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New test device design for static ferrofluid magnetic sealing

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1. Introduction

Ferrofluids belong to the magnetically sensitive fluids which are in recent years used for industrial applications within sealings elements. This paper deals with essential theory and experimental results of the newly designed device for testing the static seal using a classical ferrofluid or a ferrofluid-based magnetorheological fluid.

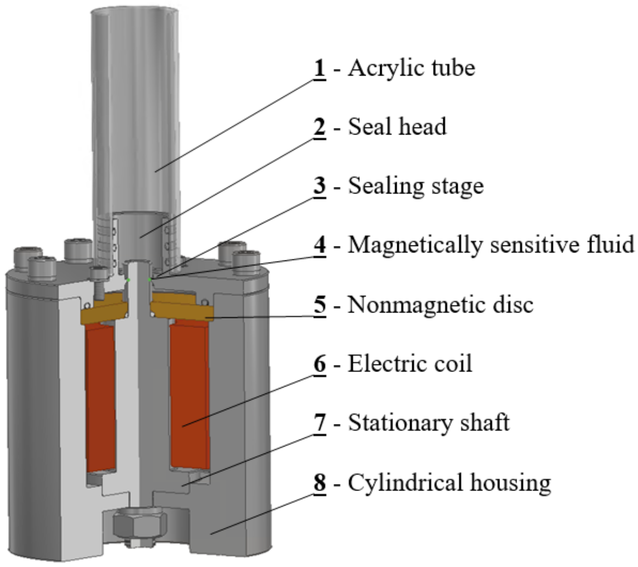

Fig. 1. Test device for the static magnetic fluid seal

A 3D schematic of the test device is shown in Fig. 1. The main parts of the proposed stand are a centre bored seal head (2) with a single stage sealing element (3) and a stationary shaft (7) with a thin layer of magnetically sensitive fluid (4) in between. The magnetic flux generated by the electric coil (6) passes through the body of the device and the layer of magnetically sensitive fluid (4). The cylindrical housing (8), stationary shaft (7), and seal head (2) are made of steel and the disc (5) is made of brass material. The electric coil has 341 turns of a copper conductor of 1.80 mm in diameter.

As resistance against the high- and low-pressure seal regions of the magnetically sensitive fluid depends on change magnetic induction, the electric current can be used to control the pressure difference. The critical pressure difference is defined as the maximum sealing pressure of the seal operating without leakage. The computation of the critical pressure difference Δp_{cr} in the layer of the magnetically sensitive fluid is based on assumptions [1], the derived ferrohydrodynamic Bernoulli equation, the magnetically saturated fluid, and neglection of the influence of the gravitational field

$$\Delta p_{cr} = M_s \cdot \Delta B_{max\text{-}min}. \tag{1}$$

M_s is the magnetization of the fluid and $\Delta B_{max\text{-}min}$ is the difference of the magnetic induction on both sides of the magnetically sensitive fluid layer.

The geometrical shape of the sealing stage was designed according to the results of the nonlinear magnetostatic analysis performed with utilisation of the finite element method.

Experimental analysis was focused on testing a magnetic field effect on the critical pressure value. The tested seal head contains one sealing stage with a radial seal gap of 0.15 mm filled with the ferrofluid volume of approximately 0.03 ml. If the residual magnetization of the test device (Fig. 2) was greater than 1 mT, the demagnetization process preceded the measurement. A very simple and efficient demagnetization procedure (see Fig.3) of the test stand, using a variable autotransformer (M10-522-20 250/8 2kVA MCP), was tested. In the initial phase of the experiment, the DC current source, generated by Agilent E3632A DC power supply, was connected to the electric coil, a ferrofluid was injected into the seal gap, and the water column in the acrylic tube was very slowly increased (Fig. 4). The experiment was stopped when leakage was detected.

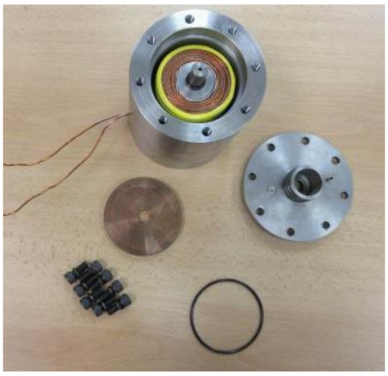

Fig. 2. Test device

Fig. 3. Assembly for the demagnetization

Fig.4. Measurement

The experiments were carried out with commercial EFH series-1 ferrofluid, manufactured by Ferrotec. This ferrofluid uses a light hydrocarbon as the carrier liquid, the volume of the magnetic particle concentration is 7.9%, the density is 1210 $kg \cdot m^{-3}$, the dynamic viscosity is 6 $mPa \cdot s$ (for 27°C), and the magnetization saturation is 35 $kA \cdot m^{-1}$.

The critical pressure values, listed in Table 1, are determined according to the measured water column height for the magnetic field intensity induced by the current 0.2 A. The mean value of the critical pressure difference is equal to 3884.3 Pa.

Table 1. Measured water column height/critical pressure values

Experiment number	Current 0.2 A
1	40.0 cm / 3916.9 Pa
2	40.5 cm / 3965.9 Pa
3	38.5 cm / 3770.1 Pa

2. Conclusion

The article presents preliminary experiment results of a newly designed device for testing the seal using a ferromagnetic fluid in static conditions for air and water environments.

Acknowledgements

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[1] Rosensweig, R.E., Ferrohydrodynamics, Dover Publications, Inc., Mineola, New York, 2014.