ON THE OPERATIONAL MODEL OF FRONT SEALING

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***Abstract**: The mechanism of generating pressure in the primary seal clearance described in the classical approach allows a stable operational regime but does not justify the real pressures in the film. Experimental works show that these real pressures can be much higher than he theoretical pressures which are calculated at plane and parallel pressures.*

Keywords: Sealing, front, film, pressure

1. INTRODUCTION

Front sealing is used with mechanical systems the good-functioning of which decisively depends on the sealing even if the cost price is minimal by reference to the whole system. The approximation of thin films introduced by O. Reynolds in 1886 represents the fundamental basis of the theoretical studies in this field.

There are two criteria for a proper operation of front sealing: stability of the sealing film and balance of mobile primary sealing. The balance is achieved when the resultant of the forces given by the hydrodynamic or hydrostatic pressure is equal to the W loading of the exterior forces and which is generally given by the equation:

$$W = \int_{(S)} p ds \tag{1}$$

where p is the pressure distributed according to a film assignment law.

Proper knowledge of the pressure field is thus necessary is every experimental, theoretical or numeric study. Up to the present moment the experimental study was very difficult as the measurements in the film separating the two surfaces, when it exists, are very provisional. This is due to the complexity of the phenomena which occur and which are of various natures (HD,THD, elastic, etc.)

Of course we agree that this cannot be always accepted as the proper operation of a front sealing is connected to the existence of a complete fluid film in the $S_1 – S_2$ interface (fig.1). We also say that the sealing operates in a hydrodynamic regime. A mixed regime, different from the hydrodynamic one, characterised by the existence of solid contacts between surfaces can exist provided that:

- The exterior forces which tend to eliminate the film are important;
- The fluid evaporates;
- The geometry of surfaces is not favourable to form and maintain the fluid film.

2. THE CONCEPT OF BALANCE

The sealing is balanced when the W separation force developed in the film is equal to the F closing force, without being a contact between the S_1 and S_2 surfaces. The W force generally depends on the film geometry and by the sealing kinematics. One must also take into consideration a connection contact. Choosing force F, thus force W which should be balanced is the result of a compromise between the admissible loss debit and the dissipated power.

Force F is the result of the contribution of the loops, F_r and the force given by the hydrostatic pressure acting upon the runner. In this simple case (fig.1) the hydrostatic pressure p_e acts on the surface $S^{'}$ equal to the surface of friction S. Then

$$F = F_f + p_e S^{'} \quad (2)$$

And the average pressure p_m borne by the film is:

(3)

$$p_m = p_m = \frac{F}{S^{,}} = \frac{F_r}{S^{,}} + p_e$$

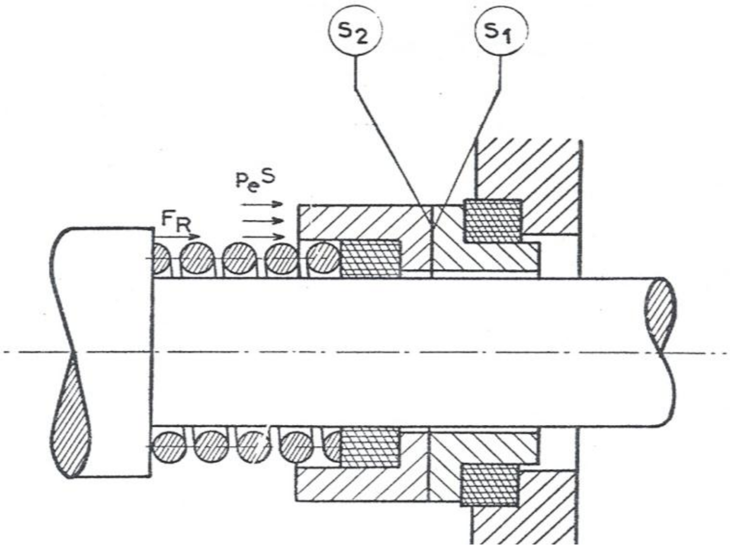

Figure 1.

