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# MEASUREMENT METHODS OF SELECTED PARAMETERS IN AN AXIAL PISTON PUMP BY MEANS OF A COMPUTER MEASURING SYSTEM

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**Summary.** The paper presents a design of a computer-based measuring system for monitoring the basic operating parameters of an axial multi-piston pump, which are subsequently used for determining a current efficiency of the pump. Besides, the characteristics are discussed of various measuring sensors, including an optoelectronic sensor for measuring the temperature of the pump cylinder block.

**Key words**: measuring system, hydraulic system, pump, measuring sensor

## INTRODUCTION

The hydraulic systems for driving and controlling machines have numerous applications due to their capability of transmitting large forces, moments, and powers. An advantage of such systems is that their component parts are of relatively small dimensions. The increasing demand for hydraulic drives makes it necessary to seek new concepts and designs of such devices in order to enhance their operating parameters and efficiency, and reduce the production cost.

The pressure in the hydraulic system is generated mainly by a positive-displacement pump, changing mechanical energy into the energy of pressure of a liquid operating agent. Then, the latter kind of energy is transmitted to a hydraulic engine where it is changed back into mechanical energy.

At present, it is axial multi-piston pumps which are the most often applied ones in high-pressure systems. The compact construction of multi-piston pumps makes it possible to obtain higher efficiency per unit of volume. Because of that the weight of machines in which multi-piston pumps are used may be lighter. In many respects, such as reliability, efficiency, energy saving and automation of industrial processes, the requirements on pumps are increasing. Intensive research on the construction of pumps will certainly bring about new developments [Stryczek 1997].

In a perfect pump, where no losses occur, the power given out by the driving engine is equal to the power supplied to the system by the operating agent, according to the formula:

$$N_t = M_t \cdot \omega = Q_t \cdot \Delta p$$

where:

$N_t$ – theoretical power,

$M_t$ – theoretical torque at the pump shaft,

$\omega$ – the angular velocity of the shaft,

$\Delta p = p_2 - p_1$ – difference between forcing pressure $p_2$ and suction pressure $p_1$,

$Q_t$ – theoretical efficiency of the pump.

In real pumps volumetric and hydraulic- mechanical losses occur. Online monitoring of the losses as well as determining the efficiency as the ratio of effective energy to input energy is of vital importance for users.

## COMPUTER MEASURING SYSTEM FOR THE PUMP OPERATION PARAMETERS

At present the measuring methods rely on the use of computer measuring systems, whose functional and metrological properties are created by programming the software.

The use of computers in measuring systems and in control systems contributes towards the automation of measurements. It also improves the functioning of measuring systems by providing more sophisticated methods of data processing [Biernacki 1997, Winiecki 1998].

Contemporary measuring devices based on microprocessor technology perform a number of functions, including measurements of diverse quantities. For monitoring the parameters of pump operation a computer measuring system has been developed. A block diagram of this system is presented in Fig. 1.

The measuring system designed and constructed by the authors of the present paper includes a standard PC [Faster Electronic - user's guide 1995]. It is intended for automatic handling of the experiment, in which data from various measuring converters are observed simultaneously and saved on a disc.

The system displays large versatility. Its modular structure makes it possible to modify the measuring stand. The user may connect to any channel of the system a desired sensor of a physical quantity. Then a converter suitable for the sensor has to be installed in that channel. The system includes a unit consisting of a digital measuring system with a processor, collecting signals from the system of modules of converters, including converters of temperature, pressure, rotational velocity, flow intensity and torque. Each unit may contain up to 16 modules. It is connected by interface RS – 232 to a standard PC. The unit processor operates the modules and provides serial transmission with the computer. If interface RS – 485 is used instead, up to 31 units may be connected to the system. The operation of the system can be compared to that of a sampling oscilloscope. The efficiency factor of the axial multi-piston pump is determined in the following way:

