 1 \tag{3}$$

This value, expressed in percent indicates the degree of imbalance in front seals.

2.RINGS MOTION

Each ring of primary sealing is connected to a support (shaft or case-frame) by joints that may be fixed or deformable. In this case, the ring rotating around the main shaft holds a maximum of 5 degrees of freedom, figure2

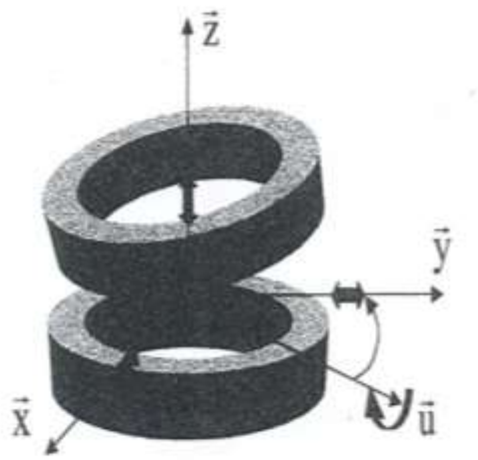

Fig. 2.Degrees of freedom

three elementary translations: an axial displacement and two radial displacements (or eccentricities) ;

two elementary rotations: angular misalignment around the orthogonal direction (χ) on the main axis (z) and a rotation around the z axis.

In numerous cases, one of the rings is rigidly connected to its support and moreover, the eccentricities of the rotating ring have a negligible effect in relation to the other degrees of freedom. This leads to a model of primary sealing with three degrees of freedom, figure 3.

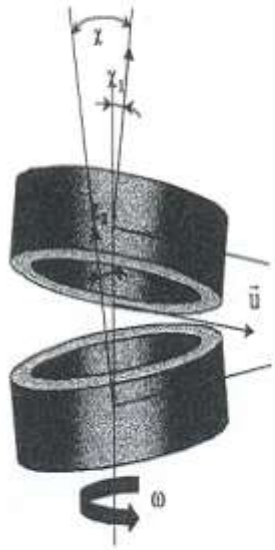

Fig.3. Primary sealing with 3 degrees of freedom

3.SEALING PARAMETERS

The operating parameters influencing an adequate sealing are defined first of all by the dimensions and assembly of the primary sealing. An important influence on non-sealing, lifetime, friction losses and operation safety are briefly presented hereunder:

The hydraulic pressure ratio K and the proportion between the pressure exercised by the elastic element against the sealed medium pressure p_{ar}/p_1;

The sliding speed between the rotor and the stator (friction);

Surface roughness of and the parallelism of the friction surfaces ;

The sealing medium temperature and the friction surfaces temperature;

The form of the sealing interface depending on the mechanical and thermal deformations susceptible of occurring during operation ;

The materials couple;

The sealing fluid with its lubricating and cooling properties, its contamination degree, etc.;

The friction type, the oscillations, the wear, the periodic idle time, the fluid circulation clockwise or counterclockwise, the eccentric operation, the assembly, the cooling etc.

In most of the applications primary sealing with level sliding surfaces are used. These surfaces can be modified due to the influence of heat, tensions and wear. Level surfaces offer the advantage of being able to be performed and controlled with simple means.

Under the influence of axial and radial forces applied on the primary sealing rings, and through the temperature differences, the rings are deformed and the interface can become concave, convex or tilted with a contact on the exterior D or interior d diameter, or tilted without any contact. If the sealing functioning conditions remain constant, the friction surfaces remain parallel under the wear effect and subject to the adequate materials couple and to the sufficient time of applying a permanent contact pressure.

In total three main factors influence the primary sealing deformations: axial, radial forces and temperature gradients.

4.THERMAL DEFORMATIONS INFLUENCE

The operating temperature differences influence the interstitium geometry. Elastic deformations depend on the elasticity module and on the dimensions and thermal deformations depend on the thermal properties of the material with a heat conductibility ratio λ, a thermal dilatation ratio α and on the thermal transmission ratio. The temperature gradients that can be in a radial or axial direction influence the interface geometry.

5.EFFECTS OF THE AXIAL TEMPERATURE GRADIENT

Deformations, due to the axial temperature gradient, generate a conical increase in a radial direction for the temperature diminution towards D and a conical narrowing of the ring for a temperature diminution in d (see fig. 4 a, b).

According to [7] the relation for the deformation under temperature influence for a linear axial gradient is:

$$S_{Tr} = \frac{\alpha\, c_a \left(r_a^2 - r_i^2\right) c_F}{2} \tag{4}$$

where:

$$c_a = \frac{T - T_A}{l} \tag{5}$$

For the case a, the deformation is considered negative and positive for the case b , figure 4.

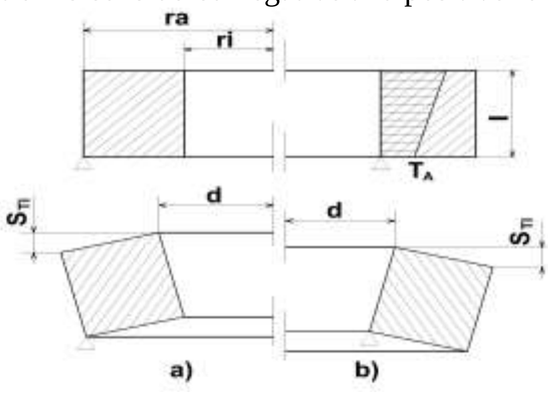

Fig.4.Deformations due to the axial temperature gradient

6.EFFECTS OF THE RADIAL TEMPERATURE GRADIENT

According to the temperature increase direction at the exterior D or interior d diameter, the repartition in the friction ring is different. The farthest areas from the temperature drops or the nearest to the heat sources will have he highest temperature. These dilate more that the rest of the areas and modify the interstitium form. Admitting a source of heat and constant operating conditions, supposing a linear temperature gradient in the radial direction,

$$c_r = \frac{T - T_A}{l} \tag{6}$$

will determine the deformation of the ring in the axial direction with the approximate relation :

$$S_{T\,a} = \alpha\, l\, b\, c_r \tag{7}$$

When the temperature drop is in D, S_{Ta} will be negative and reverse.

7.CONCLUSIONS CONCERNING THE INFLUENCE OF INTERSTITIUM DEFORMATION

The geometry of the primary sealing surfaces is affected in operation by the amount of individual mechanical and thermal deformations of the friction rings. The total deformation is:

$$S = \Sigma(S_A + S_B) \tag{8}$$

For an operation with parallel surfaces it is necessary that the amount of individual deformations according to the equations be null. Nevertheless, individual deformations depend on geometry, material and installation, and this ideal solution cannot be performed in practice. All the observations of individual deformations influence have been directed towards the interface configuration, supposing contacts of the two rings in D or d with the return to parallel surfaces after wear. The most important consequence of deformations is the leaking of the sealed fluid as a result of interface modification. If, for example, by the production of a configuration by interface deformation allowing the introduction of the fluid under pressure in the interface, a hydrostatic discharge occurs and the lost debit will increase. By rings contact return to D or d, the wear will restore a new interface with parallel or slightly conical surfaces.

From the calculation relations it comes out that deformations depend also on certain operating conditions, which can be modified through time (pressure, temperature), the sealing efficiency being thus different in time. It can be appreciated that an inadequate contact in D or d, with moderate deformations, can be improved through time by means of running wear.

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