From the relation (3) there can be noticed that if the outer pressure increases hen the average pressure increases as well. This shows that the thickness of the film becomes smaller and thus he power dissipated in the clearance also grows. This is translated by the limitation of the possibilities of front sealing.

If the action is upon a surface lower than the surface of friction S(fig. 2.), then:

$$F = F_f + p_e S \tag{4}$$

And the average pressure becomes:

$$p_m = \frac{F_r}{S} + p_e \frac{s}{S} \tag{5}$$

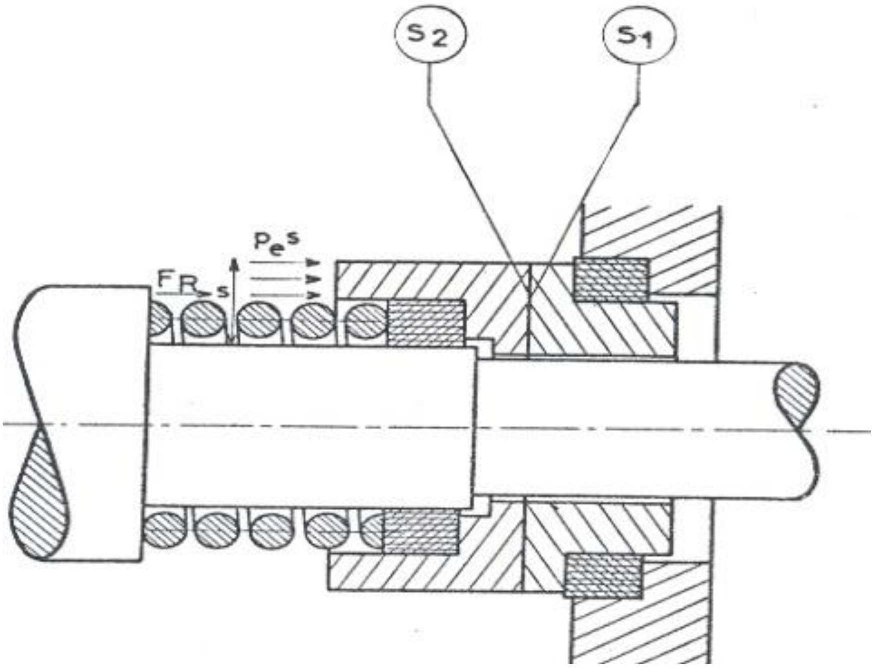

Figure 2.

By these means it is likely to find for the outer pressures given the average pressure p_m where the operation of primary sealing is correct. Particularly, p_m can always be fixed less to p_e and then F_r is required by construction, S so that p_e is higher than the relation $F_r/(S\text{-}s)$. By using this constructive procedure it results that very high pressures can be sealed. In this case it is said that the sealing is *balanced*. It is defined the k parameter given by the following expression:

$$k = \frac{s}{S}.100 \qquad (6)$$

where k is called *balancing percentage* and the value of which is comprised between 60% and 70%.

3. THE CONCEPT OF STABILITY

Force F was considered an outer force tending to close the clearance and can be fixed by the sealing construction depending on the average pressure p_m allowed in the fluid film. F and

p_m result from an empirical choice. At the same time, a research of explaining the operation mode of front sealing often requires the constructors to express hypotheses on the form of primary sealing interface. The closeness by similitude of a primary sealing with a classical skid which we shall get back to naturally leads to the search of an interface pattern where surfaces S_1 and S_2 are deemed to be perfectly plane and parallel.

