STUDY ON THE THERMODYNAMIC ASPECTS OF FRONT SEALING

PhD.Lecturer Mihaela ISTRATE,University of Pitești,Faculty of Mechanics and Technology,Târgu din Vale Street,no.1,Pitești,Romania,mmihaela_1971@yahoo.com
PhD.Lecturer Jan Cristian GRIGORE,University of Pitești,Faculty of Mechanics and Technology,Târgu din Vale Street,no.1,Pitești,Romania,jan_grigore@yahoo.com
PhD.Lecturer Monica BÂLDEA,University of Pitești,Faculty of Mechanics and Technology,Târgu din Vale Street,no.1,Pitești,Romania,bldmonica@yahoo.com
PhD.Lecturer Ancuța BĂLTEANU,University of Pitești,Faculty of Mechanics and Technology,Târgu din Vale Street,no.1,Pitești,Romania,a_balteanu@yahoo.com

***Abstract*:*T*hermodynamic lubrication in the radial sealing junctions emphasize the interest for knowing the thermal effects on the mechanical seals. This study is divided into two parts, dedicated to the elaboration of two numerical models for a seal thermodynamic behavior,first part discusses a three-dimensional numerical model in a permanent regime, in the second part of the work, a thermodynamic behavior model for the joints in a transitory regime.*

Keywords: Thermodynamic ,connection, front sealing, thermal,numerical method.

1.INTRODUCTION

The technological evolution allowed the dynamic machines to reach increasing speeds of revolutions for the shafts as well as very high pressure differences between the separation mediums. These problems solicit also the mechanical sealing. The study of front sealing functioning is complex and supposes mechanical phenomena and also interface initial geometry. Besides, numerous situations revealed the thermal effects in many operating conditions as well as their influence on the fluid viscosity sealing parameters.

The performance of a study regarding also the thermodynamic aspects is indispensable for the comprehension of a front sealing behavior. It is influenced by several factors. Viscosity affects always the lift and the power dissipated in the interface when the conicity modifies the interface geometry and the dynamic stability. The results are three types of behavior: stable, unstable and cyclic.

The effects influencing the transition between an area where the behavior is stable and an area where the behavior becomes unstable have been widely studied. Research has shown that there is a connection between the front sealing dynamic behavior (vibratory instability) and the thermal effects which are the causes of deformations. Finally, the temperature widely influences the front sealing operation causing deformations of the sealing surfaces and of other elements of the sealing device. Film temperature and pressure variations can become serious damage causes determining surfaces direct contact or an important debit of losses.

The studies modeling the front sealing THD (thermohydrodynamic) behavior should find the solution to the following equations:

a)generalized Reynolds equation for film;
b)energy equation for film;
c)heat equation for stator and rotor.

These equations can be solved analytically, subject to certain simplifying hypotheses, or numerically, in a permanent and transitory regime with limiting conditions for various domains.

2.ANALYTICAL AND SEMI-ANALYTICAL PATTERNS.

- Permanent regime modeling.

An important study is elaborated by Pascovici and Cicone.The hypotheses retained for the analytical solution of the temperature field in the interface are the following: laminar and permanent regime, asymmetric model (conicity at surfaces) and negligible radial flow (no debit).

In order to solve the energy equation for film, consider that viscosity and volume mass are always constant within the film. Thus:

$$\mu r = \mu_f e^{-\beta[T_n(r)-T_e]} \text{cu } T_m = \frac{1}{h}\int_0^h T dz \quad (1)$$

where: μ_f $si\, T_f$ are the dynamic viscosity and the reference temperature respectively, T_m – the average temperature on a given range, β- the thermoviscosity coefficient, r- the radial coordinate and z- the axial coordinate.

The energy equation becomes:

$$\mu\left(\frac{\partial V_\theta}{\partial z}\right)^2 + K_f \frac{\partial^2 T}{\partial z^2} = 0 \quad (2)$$

Using a double front sealing demonstrated a symmetric temperature distribution within the rotor.The stator is insulated and that the temperature dissipated from the interface is evacuated by the rotor. For the easiness of the analytical solution to the problem, they impose a rectilinear form at a φ angle to the flow line,figure 1.

