TESTING THE HEATING OF THE BASIC COMPONENTS OF AN AXIAL MULTIPISTON PUMP

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Abstract: In the paper a hydraulic measuring stand for measuring the increases in the temperature of the basic kinematic pairs of a pump is presented. Also, an optoelectronic sensor for measuring the temperature of the cylinder block is described. The dependence between the increases in the temperature of the basic kinematic pairs and the pressure and temperature of oil at the pump input, by the nominal angular velocity and maximal inclination of the swash plate is discussed.

1 INTRODUCTION

Axial multipiston pumps are quite widely applied. Since they can operate by high pressures and power, they are characterized by high values of power efficiency, defined as the ratio of power to mass or volume. This type of displacement machines are most often apllied in the drives of complex devices requiring high efficiency. Because of that, the exploitation parameters of pumps have to be constantly improved by modernizing the design and construction.

The studies conducted at various research centres, e.g. at Gdańsk Technical University [4], have indicated that the potential for improvement can be found in mechanical losses, which exceed other kinds of losses, so that the limitation of the mechanical losses could be the most effective way of increasing the pump efficiency. This problem, however, is highly complicated because mechanical losses occur in a number of kinematic pairs of the pump, and the associated phenomena are very compex both at the level of analytic and physical interpretation. Since the model of measurements applied so far, which was based on mechanical measuring methods and electronic systems, had not led to satisfactory results, the idea of basing the experiment on the temperature measurements of basic subsystems of the pump was developed.

All the energy losses involve the change into heat, resulting in the increase in temperature. Hence, mounting appropriate temperature sensors next to the sources of energy losess should help determine the relation between the losses and the operating conditions as well as shed some light on the course of processes taking place inside the pump.

2 MEASURING STAND

Fig. 1 presents a diagram of the hydraulic measuring stand, at which an axial multipiston pump type PTOZ with temperature sensors was examined.

At the stand, it is possible to measure the temperature of the elements mated with the pump and to determine the efficiency with respect to pressure, angular velocity and oil viscosity. To examined pump 4 oil Hydrol 30 was supplied from main tank 1 through granule filter 3. The oil excess delivered by gear pump 2 is drained through overflow valve 5 to the tank. Pump 4 is coupled to engine 6 of the thyristor system, responsible for continuous velocity adjustment in the range of 10 –3000 rpm. The measurement of the pump angular velocity consists in counting the impulses coming from the interrupted magnetic flux through gear disc 7 mounted at the engine shaft. Inductive torque meter 8 placed between the shaft of engine 6 anf the shaft of pump 4 measures directly the torque at the shaft. Also optoelectronic sensor 9 for the measurement of cylinder block temperature [1,2,3,5] is coupled with the examined pump. The sensor is a pivotal measuring device in the proposed method. The temperature of the pump internal parts, as well as the temperature of the housing, of oil in the suction and pressure conduits, and of oil leaks are measured by means of sensors with direct signal output and the results are displayed consecutively by digital multimeters 10 and 11 (Fig. 1). Pump 4 forces oil through a conduit and turbine flow meter 12 and subsequently, depending on the location of rotational distributor 13, to hydraulic engine 14 or through 15 to valve 16. From there, the oil is directed to measuring bottle 17 or directly to container 1. The system of oil temperature stabilization, consisting of heater 18, radiator 19 and mixer 20 provides the

