MEASUREMENTS OF SELECTED PARAMETERS OF A HYDRAULIC PUMP BY MEANS OF A COMPUTER-BASED MEASURING SYSTEM

Tadeusz Zloto [1)], Zygmunt Biernacki [2)], Marek Kurkowski [2)],

[1)] Institute of Machine Technology and Production Automation,
Czestochowa Technical University,
Al. Armii Krajowej 21, 42-200 Czestochowa, Poland, e-mail: zloto@itm.pcz.czest.pl
[2)] Institute of Electronics and Control Systems, Czestochowa Technical University,
Al. Armii Krajowej 17, 42-200 Czestochowa, Poland,
e-mail: biernac@el.pcz.czest.pl , marekekb@poczta.onet.pl

Abstract: The basic characteristic parameters of the pump operation are presented. The parameters are monitored by a computer-based measuring system at a hydraulic stand. The structure of the measuring system and the construction of the measuring converters applied in the system are described.

1 INTRODUCTION

Due to their important advantages, hyraulic drives and controls are commonly applied in a number of fields of mechanical engineering. The still increasing demand for hydraulic drives encourages research on new constructional solutions intended to improve operating parameters, efficiency and to lower production cost.

Each hydrostatic system has a displacement pump as a basic part. The pump changes 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 multipiston pumps which are the most often applied in high-pressure systems. The compact construction of multipiston pumps makes it possible to obtain higher efficiency per unit of volume. Because of that the weight of machines in which multipiston 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.

2 CHARACTERISTIC QUANTITIES OF THE PUMP OPERATION

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:

$$N_t = M_t \cdot \omega = Q_t \cdot \Delta p \qquad (1)$$

where:

N_t is the theoretical power

M_t is the theoretical torque at the pump shaft

ω is the angular velocity of the shaft

$\Delta p = p_2 - p_1$ is the difference between forcing pressure p_2 and suction pressure p_1

It is known [4] that volumetric losses, which deteriorate the theoretical efficiency of pumps, result mostly from leakages of the operating agent from displacement chambers through gaps between displacement elements and the walls of chambers or body of the pump. Knowing volumetric losses one may determine volumetric efficiency of the pump as a ratio of real flow intensity to theoretical flow intensity:

$$\eta_v = \frac{Q_{rz}}{Q_t} = \frac{Q_t - Q_s}{Q_t} = 1 - \frac{Q_s}{q_t \cdot n} \qquad (2)$$

The hydraulic-mechanical losses, on the other hand, cause the real torque applied to the pump shaft to be greater than the theoretical torque. This kind of loss is associated with the flow resistance of the operating agent in the internal channels of the pump as weel as with friction losses occurring on the surface of all the moving parts. Since it is difficult to differentiate between the losses resulting from the two sources mentioned above, they are considered jointly as hydraulic-mechanical efficiency, which may be expressed as the loss torque. The real torque can be represented as a sum of the theoretical torque and the loss torque:

$$M_{rz} = M_t + M_s \qquad (3)$$

The hydraulic mechanical efficiency of the pump is defined as:

$$\eta_{hm} = \frac{M_t}{M_{rz}} = \frac{M_t}{M_t + M_s} = \frac{1}{1 + \frac{M_s}{M_t}} \qquad (4)$$

Ultimately, the total efficiency η_c of the pump is equal to the ratio of the effective power to the power supplied to the pump shaft:

$$\eta = \frac{N_e}{N_{rz}} \qquad (5)$$

After transformations the following was obtained:

$$\eta = \frac{q_n \cdot n \cdot \eta_v \cdot \Delta p}{2\pi n \cdot M_{rz}} = \eta_v \frac{q_{rz} \cdot \Delta p}{2\pi \cdot M_{rz}} = \eta_v \cdot \eta_{hm} \qquad (6)$$

Thus, the total pump efficiency is the product of volumetric efficiency η_v and hydraulic-mechanical efficiency η_{hm}.

Fig. 1 presents the characteristic quantities necessary for determining the pump efficiency [4].