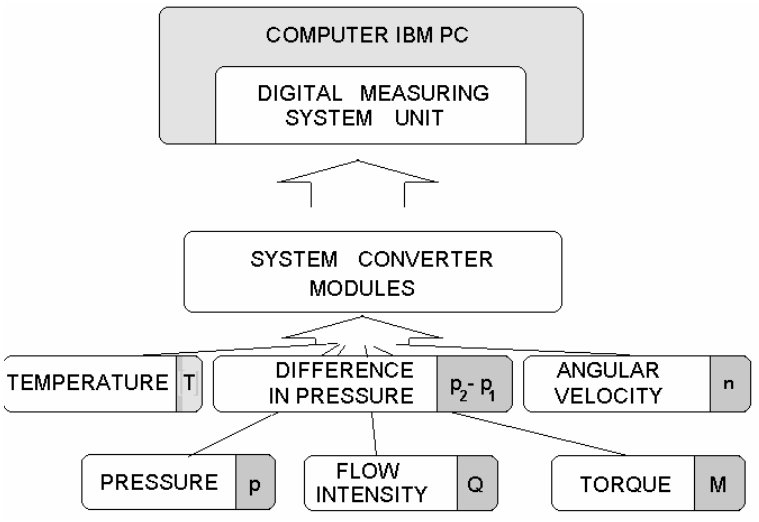


Fig. 1. Block diagram of the measuring system

The torque at the pump shaft is measured by means of an inductive torque meter Mi5 [Torque meter – user's guide 1990]. The measuring system of the inductive torque meter consists of a torque converter and an electronic measuring subsystem (Fig. 2).

The measured moment is converted into an analog electrical quantity by means of a system consisting of a measuring torsional shaft, induction coil and Wheatstone bridge. The action of the torque results in the torsion of the measuring shaft. The loss of equilibrium of the inductive converter built in the Wheatstone bridge is proportional to that torsion. The inductive converter is powered by voltage 5 V and frequency 5 kHz from the carrier frequency generator through a rotating transformer. Then, the electric measuring signal is transmitted from the Wheatstone bridge to the electronic measuring system through another rotating transformer. In the electronic measuring system the amplified and filtered signal is indicated by an analog meter scaled in torque units, or by a digital meter in the discrete form.

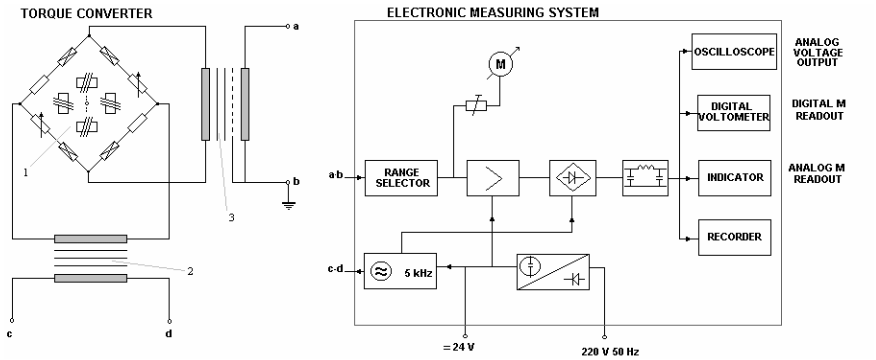


Fig. 2. Schematic diagram of the inductive torque meter
1 – inductive converter with a Wheatstone bridge, 2 and 3 – rotational transformers

Flow intensity Q is measured by means of a measuring set consisting of a turbine converter and a counting analog flow meter (Fig. 3).The measured intensity is converted into an (analog) electrical quantity by means of an axial turbine converter. The rotor of the turbine is made of ferromagnetic material. When the rotor is rotating, sinusoidal or impulse elektromotive force is induced in the winding situated within the housing. For every single rotation of a turbine blade with respect to the winding, a single impulse is induced. The angular velocity of the turbine rotor is theoretically assumed as a linear function of intensity $Q$(t) of the flowing oil [Balawender 1983].