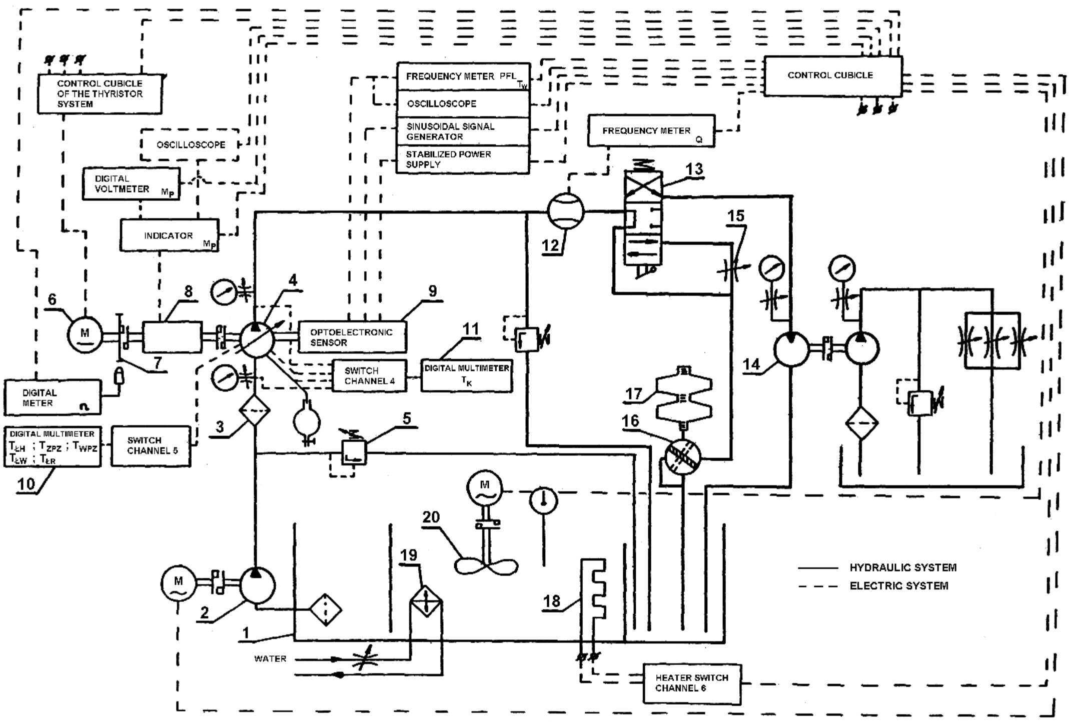

Fig. 1. Diagram of the hydraulic measuring stand

required temperature of oil in the tank. Due to a large capacity of the tank the temperature in the pump suction port is kept constant during the experiment – from ± 0,5 K to ± 0,2 K,depending on the operation parameters of the hydraulic system.

For the measurements of the pump cylinder block an eptoelectronic sensor was designed and constructed [2]. In this sensor (Fig. 2), the transmission of signals is based on optical and electronic devices. The sensor includes LED 6, placed at the rotating part at the extension of the cylinder block shaft, and phototransistor 9 placed in the stationary part.

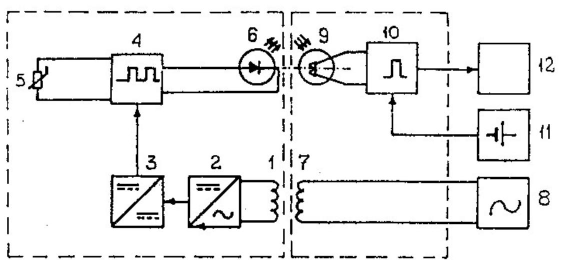

Fig. 2. Block diagram of the optoelectronic sensor for the measurements of cylinder block temperature

The rotating part also contains thermistor 5, multivibrator 4, constant-voltage regulator 3, rectifier 2 and the rotating part of the power supply transformer 1. As the temperature changes, the resistance of thermistor 5 also changes, affecting the operating frequency of multivibrator 4. Electric impulses generated in multivibrator 4 are changed into light impulses in LED 6. In this form they are transmitted to the stationary part of the device. In phototransistor 9 the impulses are changed back into electric ones and their frequency is identical to that of multivibrator 4. After standardization in monovibrator 10 they are transmitted to digital frequency meter 12, and the obtained result is a function of temperature.

