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PRELIMINARY TESTING OF THE GEAR PUMP WITH INTERNAL GEARING WITH MODIFICATION OF THE SICKLE INSERT

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Abstract: *The paper presents the requirements for hydraulic positive-displacement pumps. Modifications have been made to the sickle insert of the gear pump with internal gearing. This procedure allowed to obtain radial compensation. The preliminary test stand to plot the characteristics of the pump before and after modification was discussed. The results of measurements from the conducted tests are presented.*

Key words: Gear pump, internal gearing, capacity, sickle insert.

1. Introduction

The gear pump currently, it is one of the most frequently used positive-displacement pumps in hydraulic drive systems. Today's development of hydraulic technology is related to the widespread of electronics and automation systems in machine construction. The advantage of hydraulic drive systems is the wide possibility to control both the speed and power of receivers. The introduction of modern, multi-level electronic systems in hydraulic systems has contributed to smooth regulation and a significant reduction in the noise emitted by them. Additional works related to the optimization of the construction of hydraulic system components are currently in progress. This mainly applies to two directions: minimizing their mass, which is associated with the reduction of their dimensions or the use of new light and high-strength composite materials (Błażejewski et al., 2018) and the reduction of noise emissions (Fiebig et al., 2015). Over the last few years, the development of micro-hydraulics has been observed, which is widely described in the literature (Kollek et al., 2014). An unquestionable advantage of hydraulic systems is the transfer of high power, which is associated with high pressures generation. Gear units: pumps and motors, are widely used in hydrostatic drive systems (Śliwiński, 2012). The universality of gear pumps results from their simple construction, relatively low price and high durability (Rundo, 2017). This construction is used in the production of displacement micropumps. The requirements for micropumps are: low geometrical efficiency, obtaining high discharge pressures, small changes in performance with increasing pressure, high efficiency and durability, resistance to contamination and low manufacturing costs. They can be found both in drive and lubrication systems of machines and vehicles. They are characterized by high working pressures reaching 35 MPa and volumetric efficiency exceeding 90%. They are also distinguished by their long service life. In addition, they can pump liquids at high rotational speeds, which places them first among positive-displacement pumps in this respect. The basic division of gear pumps distinguishes between gear pumps with external and internal gearing (Lambeck, 1983). The most common pumps in the industry are gear pumps with external gearing - thanks to their simple design and

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low price. The use of pumps with internal gearing is becoming more common (Stryczek et al., 2014). This is due to the fact that they emit lower noise level, are characterized by lower unevenness of efficiency and more compact construction in relation to pumps with external gearing. As a result of the cooperation between the external and internal gearing, a very high degree of gears coverage and a favorable seal at their contact point is achieved due to an increased circumference of the wheels in contact with the suction and discharge space. In addition, the high degree of coverage results in smoother pump operation, reduced filling losses, reduced pulsation of capacity and pressure, and lower noise levels. For this reason, it is worthwhile to apply further measures aimed at increasing the efficiency of these pumps and achieving higher pumping pressures (Lewis et al., 2005).