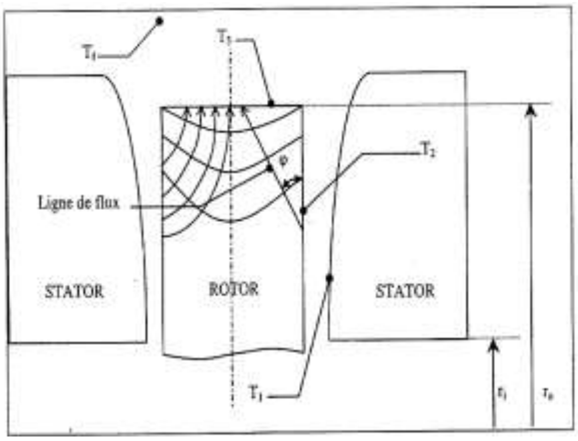

Fig.1

With the hypothesis that all the surfaces exposed to the exterior are insulated,obtain the following relations for the temperatures:

$$T(r,z) = T_2(r) + \frac{\mu\omega^2 r^2}{K_f}\left(1 - \frac{z}{2h}\right)\frac{z}{h} \tag{3}$$

$$T_1(r) = T_2(r) + \frac{\mu\omega^2 r^2}{2K_f} \tag{4}$$

$$T_m = T_2(r) + \frac{\mu\omega^2 r^2}{3r} \tag{5}$$

where: K_f represents the fluid conduction coefficient.

The unknown remains T_2 which is determined from the thermal balance supposing that the heat evacuated into the rotor by conduction is entirely transmitted by the convection of the surrounding fluid. T_2 can be therefore expressed according to the feeding fluid temperature T_f which is known.

$$T_2 = T_f + \frac{2\mu\omega^2 r^3}{h\sin 2\varphi}\left(\frac{\cos^2\varphi}{H\,r_0} + \frac{\ln(r_0 / r)}{K_s}\right) \tag{6}$$

Propose an analytical model taking also the stator into account in the front sealing thermal balance, shown in figure 1.

- Transitory regime modeling

Few analytical works approached the thermal behavior to the front sealing in the transitory regime.Elaborate[13] an analytical model using a simplified theory of heat transfer.This model takes into consideration a linear heat flow variation at start and allows the accurate determination of heat evolution in the interface and the rotor.

Establish an analytical model in a transitory regime allowing the study of the thermoelastic phenomena during the sealing start period. In order to calculate the rotor deformations, uses the same approximation as Lebeck (1991) but the axial temperature variation is interpolated through an exponential function.

3.NUMERIC MODELS.

- Permanent regime modeling.

Establish a complete THD model [4] which takes into consideration the three-dimensional calculation of the pressures and temperatures field within the film starting from the heat equation within the stator and the rotor. For the rotor, the heat equation is simplified. The equations used and the calculation of rings deformations are solved through the finite elements methods. [4] elaborates a THD behavior model with finite differences,this model solves the generalized Reynolds equation and the energy equation within the film simultaneously. Zhu[4] used a finite element program named CSTEADY for the calculation of the temperature fields in the rings and for deformations.

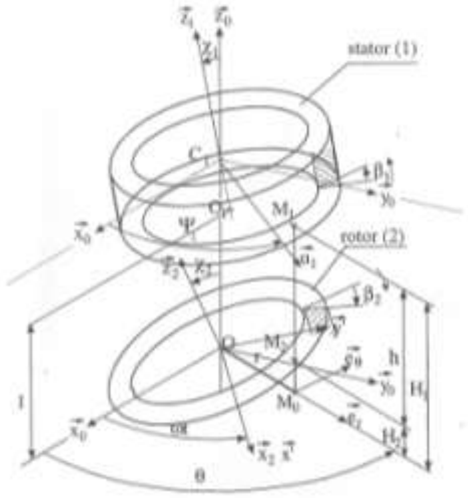

Fig. 2

4.EXPERIMENTAL STUDIES

Measures the temperatures in interface [4] with 5 thermocouples mounted within the stator. The average temperature varies a lot with the speed of revolutions, with the debit and with the used fluid. Digard et all.[4] elaborates an experimental study for low pressure front sealing where he examines the influence of the temperature gradient on the interface geometry.Accomplish[5] an study on the thermal behavior to a front sealing in a transitory regime. The results emphasize the considerable effect of temperature increase within the interface and show that thermal deformations can be more important than mechanical deformations caused by pressure.

