ЗАКОРДОННІ НАДХОДЖЕННЯ

EXPERIMENTAL RESEARCH OF A ACTIVE FACE SEALS

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The paper deals with active seals used in sealing of rotating shafts. There is an overview of the design and theoretical research concerning the clearance height control in noncontacting face seals, followed by a discussion of selected experimental data. The design and the principle of operation of the test facility used for the experiments are also included.

Keywords: active seal, non-contact face seal, test rig.

1. INTRODUCTION

Noncontacting face seals are often used in rotating machinery to provide fluid sealing. The very basic objective in face seal design, however, still remains to maintain a full and stable film at the sealing gap. Two requirements that often oppose each other are minimum leakage and minimum wear, i.e., long life. Seal failure is often characterized by excessive wear of the seal faces when the fluid film thickness is too small, or by excessive leakage when the fluid film thickness is too large. The key factor in seal design is to maintain a predetermined clearance between the sealing rings. A seal with actively controlled seal clearance is one of the most promising ideas in future seal development.

A seal with controlled parameters called an active seal is a relatively new concept. The first suggestions to treat a seal as a controllable object were made in the experimental works [1,2,3,4] concerning mechanical contacting face seals. The investigations consisted in measuring the temperature or leakage rate and controlling the change in the force by applying an appropriate load on the sealing rings. The advances in electronics and digital engineering have allowed investigating the problems related to active seals experimentally.

An even more sophisticated idea of control are described in the patent [5] (Fig.1). and in Ref. [6]. The face temperature is used as an input to a control system that utilizes piezoelectric actuator to obtain a desired the load on the sealing rings.

An interesting experiment was described in Ref. [7], where the clearance height was controlled by means of an electropneumatic transducer. Reference [8, 9] reviews the most interesting theoretical as well as experimental findings in this field.

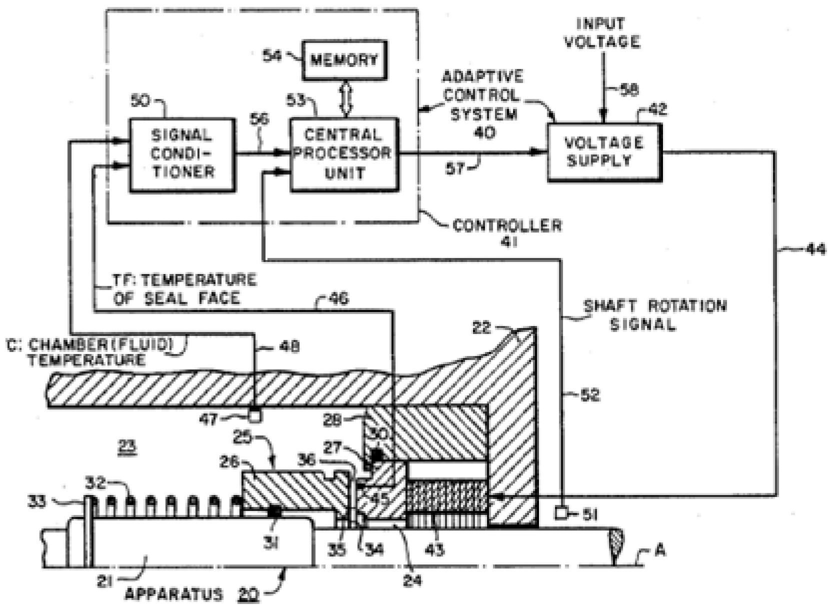

Fig. 1. Schematic diagram of the face seal with the control system, patent [5]:
26, 27 – sealing rings, 43 - piezoelectric actuator.

The Author is also involved in the theoretical and experimental studies of the active face seal models. The following paper describes a test site active face seals and presents some results of experimental research.

2. DESCRIPTION OF THE TEST RIG

The original test rig was used in this research to study and implement the seal clearance control technique. The photographs in Fig.2 show the instrumentation and rig assembly.

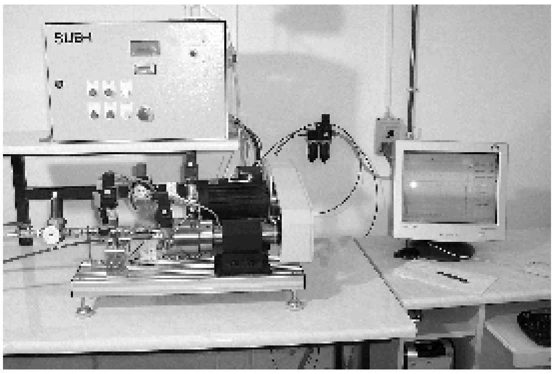

Fig. 2. View of the test stand

The test rig consists of the following systems and units: a mechanical system – a measuring and monitoring head, a drive unit and a base, a unit supplying fluid to the sealed chamber at required pressure, a unit pressing against the flexibly mounted ring, a control system, and a measuring system responsible for acquiring and processing experimental data.