2. Measurement stand

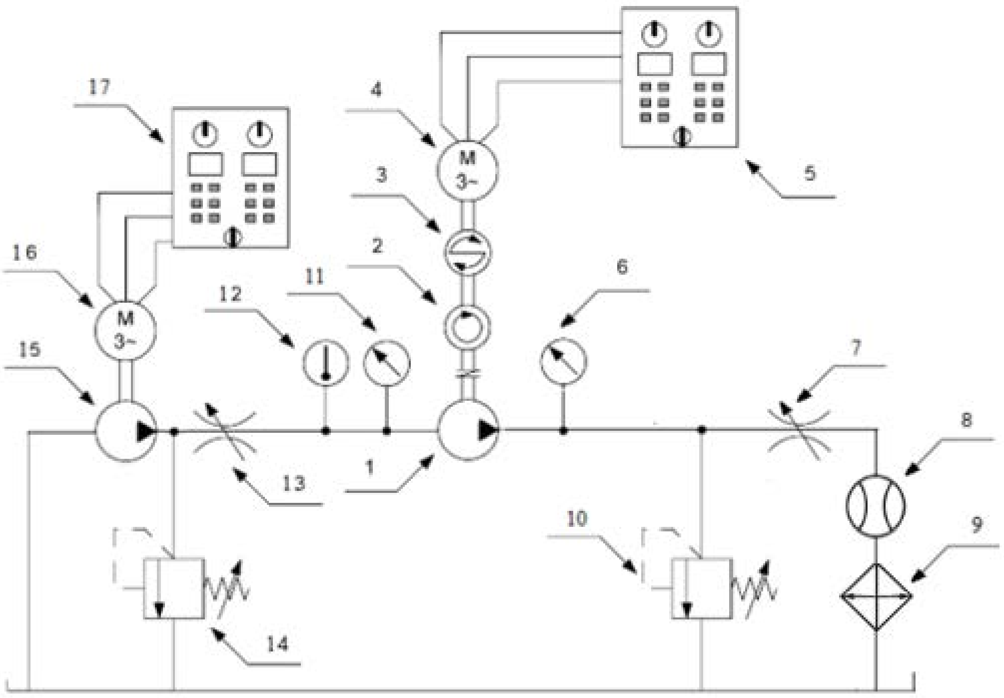

Fig. 1: Hydraulic diagram of the test system. 1 - Gear pump tested, 2 - tachometer, 3 - torque meter, 4 - electric motor, 5 - control cabinet, 6 - pressure gauge, 7 - throttle valve, 8 - flow meter, 9 - cooler, 10 - safety valve, 11 - manovacuometer, 12 - thermometer, 13 - throttle valve on the feed pump discharge line, 14 - safety valve on the feed pump discharge line, 15 - feed pump, 16 - electric motor driving the feed pump, 17 - control cabinet of electric motor driving the feed pump.

A diagram of the test system is shown in Figure 1. An additional pump 15 on the tested pump 1 power supply allowed a constant pressure to be maintained on the suction port of the tested pump. The tested pump 1 was protected against overload by an adjustable safety valve 10. The load of the unit is realized by a throttle valve 7. Actual capacity was measured by means of flow meter 8. Pressure gauge 6 allowed to read the delivery pressure of the pump. The torque was measured with a torque meter 3. The rotational speed n of pump 1 is controlled on the torque meter shaft by means of a magnetic sensor. Torque meter is mounted in accordance with Fig. 1 on the shaft of the drive motor, using a flexible coupling. The measuring set allowed to record the torque on the motor shaft and its rotational speed in real time. The tests were carried out after the trial run of the test stand. During this movement, the operation of the pump, safety valve and indications of all measuring instruments were checked. After determining the proper operating parameters of the pump, the measurements of the pump’s characteristics were undertaken. The measurement was carried out at 3 selected rotational speeds. The pump load was carried out for p_t from 6 to 20 bar in 1 bar increments due to the pump body and modified plastic sickle insert. After stabilization of the working conditions, the measured values were read out on the meters. The study was carried out for a constant temperature of the working medium of 333 K. The measurements were carried out with the use of measuring instruments connected to a computer, thanks to which the measurements were recorded. Further data processing was carried out in Microsoft Excel software.

3. Results of the study

The hydraulic system has been activated to carry out basic tests. Measurements of pressure on the pump discharge line were carried out. The tested pump differs from the conventional pump by an additional modification in the sickle insert which is radial compensation. The details of the modification were not presented due to the pending patent proceedings. Measurements were carried out on one pump, only the sickle inserts were changed. The first insert was made of POM plastic without modification, the second one was also made of POM plastic but with modification, and the third one was made of PA plastic also with modification. Each time the sickle insert was changed, the screws for folding the pump body were tightened to the same torque of 20 Nm with a torque wrench. The results of the measurements are presented below.

