AN OPTOELECTRONIC SENSOR IN THE MEASUREMENTS OF THE TEMPERATURE OF A PUMP CYLINDER BLOCK

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Abstract: *In the paper a method is presented for remote measuring the temperature of a cylinder block in a piston axial pump. The method employs an electronic measuring system with an optoelectronic sensor, designed be the authors. The functioning principle, the component subsystems, and the accuracy of the measuring system are discussed. The results are also presented of measuring temperature increments in the kinematic pair piston - cylinder, depending on the parameters of pump operation.*

1. Introduction

The research on hydraulic pumps requires measuring the temperature of rotating parts under various operating conditions. Such measurements can be performed by means of electrical methods employing thermoelements or thermistors as measuring sensors. A method of measuring the temperature of a cylinder block in an axial piston pump should be characterized by the following properties:

- a continuous measurement of the temperature during the operation of the pump, with on-line access to the results of measurements, which are also recorded,
- high accuracy of measurements,
- high reliability of the subsystems in the pump, allowing for the broad variability of its operating conditions,
- small dimensions of the device transmitting the measuring signals from the cylinder block to the stationary part of the system.

As has been demonstrated [2], not every method of measuring temperature meets the above mentioned requirements. Because of that a new device has been developed for measuring the temperature of a cylinder block in an axial piston pump.

2. A remote method of measuring the temperature of the cylinder block

The electronic sensor for measuring the temperature of the cylinder block in an axial piston pump [1,3] is presented in Fig.1. The principle employed is that of optic coupling of the phototransistor 9 placed in the stationary part with the LED 3 mounted coaxially in the cylinder block. In the cylinder block there are also a thermistor sensor 1, multivibrator 2, constant-voltage regulator 4, rectifier 5 and the rotating part 6 of the rotational transformer. An increase in the temperature of the cylinder block induces a change in the resistance R_ϑ of the sensor 1, which, in turn, affects the frequency of the multivibrator 2. The electrical impulses generated by the multivibrator 2 are transformed into light impulses by the LED 3 and subsequently transmitted to the stationary part of the system, where the phototransistor 9 transforms them again into electrical signals of frequency equal to the frequency of multivibrator 2. The signals, standardized in the monovibrator 10, are transmitted to the digital frequency meter 11. Some examples of frequencies obtained as a function of the sought temperature $f = F(\vartheta)$ are presented in Fig. 2.

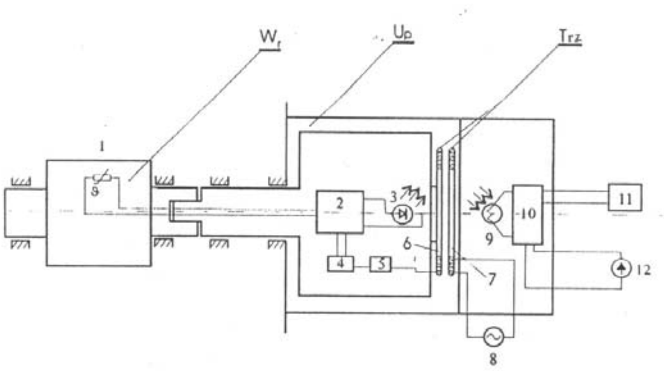
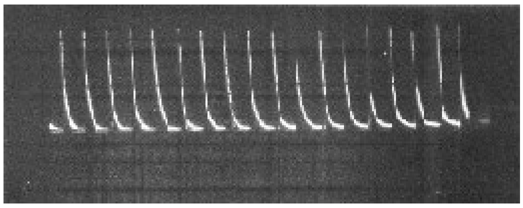


Fig.1. Block diagram of the measuring system: W_r - cylinder block, U_p - measuring device, T_{rz} - rotational transformer

(a)



(b)

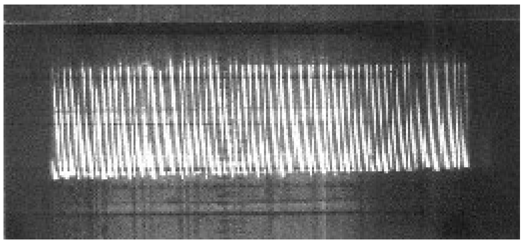


Fig.2.Output signals of the measuring system: (a)- for 308,2 K, (b)- for 328,2 K

The device was calibrated within the temperature interval 293,2 – 423,2 K with the resolution of 0,2 K by means of a UT-2 ultrathermostat and a quartz thermometer with the resolution 0,1 K. The analysis of the empirical results of calibration was performed with an IBM PC, using the methods of correlation analysis and of linear regression, and HG-3 software. This enabled the calculation of the boundary error of calibration as a sum of the absolute values of the two errors: the error of temperature indication on the calibrating thermometer $\Delta\vartheta_T = 0,1K$ and the temperature error of the electronic measuring equipment $\delta_\vartheta = 0,1$ [%/10K]. Finally, the relative boundary error of a temperature measurement by means of the device was formulated as follows:

$$\delta\vartheta = |\delta\vartheta_T| + |\delta\vartheta_p|$$

For a specific measuring interval the values of the relative boundary error are to be found within the interval [0,6 ÷ 0,2] [%].