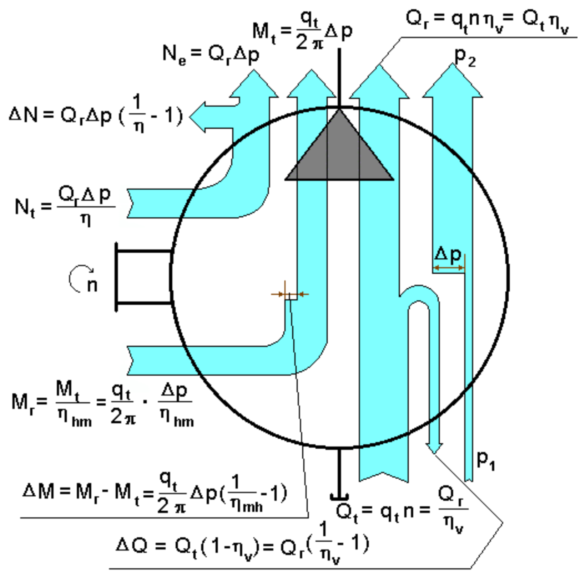

Fig. 1. Quantities characterizing pump operation

3 COMPUTER MEASURING SYSTEM FOR THE PUMP OPERATION PARAMETERS

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.

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. 2.

The measuring system designed and constructed by the authors of the present paper includes a standard PC [5]. It is intended for automatic handling of the experiment, in which data from various measuring converters is observed simultaneously and saved on the disc.

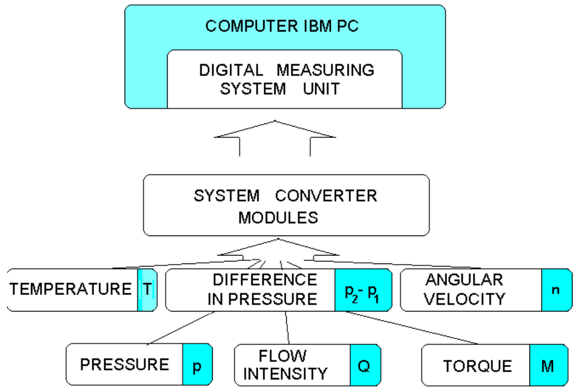

Fig. 2. Block diagram of the measuring system

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 multipiston pump is determined in the following way:

⇒ The torque at the pump shaft is measured by means of an inductive torque meter Mi5 [6]. The measuring system of the inductive torque meter consists of a torque converter and an electronic measuring subsystem (Fig. 3).

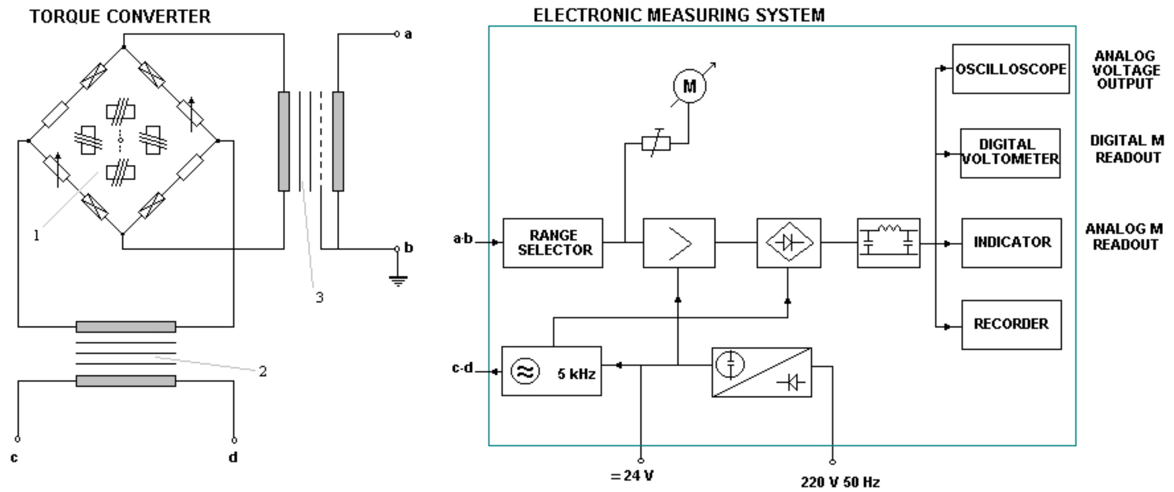

Fig.3. Schematic diagram of the inductive torque meter
1 – inductive converter with a Wheatstone bridge, 2 and 3 – rotational transformers

⇒ Flow intensity Q is measured by means of a measuring set consisting of a turbine converter and a counting analog flow meter (Fig. 4). The angular velocity of the turbine rotor is theoretically assumed as a linear function of intensity Q(t) of the flowing oil [2].