In this case (fig.3.) the Reynolds equation is reduced to:

$$\frac{d}{dr}\left(r\frac{dp}{dr}\right)=0 \tag{7}$$

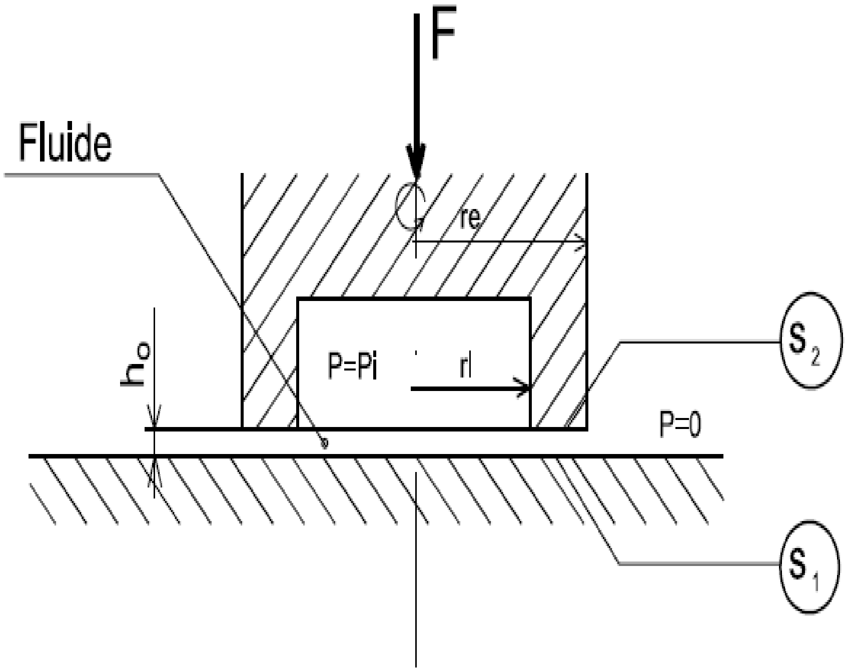

Figure 3. Interface with plane and parallel surfaces

With the conditions to the limit:

$$p = p_i, r = R_i$$
$$p = p_e, r = R_e$$

By integration on surface S, it is obtained:

$$p = p_i \frac{\ln r - \ln R_i}{\ln R_c - \ln R_i} \tag{8}$$

The force developed in the film becomes:

$$W = \frac{\pi p_i}{2}\left[\frac{R_e^2 - R_i^2}{\ln R_e - \ln R_i} - 2R_i^2\right] \tag{9}$$

We find that the force developed by the film depends only on the p_i pressure, on the sealing and on the primary sealing geometry. It is independent of the thickness of the fluid film, thus of the radial flow. To achieve the balance upon the sealing, the F closure force must be equal to the W separation (opening) force. Actually, it is almost impossible to maintain a balance compatible with satisfactory operational conditions. The W loading capacity's independence of the thickness of the film shows that no force can oppose to the sealing opening or closure under the effect of transitory disturbances.

In conclusion, a primary sealing where the surfaces are perfectly plane and parallel is in balance regardless of the changes brought to the film thickness an in unstable balance for variations of the F force. It is thus obvious that a front sealing showing such a configuration cannot work properly.

The apparent analysis between the front sealing and the classical skids explains this first approach of the matter. At the same time, two fundamental differences come to limit this analogy:

a. In an axial bearing, the radial flow is imposed by the feeding system of the bearing at the same film thickness. On the contrary, in the case of primary sealing, it depends on the geometrical and kinematic conditions. It cannot be directly imposed by the construction. For a maximum sealing, it is desirable that the loss flow is kept as low as possible.

b. In a front sealing, the film is a few microns thick.

In an axial bearing it is a few millimetres thick. This difference is size is very important in continuing the study.

From this presentation the limits of the analogy were understood better. This led to the search of some stable operational conditions which means that the changes brought to the thickness of the film should also be taken into consideration. This is the reason for which this pattern should be revised. As such, flaws can be introduced in radial direction, flaws which surely exist in reality. In this respect, primary sealing can work with a convergent or divergent cone in radial direction (fig.4. and 5.).