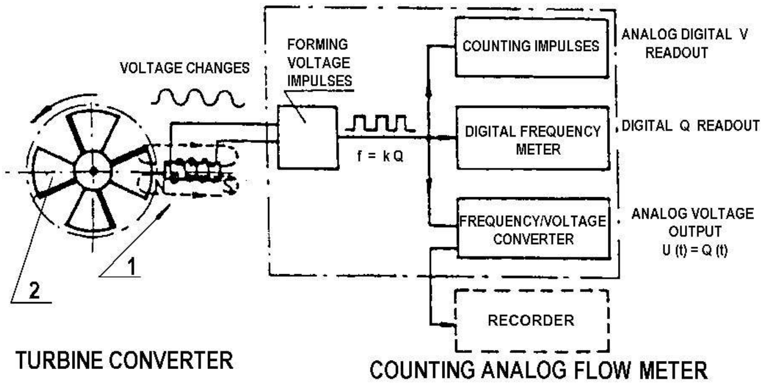


Fig. 3. Schematic diagram of the measuring system of the turbine flow meter
1 – inductive converter, 2 – rotor

The angular velocity of the pump shaft and the engine is measured by counting the impulses sent by a magnetic disc converter situated at the engine shaft. The impulses are counted by means of a table digital frequency meter, type NT2, which can simultaneously measure rotations.

The pressures $p$ were measured by means of electronic membrane pressure sensors.

A diagram of a pneumatic-electric converter, which functions as a manometer with an output electric signal is presented in Fig. 4.

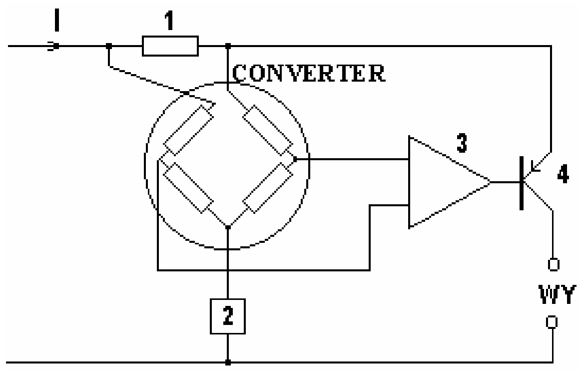


Fig. 4. Diagram of the converter of pressure into current with a piezoresistive sensor:
1 – feedback resistor, 2 – regulator of current powering the converter, 3 – amplifier,
4 – current regulator

The pressure is converted into an electric signal by means of the piezoelectric sensor. Resistors connected in a bridge are diffused in a quartz plate.

The pressure deforms the plate, the diffused resistors change their resistance, and the bridge loses the equilibrium. Subsequently, the output signal of the bridge is transformed in the electronic system into a current signal whose value is proportional to the measured pressure [INTROL – commercial catalogue 1999].

On the basis of the author's own design [Bloch and Zloto: Patent nr 135271] a sensor was constructed for measuring the temperature of the cylinder block in an axial piston pump. The sensor, together with the pump system is presented in Fig. 5, and a block diagram of the sensor can be seen in Fig. 6.

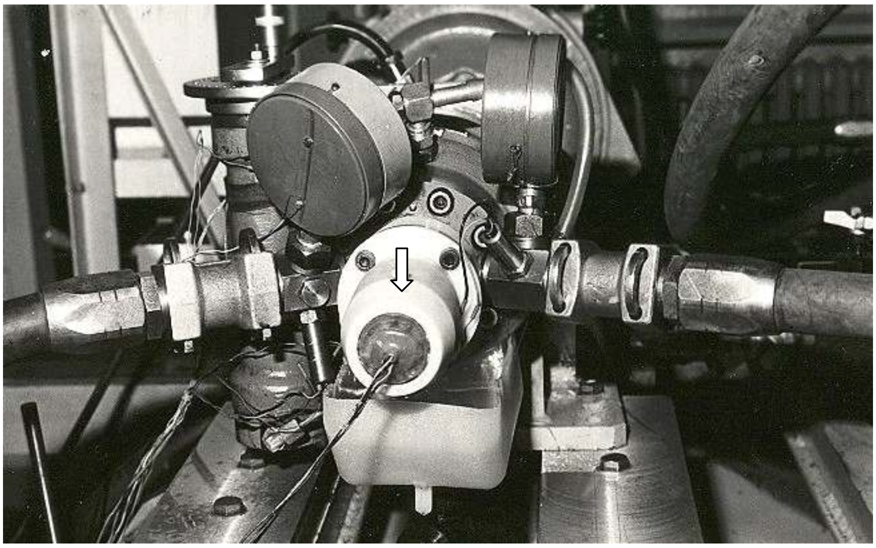

Fig. 5. The view of an optoelectronic sensor for measuring the temperature of the cylinder block in a pump. The sensor is mounted on a hydraulic stand

The sensor consists of a movable part, coupled with the cylinder block of an axial piston pump, and a stationary part. Power is supplied to the movable part from the AC generator 1 through the rotating transformer 2 and rectifier 3. The changes in the temperature $\vartheta$ of the cylinder block cause changes in the resistance $R_\vartheta$ of the thermistor 5, which, in turn, influences the frequency of electrical impulses generated by the multivibrator 4. The electrical impulses from the multivibrator 4 are transformed into light impulses in the LED 6 and transmitted axially to the phototransistor 7, where they are transformed back into electrical impulses of the frequency identical to the frequency of the impulses generated in the multivibrator 4.