3 RESULTS OF MEASURING THE HEATING OF THE BASIC KINEMATIC PAIRS OF THE PUMP

Let us now discuss the selected results of the measured temperature increases of the basic kinematic pairs (piston- cylinder, slipper –swash plate and cylinder block – valve plate) with regard to temperature at the pump inlet. In Fig. 3 bar charts represent the temperature increase of the piston- cylinder pair depending on pressure, for various values of temperature T_z at the pump inlet, with inclination angle $\alpha = 16°$ of the swash plate and angular velocity $\omega = 157$ rad/s.

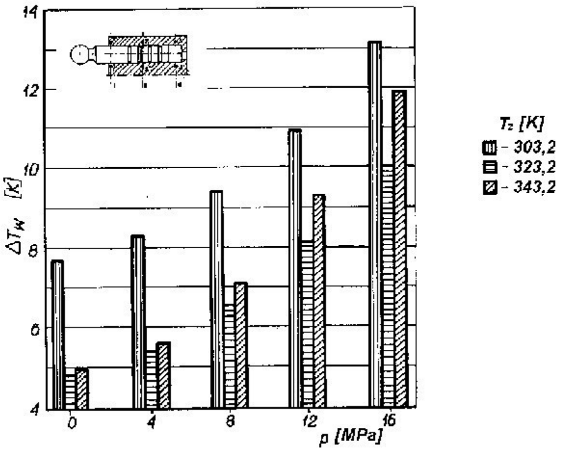

Fig. 3.Influence of temperature T_Z of oil supplied to the pump on temperature increase ΔT_w of the kinematic pair piston-cylinder as a function of pressure p

An increase in pressure causes an increase in temperature. It can be explained by the fact that the increase in pressure is accompanied by an increase in thrust, which, in turn, is associated with an increase in energy losses. The results of the experiment indicate clearly that with oil temperature $T_Z = 303.2$ K at the pump inlet i.e. with the maximal viscosity, the increase in temperature is the largest. It can also be observed that the smallest temperature increase for that pair occurs for $T_Z = 323.2$ K which may be taken as evidence of deteriorated mating.

Fig. 4 presents the temperature increase for the kinematic pair slipper – swash plate depending on pressure for various temperatures at the pump inlet by inclination $\alpha = 16°$ of the swash plate and angular velocity $\omega = 157$ rad/s. The operating conditions of the kinematic pair slipper – swash plate are somewhat different from those of piston-cylinder and cylinder block – valve plate. A part of the surface of the swash plate has a direct contact with oil mixed by the system of rotating pistons and cylinder block. In the case of large differences between the stabilization temperature at the pump inlet and the ambient temperature, intensive carrying away the heat from the swash plate occurs via the pump housing. The examination of this kinematic pair has led to determining the process of heating of the swash plate at the place of contact with the slipper**.**

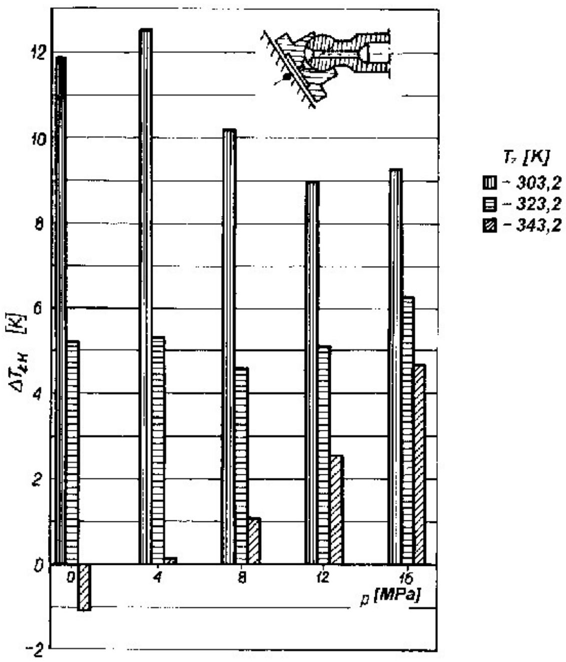

Fig.4. Influence of temperature T_Z of oil supplied to the pump on temperature increase ΔT_{LH} of the kinematic pair slipper- swash plate as a function of pressure p