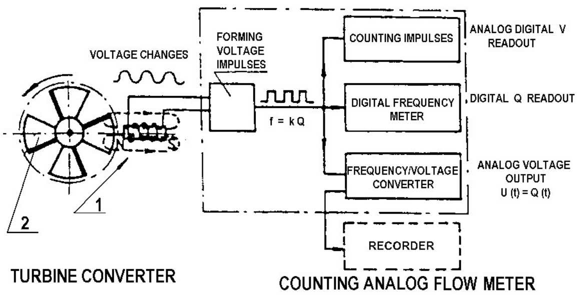

Fig. 4. Schematic diagram of the measuring system of the tubine flow meter
1 –inductive converter, 2 – rotor.

⇒ The rotational 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 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. 5. 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.

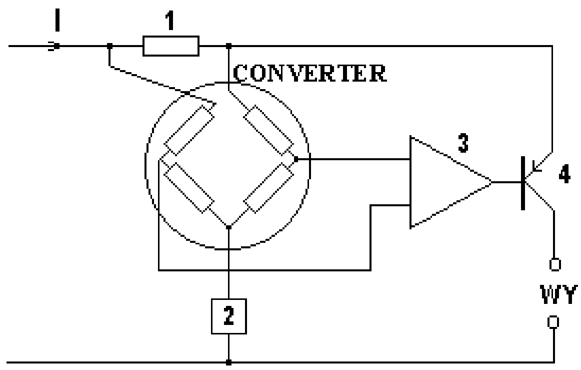

Fig. 5. Diagram of the converter of pressure into current with a piezoresistive sensor
1 – feedback resistor,
2 – regulator of current powering the converter ,
3 – amplifier,
4 – current regulator.

The results of the measurements of the pump operation parameters are displayed at the screen of the presented measuring system (Fig. 6).

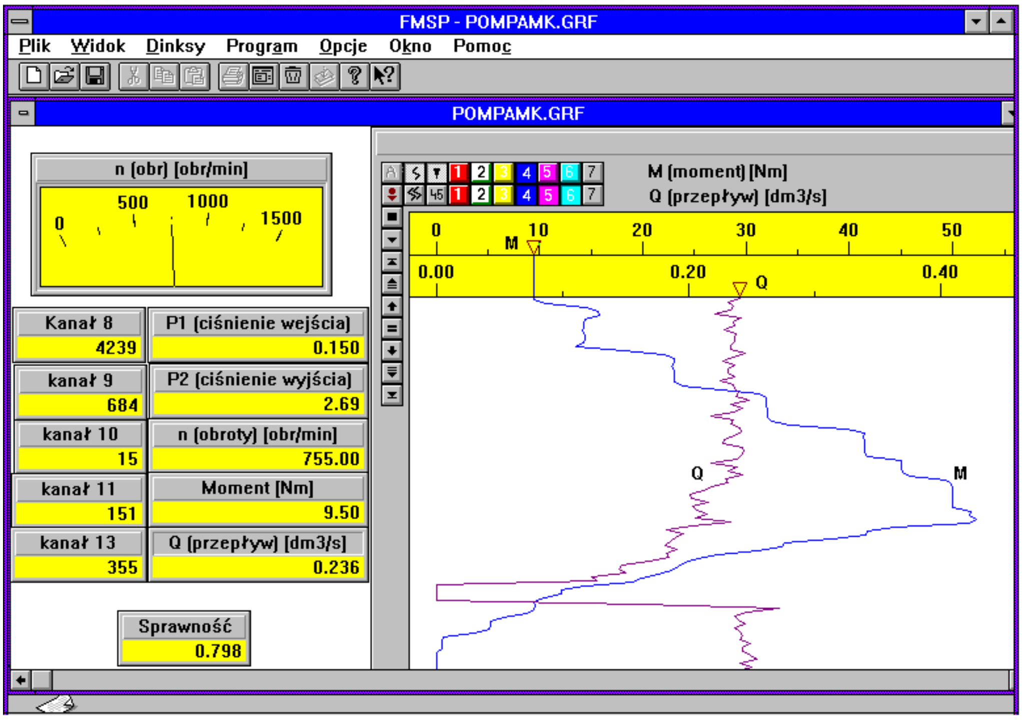

Fig.6. Graphic representation of the results during a change in the pump parameters

4 CONCLUSIONS

The analyses of the results obtained in the experiment lead to the following conclusions:

♣ The parameters of the pump operation can be monitored online by means of the computer-based measuring system.

♣ Apart from monitoring and displaying the results, the system makes it also possible to control the experiment.

♣ Standard measuring converters can be applied in the system for indirect assessment of the pump efficiency.

♣ 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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