The face seal to be tested is placed in the testing chamber [10]. The schematic of the testing chamber is shown in Fig. 3.

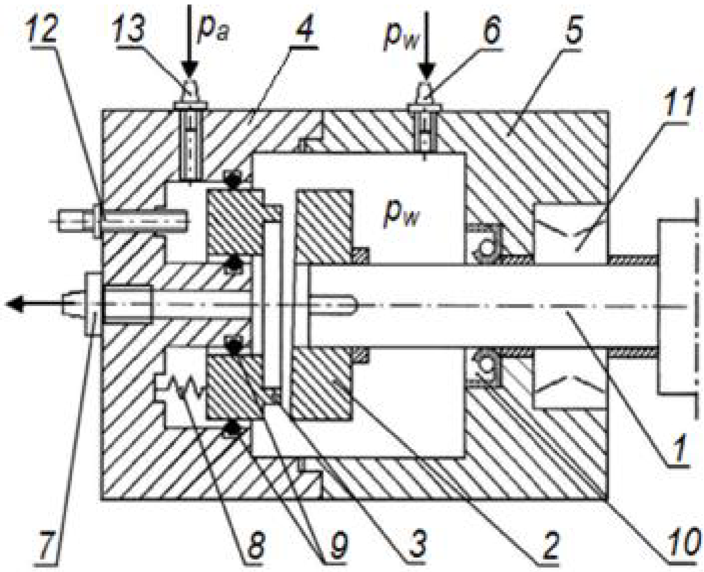

Fig.3. Schematic diagram of the test chamber: 1- shaft; 2, 3- sealing rings; 4, 5- chamber elements; 6- inlet of the sealing medium; 7- leakage outlet; 8- compression springs; 9- O-rings; 10, 11- bearing system; 12- noncontacting inductive sensor; 13- air inlet.

One of the sealing rings is mounted flexibly on the chamber housing, the other is fitted on the spindle and performs a rotational motion. The spindle drive unit allows flexible control of revolutions, the maximum value being 3000 rev/min. The sealed fluid is supplied to the chamber through a special hydraulic system with a nominal value of 0.6 [MPa].

The testing chamber is equipped with measuring sensors. In the experiment, the load of the flexibly mounted ring was assured by the pneumatic system. The clearance was controlled by changing the loading force acting on the flexibly mounted ring with the aid of the control system. An eddy current proximity probe was used to measure the clearance of the seal, i.e. the dynamic response of the flexibly mounted ring - stator. After reducing voltage (filtering), the proximity probe signal is sent to a personal computer through an A/D converter of the board.

The seal clearance is then calculated and compared with the desired seal clearance. Basing on the error signal between the measured clearance and the desired clearance, a control signal is calculated according to the control algorithm. The control signal is then sent to the electropneumatic transducer through the D/A converter. The electropneumatic transducer provides air pressure (i.e. the loading force) that is proportional to the voltage signal obtained from the D/A converter.

3. EXPERIMENTAL RESULTS

At the first stage of the investigation, it was essential to determine the static characteristics of the seal. The pressure of the air in the stator chamber imposing a load on the flexibly mounted ring was altered by means of an electropneumatic regulating valve. The air pressure as well as the clearance height were measured at a predetermined value of the sealing medium pressure.

For the desired value of air pressure, i.e., the pressure force, we obtained the mean value of the clearance stabilized after a period of about 1 [s]. The value of air pressure was reduced until we reported some loss of stability in the form of a large leakage and an increase in the ring vibration amplitude. This testified to a turbulent flow in the gap. The height H was about 150 [μm] then. Figure 3 shows examples of static characteristics determined for three different values of water pressure p_{w1}=0.218, p_{w2}=0.272 [MPa], p_{w3}=0.343 [MPa].

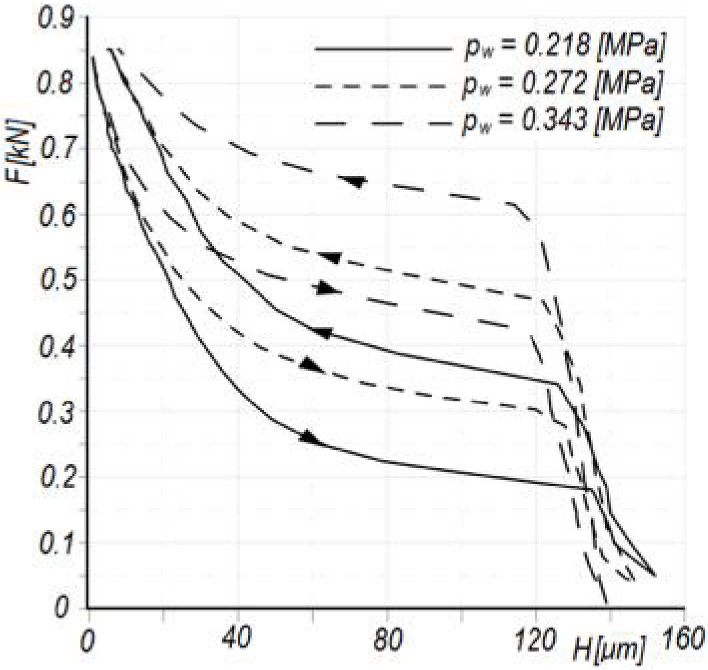

Fig.3. Static characteristics of the seal being tested [9, 11]