By lower pressures, about 4 MPa and the maximal angular velocity higher temperatures can be observed than by higher pressures of about 10 MPa. Higher temperatures accompanying lower pressures can be explained by lesser rigidity of the hydrostatic support of the slipper and by a significant effect of inertia causing the beveling of the slipper. Due to the beveling, the oil film breaks at the edge of the slipper and friction increases. This process involves the losses of energy changing into heat, which manifests itself as increase in temperature. With higher pressures the rigidity of the hydrostatic support is large, so that the influence of inertia does not occur. Only fluid friction occurs between the slipper and the swash plate, energy losses are lower and, consequently, temperatures are lower.

Fig. 5 presents the values of increases in temperature of the kinematic pair cylinder block – valve plate in the area of the lower dead centre ZPZ depending on pressure p for various temperatures at the inlet, with the constant angle $\alpha = 16°$ of swash plate inclination and angular velocity $\omega = 157$ rad/s.

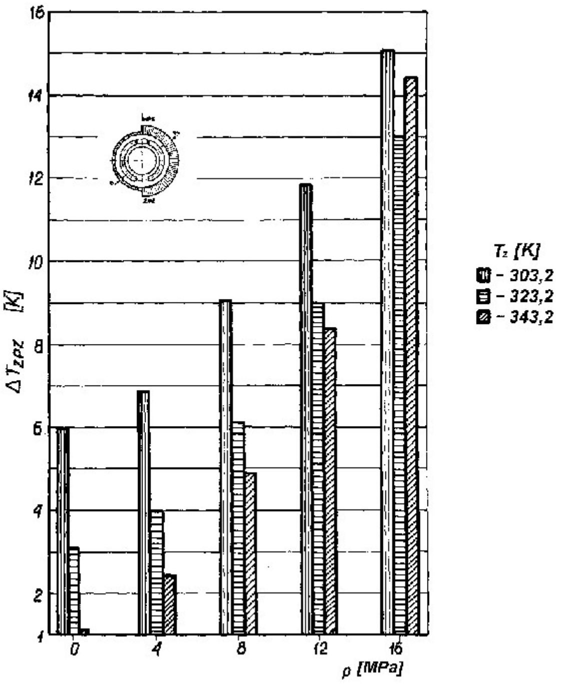

Fig. 5.Influence of temperature T_Z of oil supplied to the pump on temperature increase ΔT_{ZPZ} of the kinematic pair cylinder block – valve plate as a function of pressure p

It is characteristic for the kinematic pair heating, that the increase of temperature at the maximum pressure of p = 16 MPa and at the stability temperature of T_Z = 343,2 K is larger than the increase of temperature at the stability temperature of T_Z = 323,2 K and at the same pressure (Fig. 5) In spite of the fact that at the stability temperature of T_Z = 343,2 K significant carrying away of heat takes place through the housing and significant power losses occur due to volumetric flow intensity through a leak. It seems that lubrication has deteriorated and viscosity has decreased (T_Z = 343,2 K) so that mitigated solid friction may occur due to the increase in friction factor.

The examination of temperature increases of kinematic nodes in a working pump may lead to better understanding of the processes occurring in the pump, and, consequently, to the modifications of the pump construction. The greatest difficulty associated with the presented method lies in the interpretation of the results of measurements. It requires detailed knowledge on thermal processes occurring inside the machine during heat transmission to the environment as well as the ability to connect those processes with energy losses resulting from various kinds of mechanical friction, viscosity friction, leaks, etc.

4 CONCLUSIONS

- In the experiments the values of temperature increases were determined as functions of operation parameters for the constructional nodes of an axial multipiston pump.
- The mating of the slipper with the swash plate depends to a large extent on inertia.
- The study indicates that the temperature measurements inside a working pump may contribute towards better understanding of the processes occurring inside the pump. Because of that further research on that subject appears desirable, especially detailed examination of the relations between power losses and temperature at the particular constructional nodes.

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