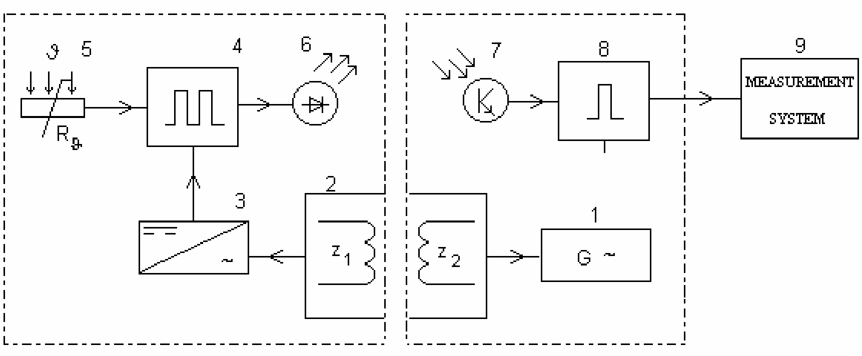


Fig 6. Block diagram of the measuring sensor

Having been standardised in the monovibrator 8 they are transmitted further to the computer measuring system 9. The resultant values of frequency sent to the measuring system are the function of the temperature being measured $f = F(\upsilon)$.

The results of the measurements of the pump operation parameters are displayed at the screen of the presented measuring system (Fig. 7 ).

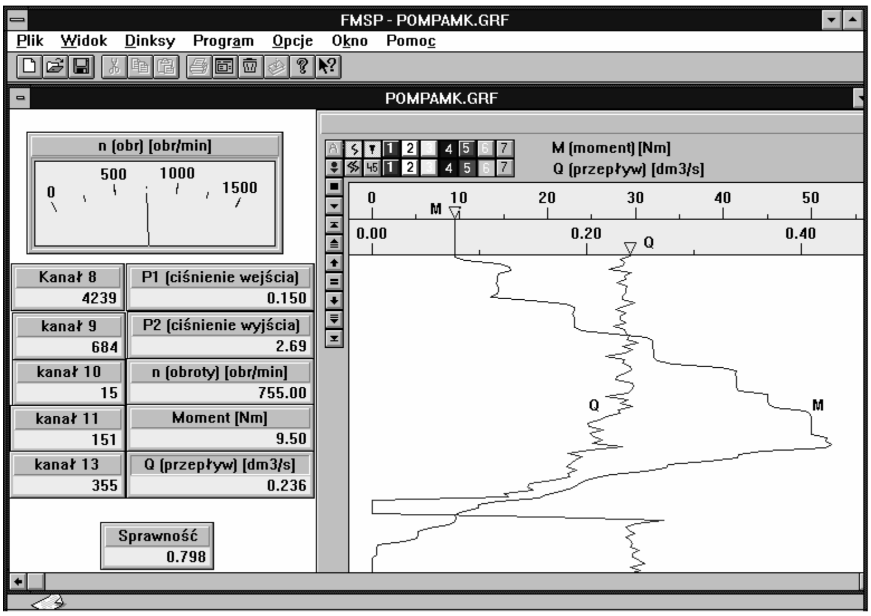


Fig. 7. Graphic representation of the results during a change in the pump parameters

## CONCLUSIONS

1. The parameters of the pump operation can be monitored online by means of the computer-based measuring system.
2. Apart from monitoring and displaying the results, the system makes it also possible to control the experiment.
3. Standard measuring converters can be applied in the system for indirect assessment of the pump efficiency.
4. The accuracy of the obtained results depends mainly on the metrological parameters of the intermediary systems, i.e. modules converting the measuring signals.

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