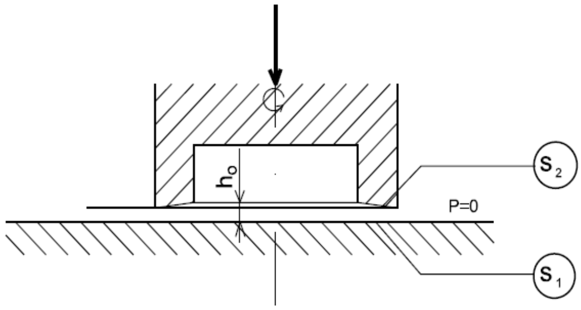

Figure 4.Convergent cone in radial direction

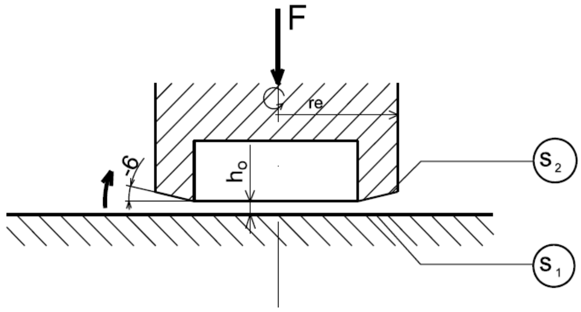

Figure 5. Divergent cone in radial direction

Watson[1] studied this hypothesis of convergent or divergent profile in more detail. By calculation, he noticed here is a relation between the force developed in the film, the h_0 thickness and the cone pitch in radial direction. This resulted in three distinct cases.

a) If the radial flow is made in a convergent cone (fig.4.) , then $\frac{\partial W}{\partial h_0}$ <0. This means that after a transitory disturbance of the W loading or the h_0 thickness the sealing always tends to reach a balance positions. This sealing works in a stable way.

b) If the pitch is null, which means parallel surfaces, $\frac{\partial W}{\partial h_0} = 0$. This outcome which we have already shown characterises an unstable or dismissive balance.

c) For a divergent profile (fig.5.) $\frac{\partial W}{\partial h_0} > 0$ the balance is unstable. All the disturbances of the loading and film thickness end to completely open or close the primary sealing.

In the first case the flow becomes very important and in the second case the dissipated power becomes considerable and a fast destruction of the sealing is achieved.

These three results are summed up in figure 6.

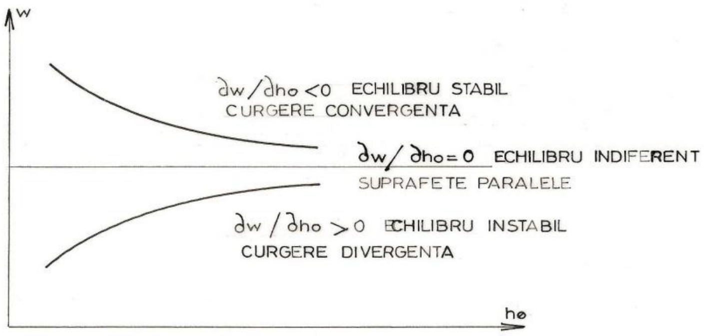

Figure 6.

It was proved that a convergent-profile sealing can work satisfactorily. At the same time, it can also produce an abrasive wear which tends to change the profile pitch, the geometry of the film evolving to the patter with parallel surfaces. The sealing no longer works in a stable way and the result is the damage brought to the active surfaces or to the complete opening of the sealing (very high loss flow).

4. CONCLUSIONS

This classical approach developed around the two operational criteria (balancing and stability) forms a general framework in order to understand the normal operation of a front sealing.

Nevertheless, in various cases, due to reasons hard to explain, front sealing sometimes deteriorates fast or do not show a sufficient sealing. It seems that there are other factors determining another operational mechanism and, as such, this classical approach does not take certain parameters into account as their action is preponderant in the real functioning of primary sealing.

The mechanism of generating pressure in the primary sealing clearance described in the classical approach allows a stable operational regime but it does not justify the real pressures in the film. Experimental works showed that these real pressures can even be much higher than the theoretical pressures which are calculated at plane and parallel surfaces. These pressures are created by other lift mechanisms other than the hydrostatic lift mechanism.

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