Among the three-dimensional thermohydrodynamic models in a permanent regime, the most recent is the model [4]. The geometrical and cinematic model used in this study is described in figure3. It represents a floating stator with three variances (1) and a rotor (2) with a revolution motion having a ω angular speed. The friction surfaces of the two rings can have the misalignments given by the angles χ_1 and χ_2 and the conicities given by the angles β_1 and β_2 . The rotor can present on the friction surface n sinusoidal ripples or any other deformations.

Starting from this three-dimensional model determines the pressure field within the film, the temperature field within the film and within the primary sealing for a configuration of the primary sealing with flat surfaces. The calculation can be extended also to misaligned, conical, rippled surfaces or to any other surfaces with referred limited conditions, solving the problems exposed hereinabove on a rotor with flutes on the sealing surface.

The study performed on the model presented in figure 3 allowed the acquaintance with the influence of the geometrical parameters and of the operating conditions on the thermal behavior in permanent regime for a front sealing.

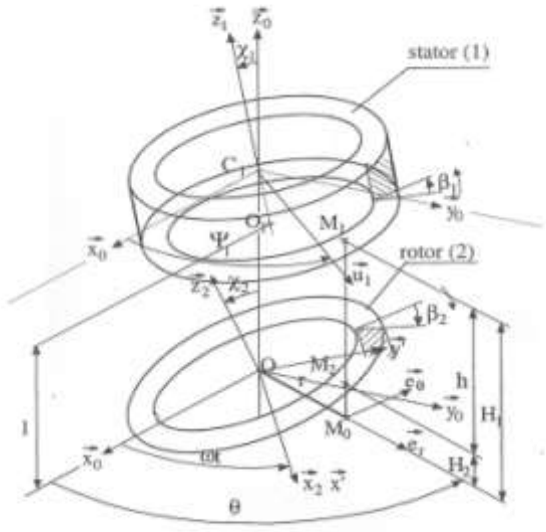

Fig.3

5.CONCLUSIONS

The concept, design, manufacture, assembly and use of the front-type mechanical sealing systems are a direct consequence of the introduction of new technological processes, of new general use and process installations and equipments respectively. Research led first of all to the increase of the safety and reliability degree as well as to the expansion of the stress conditions and to the increase of the dynamic equipments functional parameters, such as:

- the increase of temperatures and pressures lead to the introduction of the balancing sealing system , of new materials and to the introduction of new geometrical and dimensional elements;
- the necessity of sealing the fluids with solid suspensions, having a corrosive-abrasive character as well as the fluids having a predisposition to coke lead to the expansion of the bellows system;
- the sealing of fluids with high vapor pressures lead to the use of specific materials and to adaptors for recovery system sealing, etc.;
- the necessity of implementing the interchangeability system;
- the adaptation of the classical front sealing system with secondary sealing in order to comply with the ecological safety standards, etc.

In order to comprehend and to find adequate solutions in the sealing systems concept, design, manufacture and selection, the following considerations are taken into account:

-the sealing systems are in fact special subassemblies of the dynamic and general use equipments;

- the functional and constructive, manufacture, exploitation and maintenance criteria are conditioned by a complex of parameters depending on: the characteristics of the sealed fluid, the functional operating and exploitation parameters of the basic equipments correlated with the primordial requirement for safety in operation and with the economical criteria.

Aspects approached by the authors of the articles studied during front sealing development:the development of the processing and resolution speed for the computer graphics and specialized software rendered the evolution of the computer assisted design systems for front sealing possible. Finite element programs for sealing rings tensions and deformations or even for fluid flow through the sealing interstitium were elaborated [7, 4, 10]. Front sealing rings modeling was performed in order to comprehend the causes for sealing obsolescence [8];

The control for front sealing operation was intensified and modernized. Front sealing operation was monitored on the computer [7, 9].

