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Hydrodynamic Seal on the Basis of a Cylindrical Layer of the Compressible Fluid with a Running Wave

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Abstract

The hydrodynamic seal is based on a cylindrical layer of the compressible fluid with a running wave, which, unlike the conventional hydrodynamic seal, has the characteristics that do not depend on the rotation speed of the sealed shaft. The flow of the compressible fluid in the cylindrical gap is concerned, the pressure distribution in the layer are obtained, pressure drops (counterpressure) along the axis of the shaft depending on the gas content in the liquid are determined.

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1. Introduction.

Contactless liquid seal is the device, the sealing action of which is achieved as a result of energy loss during the motion of the fluid in the channels formed by the seal elements. Most often the non-contact seals are used for sealing rotating shafts. The medium filling the seal, is treated in the apparatus of the working fluid or process fluid, preventing contact of the fluid with the environment. According to the principle of the non-contact seal can be static or dynamic. The work of static compression is connected with the forces arising from the contact of fluid with the sealing surface and overcome local resistances. The work of contactless dynamic seal is associated with the pressure (backpressure) created, for example, the screw surface of the rotating shaft and preventing the reduction of pressure in the working chamber of the main unit [1].

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Dry gas seals (DGS) are applied relatively recently. Nowadays more than 80% of the fleet of centrifugal compressors (turboexpanders) are equipped with such devices and the final version of standard for their device API 614, "Lubrication, Shaft-Sealing, and Control Oil Systems and Auxiliaries for Petroleum, Chemical, and Gas Industry Services" was developed by the American Petroleum Institute only in 1999, Improving the DGS is a relevant scientific, engineering and technological task.

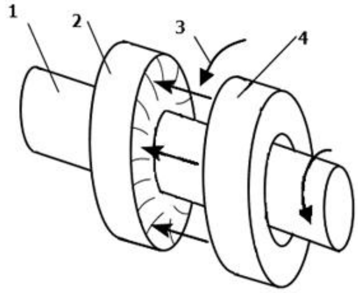

Fig.1. Sealing step of DGS.

The main working part of the sealing step is a pair of sealing (fig.1), one part of which is fixed bearing (4) made of high quality graphite with anti-friction treatment and “tighten” in the axial direction with the spring to the bearing (2) and the second movable foot bearing (2) is made of carbide material and mounted on a shaft 1 of the compressor.

Foot bearing 2 in the axial direction is fixed, at its working surface is made of spiral grooves, so when the shaft rotates, the process gas is captured by the grooves 3 and is blown into the gap between the foot bearings 2 and 4. This creates the required dynamic gas compression that reduces to an acceptable level, the output of the working gas through the gap of the bearing is between the shaft and the inner cylindrical surface of the bearing 4.

The obvious disadvantage of this device is the dependence of the characteristics of the seal on the speed of rotation of the shaft 1. During variable speed or reverse rotation this device will enter the mode of dry friction, and will have bad indicators of reliability. To eliminate this disadvantage and to reduce the output of the working gas it is suggested making compound bearing 4 so that on part of her internal cylindrical surface is incarnated waveformated motion (running wave) [2]. The direction of movement of running wave should be in the direction of the working gas with amplitudes commensurate with the size of the gap and the gradients are so large that the added pieces could have fit at least one or two wavelengths.

This seals is most effective while working with liquids, and the dynamic range of the generated backpressures is determined by the amplitude and frequency of the running wave. At very high speeds of wave motion in the fluid the cavitation can start, it reduces its operational capabilities, so in this report the characteristics of the compression with two-phase fluid are considered.

2. The equation for the pressure distribution.

A standard unit is selected as the main research object, two oppositely directed symmetric running waves (fig. 2), in the plane of symmetry which is observed zero consumption of lubricant. The dimensionless gap function we write in the following way:

$$H_i = \frac{h_i}{h_0} = \left\{ \begin{array}{c} 1 + e\cos\theta + A_0 \cos 2\pi\left(\tau + r\right), \quad i = 1 \\ 1 + e\cos\theta + A_0 \cos 2\pi\left(\tau + r\right)\cos 2\pi\left(\dfrac{\nu}{\omega}\tau + \phi\right), \quad i = 2 \end{array} \right\}, \qquad (1)$$

in which the notation means: $r = z/\lambda$ – dimensionless axial coordinate; $\beta = \overline{B}/\lambda$ is the dimensionless length of the layer; $E_o = \overline{E}/h_o$ – the dimensionless oscillation amplitude; h0 is the nominal gap in a coaxial position of the