3. Experimental measurements of the temperature of the cylinder block

The experiments were conducted on a universal hydraulic stand equipped with an optoelectronic sensor [4]. The investigation of the temperature increments in the cylinder block (i.e. the kinematic pair piston-cylinder) followed some preparatory work on the construction and installation (Fig. 3).

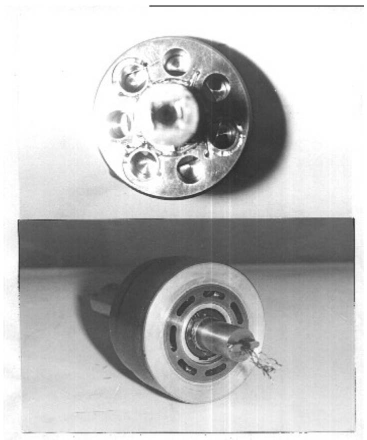


Fig. 3. View of the cylinder block with the thermistors installed

The experiments were performed with prescribed angular velocities of the pump shaft ω =52, 79, 105, 131 and 157 rad/s and with constant viscosity of the oil μ_1 = 0.0616 Pas, μ_2 = 0.0253 Pas and μ_3 = 0.0122 Pas, respectively. The pumping pressure was increased gradually from 0 to 16 MPa. The measurements were performed for three pairs of sensors mounted near the working pistons at the following locations: (Fig.4):

- at the front of the cylinder block from the side of the swash plate (sensors nr 1 and 1')
- in the middle part of the cylinder block (sensors nr 2 and 2')
- at the back of the cylinders (sensors nr 3 and 3')

No significant differences were found between the mean values of the indications of the sensors 1 and 1'; 2 and 2'; 3 and 3' at the level of significance α = 0,1 therefore, in subsequent considerations only the sensors 1, 2, and 3 were taken into account. The results are presented in Fig. 4. The analysis of the results enable an evaluation of the two hypotheses concerning the load distribution along the piston: one stating that the load accumulates at the extreme positions of the piston and the other stating that the load is distributed evenly at the whole length of contact between the piston and the cylinder. It is the former hypothesis that appears to be borne out by the results, as the temperature increments measured by the sensors at the extreme positions 1 and 3 are higher. Besides, it can be noted that the smallest power loss occurs with oil viscosity μ_2=0,0253Pas at the entrance to the pump.
Experiments were conducted on three sets of pistons of various diameters, which were selected in such a way, that diameter clearances 2h equal to 10, 18, and $30 \cdot 10^{-6}$ m, respectively, occurred between a piston and the cylinder.

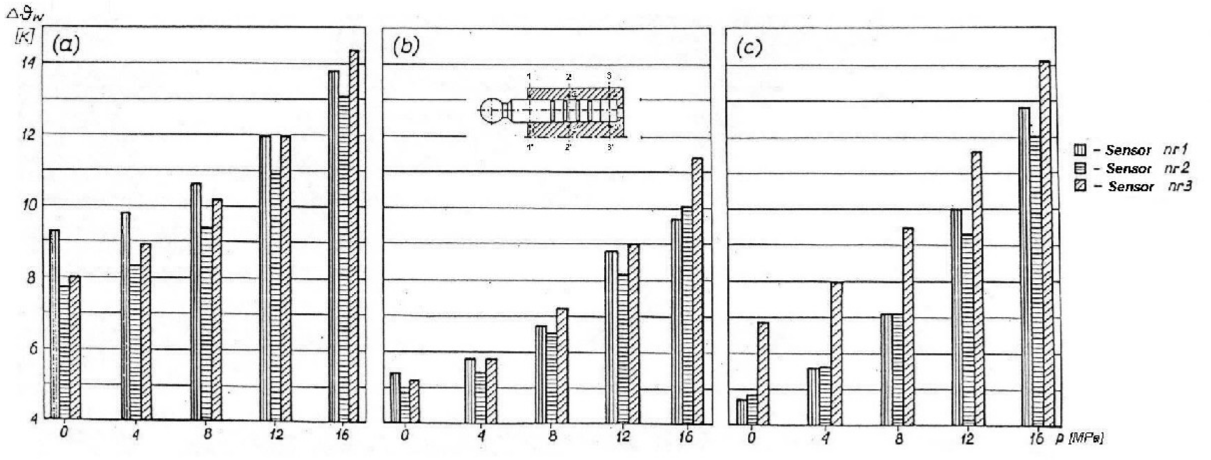


Fig.4. Dependence of the temperature increments $\Delta\vartheta_w$ in the kinematic pair piston-cylinder on the location of a sensor, and on the pressure p for the oil viscosity μ: (a) μ_1= 0.0616 Pas, (b) μ_2= 0.0253 Pas, (c) μ_3= 0.0122 Pas, ω = 157 rad/s, 2h = $18 \cdot 10^{-6}$m