Numerous works related to thermodynamic lubrication in the radial sealing junctions emphasize the interest for knowing the thermal effects on the mechanical seals. More specifically, the heat dissipated by the fluid film shearing causes important temperature gradients in the joining rings. These exercise solids thermoelastic deformations, affecting mainly the interface geometry. Having the same size order as the film thickness, deformations play an important role in the stability of radial sealing joints, and they can lead, in the worst case, to mechanic seal dysfunctions. It is very important to know the thermal phenomena governing these joints functioning, both from a fundamental and from an implementation point of view.

REFERENCES

[1] Crudu,I., *Etanşări pentru organe de maşini in mişcare.Tribosisteme industriale*, Tribotehnica 80, Bucureşti,

[2] Istrate, M., *Studiul etanşărilor primare la etanşările frontale,* Editura Larisa, Câmpulung, 2013

[3] Istrate, M., Baldea,M., *On predictive control using vibration detection method on condensation damage to the machine with single stage pump,*Scientific Bulletin.Automotive,year XII,nr.16,2013

[4] Danos, Jean-Christophe ,*Lubrification thermohydrodynamique dans les joints d`etancheite a face radiales*. These pour l`obtenir du Grade de Docteur de l` Universite de Poitiers, 11 dec. 2000

[5] Doust,TG and Parmar,A, *Transient Thermoelastic Effects in a Mechanical Face Seals*. The 10 th International Conference on Fluid Sealing, Innsbruck, 3-5 Aprilie 1984, Paper F4, p. 407-421.

[6] Popa, N.,*The Reynolds equation solving for the constant central thickness hydrodynamic mechanical face seals*, 3rd Vienna International Conference on Nano-Technology, march 18-20, 2009, Vienna, Austria

[7] Etsion, I. and Auer, B.M. *Simulation and Visualization of the Face Seal Motion Stability by Means of Computer Generated Movies.* The 9 th International Conference on Fluid Sealing, 1-3 Aprilie 1984, Paper E1 p.153-162.

[8]Salant, F.R. and Key, W.E. *Development of an Analytical Model for Use in Mechanical Seal Design*. The 10 th International Conference on Fluid Sealing, Innsbruck, 3-5 Aprilie 1984.

[9]Schopplein, W., Zeus, O. Skliding Materials. *The State of Art and Development Trends*. International Sealing Conference 1986, Lenngries

[10]Huitric, J., Bonneau, D., Tournerie, B. *Finite Element Analysis of Grooved- Face Seals for Liquid*. The 13 th International Conference on Fluid Sealing, 7-9 Aprilie,1992,Brugge, Belgium,

[11]Dumbrava, M., Morariu, Z.,*Consideraţii asupra regimului de frecare la etanşările frontale*, 10-12 nov. 1988, I.P.Iaşi.

[12]ZEUS, O. *Cavitation Damages at Faces Materials of Mechanical Seal*,Pump Congress Karlsruhe 92, p.84, 6-8 oct. 1992, p.84, Karlsruhe

[13]Pascovici, M.D. and Etsion, I., The *Accuaracy of the Isoviscous Solution of the Reynolds Equation in Mechanical Seals*,Journal of Enegineering Tribology,1992

[14]Doane,J,C, Myrum,T, and Beard,J, *An experimental-computational investigation of the heat transfer in mechanical face seals*,International Journal of Heat and Mass Transfer,Vol.34,Issues 4-5,Pag.1027-1041,April-may 1991

[15]Zeus,D**.**,*Viscous Friction in Small Gaps-Calculations for Non-Contacting Liquid or GasLubricated End Face Seals*,STLE Tribology Trans., 33 (3), p. 454, 1990

[16]Buck,G.S. *Heat Transfer in Mechanical Seals*,6 th Int. Pump Users Symp.,April 24-28, 1989,Huston, Texas

[17]Cicone,T.,Apostolescu,A., *Temperature distribution in the rings of liquid face seals-evaluation of simplified analytical models using 3D FEM analysis*,BALKANTRIB'O5, 5th International Conference on Tribology,June 15-18,2005, Kragujevac, Serbia and Montenegro

[18] Tournerie,B.,Brunetière,N., Danos,J.C.,*2D Numerical modeling of the TEHD transient behaviour of mechanical face seals*,Proc. of the 17th BHRG Conf. on Fluid Sealing, 2003,York, UK.