The characteristics shown in Fig. 3 are nonlinear and form a hysteresis loop, which confirms the presence of a considerable amount of friction forces in the system. Other nonlinearities are related to the elastic properties of the elastomer ring and the presence of a medium film in the clearance. An increase in the clearance height causes a decrease in the stiffness coefficient of the system. Moreover, as water pressure p_w rises, we observe some changes in the static characteristics of the seal. Since the point of static equilibrium of the ring changes, the working point of the whole system changes too.

Next, it was necessary to check if the control system described above operates as predicted. The tests were conducted under the following conditions: the sealed water pressure p_w=0.2175 [MPa]; shaft rotation speed ω=10 [Hz], and rotor misalignment (1.5-2.5) [mrad].

Next, it was necessary to check if the control system described above operates as predicted. To adjust the air pressure in the chamber loading rings assumed linear PID controller, the settings (parameters) were selected according to the method of Ziegler - Nichols for the previously identified model of the seal.

The aim of the test control was to reduce the clearance height of the initial value Ho to the desired value H1 and its maintenance during operation of the seal. An example of the control results obtained are shown in Figure 4.

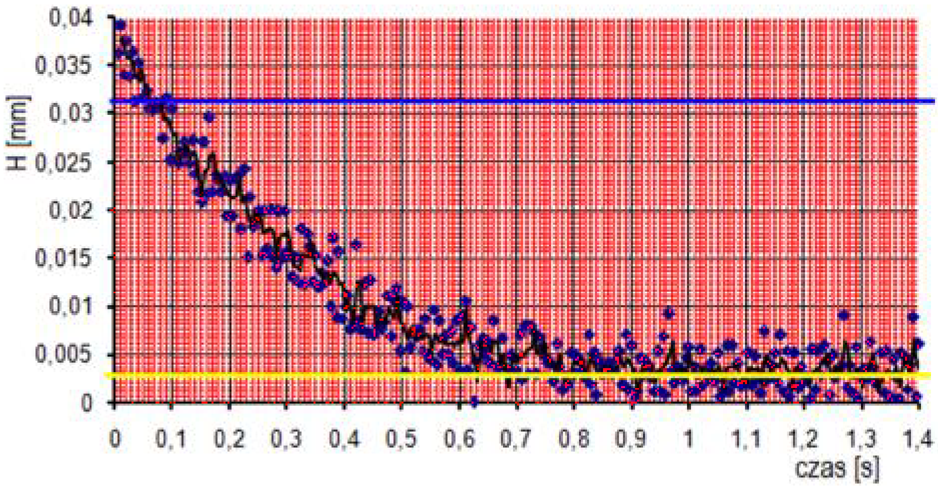

Fig. 4. Results of the clearance seal control [9, 11]

On the basis of the obtained characteristics (Fig. 4) can be stated that designed automatic control system is working properly. After ~ 0.8 [s] has reached the desired value of the clearance seal .

For smaller values of the gap we can see that the accuracy of the control system is not satisfactory. In addition, there is large distortion measurement signal. Extensive experimental results are presented in the above-cited dissertation [11].

6. CONCLUSIONS

Clearance control is a frequently discussed problem; yet, in most cases, the studies are purely theoretical. To examine the behavior of noncontacting face seals with a control system, a special test rig had to be designed and constructed. The experimental data confirms the feasibility of the clearance height control in seals. The author of the paper hope that the solutions described above will soon become common industrial practice.

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Кундера Ч. Экспериментальное исследование активних торцевих уплотнений

В статье рассмотрено конструкции активных уплотнений, используемых в герметизации вращающихся валов. Выполнено теоретические исследования методов контроля высоты в бесконтактных торцевых уплотнениях, с последующим анализом экспериментальных данных. Представлено конструкцию и принцип работы экспериментального стенда.

Ключевые слова: *активное уплотнение, бесконтактные торцевые уплотнения, испытательный стенд.*

Кундера Ч. Експериментальне дослідження активних торцьових ущільнень

В статті розглянуто конструкції активних ущільнень, що використовуються в герметизації обертових валів. Виконано теоретичні дослідження методів контролю висоти в безконтактних торцевих ущільненнях, з подальшим аналізом експериментальних даних. Представлено конструкцію і принцип роботи експериментального стенду.

Ключові слова*: активне ущільнення, безконтактні торцеві ущільнення, випробувальний стенд.*

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