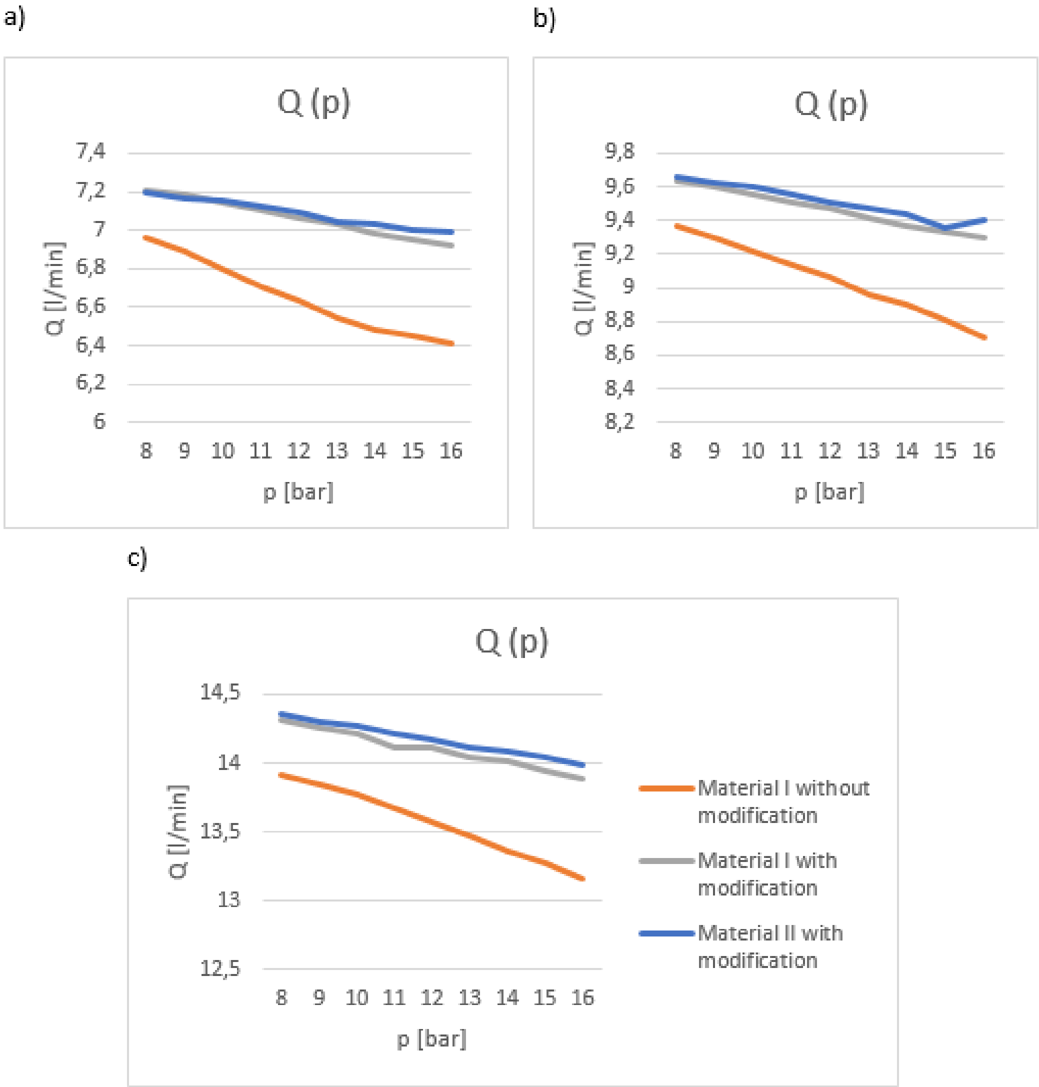

Fig. 2: Characteristics of gear pump with internal gearing with different sickle inserts tested at different speeds of the pump shaft: a) n = 750 [rpm] b) n = 1000 [rpm] c) n = 1500 [rpm].

It can be seen on the basis of the measurements carried out that the introduced modification allows the pump capacity to be maintained at an increase in pressure. Without modification, the capacity decreases significantly with pressure increase. For a pump with an insert without modification, the rate of capacity decrease with increasing pumping pressure is higher than for a pump with a modified insert. In addition, an increase in the actual capacity of the pump with modified insert compared to a pump with an unmodified insert for the same pumping pressure was noted. For confirmation, the advantages of the design modification of the sickle insert, various materials with different mechanical parameters were considered.

4. Summary

The subject of the research is an internal gearing pump with compensation for radial clearances by inserting an incision in the sickle insert. This type of pump is used to generate the flow rate and pressure in the liquid stream in all types of hydraulic systems and lubrication systems. It is known from the Polish patent description to execute in the pump body with external gearing for compensation radial clearances by inserting symmetrically on both sides of the pumping chamber, along the working chamber of two channels separated from the working chamber by flexible languages. This embodiment compensates for radial clearances caused by stresses in the pump body resulting from the action of high pressure. This type of radial compensation has been introduced in a gear pump with external gearing . It is known from the German patent description to introduce radial compensation by modifying the sickle insert. In both solutions, the sickle insert consists of several elements, as a result of pressure increase in the pressure chamber, the insert elements are in contact with the tooth tips. By pressing the mentioned elements, an increase in tightness in relation to pumps without compensation is achieved. Currently manufactured pumps own axial and radial compensation. Axial compensations are most often used because they are cheap and relatively easy to make. Radial compensation is less commonly used. Due to the introduction of increasing pressures in hydraulic systems, the use of radial compensation is indispensable to obtain a higher pressure in this type of pumps. The essence of the mentioned introduction of modifications in the positive displacement pump is the hollow of the sinus inside the crescent insert over its entire width. The entrance to the bay chamber is located on the pressure chamber side. As a result of the introduced design change, two flexible languages were created in the sickle insert. As a result of pressure increase in the pressure chamber due to loading, the resulting tongues are pressed against the surface of the toothed wheels. In order to prevent the sickle insert from moving during the rotation of the gears, a pin was used, placed in the pump body. The main benefit of the introduced structural change is the compensation of radial clearances, reduction of the efficiency drop along with the increase of the pump discharge pressure and its efficiency improvement. The results presented above confirm the validity of these conclusions. Regardless of the material used for the insert, the modification introduced brings comparable performance. The next step to increase the efficiency of the pump is to place a piston inside the channel, which on one side is supported by a spring, and on the other by the pressure prevailing in the pumping chamber of the pump. The piston moves as the pressure in the pump's pressure chamber increases. When the pressure drops, the piston will return to its original position by means of a spring. This means that pumps with a modified insert are characterized by higher volumetric efficiency values than the pump without a modified insert. If the hydraulic-mechanical efficiency remains unchanged, the overall efficiency of the modified unit will increase. This further increases the competitiveness of the pumps with internal gearing compared to the external gear pumps.

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