The results of measurements obtained from the sensor 2 presented in Fig. 5 demonstrate that the greatest loss accompanies the greatest diameter clearance (2h) between the piston and the cylinder.

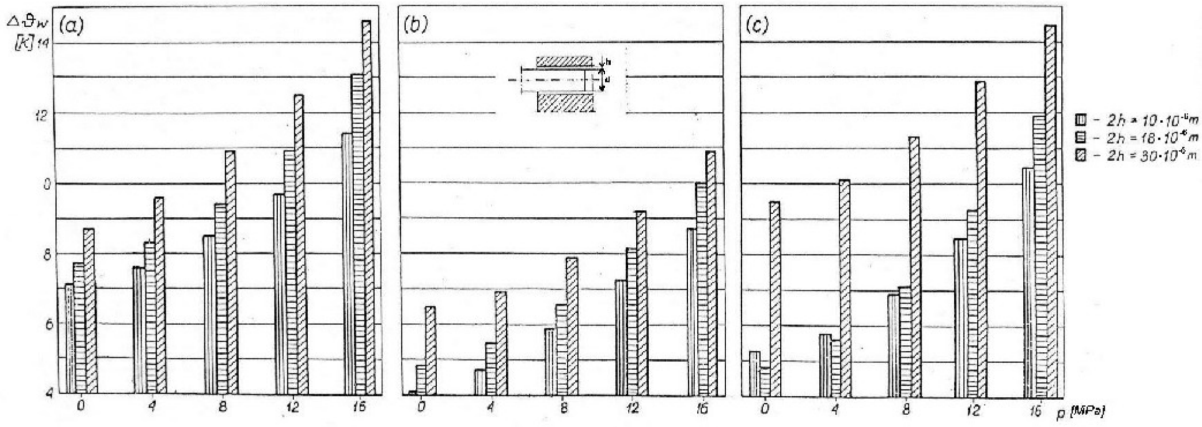


Fig.5. Influence of the diameter clearance 2h between the piston and the cylinder on the temperature increment $\Delta\vartheta_w$ in the kinematic pair piston-cylinder as a function of the pressure p for the oil viscosity μ: (a) μ_1 = 0,0616 Pas, (b) μ_2 = 0,0253 Pas, (c) μ_3 = 0,0122 Pas

One can suppose that with the greater clearance the piston can assume a skew position more freely, which can lead to higher pressure per unit area. The increase in the unit pressure, in turn, can cause the occurrence of micro-wedges in the lubricating liquid filling the cavities and pores, which may result in the increase in the friction factor, and, at the same time, cause a loss of the mitigated solid friction.

4. Concluding remarks

- An optoelectronic sensor constructed on the basis of the author's design was used for the investigations of the temperature increments in the kinematic pair piston-cylinder.
- The sensor is of small dimensions and high reliability. Its accuracy has been found to be better that that of the conventional inductive type measuring systems [2].
- It has been demonstrated that the measurement of temperature in the kinematics pair piston-cylinder is necessary for determining the processes occurring inside the pump. The research oriented towards establishing the relation between power loss and temperature should be continued.

References

[1] Biernacki Z. *Sensory i systemy termoanemometryczne (Sensors and thermoanemometric systems).* WKiL, Warszawa 1997.
[2] Wisniewski S. *Pomiary temperatury w badaniach silników i urzadzen cieplnych (Temperature measurements in the investigations of motors and heat devices).* WNT, Warszawa 1983.
[3] Bloch R., Zloto T.*: Urzadzenie do pomiaru temperatury wirujacych elementow maszyn (A device for measuring the temperature of rotating parts of machines).* Patent nr 135271.
[4] Zloto T.*: Pomiary temperatury wirnika pompy wielotloczkowej osiowej metodą bezstykowa przetwornikiem optoelektronicznym podczas badania jej sprawnosci (Remote measurements of the temperature of the cylinder block in an axial piston machine by means of an optoelectronic converter during efficiency testing).* XXVIII Miedzyuczelniana Konferencja Metrologow. MKM96.Czestochowa 1996.