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DEVELOPMENT AND EXPERIMENTAL RESEARCH OF A WATER HYDRAULICS PISTON AXIAL PUMP - THE MOST IMPORTANT COMPONENTS OF THE REVERSE OSMOSIS SYSTEM

RAZVOJ I EKSPERIMENTALNA ISTRAŽIVANJA KLIPNO AKSIJALNE PUMPE VODNE HIDRAULIKE-NAJBITNIJE KOMPONENTE SISTEMA REVERZIBILNE OSMOZE

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SUMMARY

This paper presents the results of experimental testing performed in order to determine operating parameters of an axial piston water hydraulic pump. The test installation for the axial piston water hydraulic pump was designed combining the existing test stand for oil hydraulics testing and a newly built part for testing water hydraulics components. The unique test stand, built for this research, provides a good starting point for further study of different water hydraulics components.

Key words: axial piston pumps, measuring equipment, development, research, water hydraulic components, reverse osmosis,

INTRODUCTION

Water and energy are two most important factors in the development of human society. Climate change, urban population growth and industrialization have increased the demand for drinking water. Research has shown that a small percentage of all freshwater produced in the world is from renewable sources. By developing technology, lowering equipment prices and increasing attention to the environmental problems of fossil fuels, utilizing renewable energy is growing [1].Water scarcity is the major problem the world is facing at present, with increasing demands of good quality of water in many regions due to the massive increase in the population and growth of economies [2]. The importance of high quality drinking water for public health and production processes makes water treatment and desalination plants crucial infrastructure elements.Water from seasand other saline water bodies is not suitable for direct human consumption, agricultural and industrial purposes. Ninety-seven percent of the Earth's water is found in the oceans, with the salt content of more than 30,000 mg/L [3]. Water, with a

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dissolved solids (salt) content below about 1000 mg/L, is considered acceptable for community water supply [4]. Because of the potentially unlimited availability of seawater, people have made great efforts to develop feasible and cheap desalting technologies for converting salty water into fresh water. A variety of desalting technologies have been developed over the years, including primarily thermal and membrane processes. Desalination is the process of removal of salts from the feedwater, typically containing a high concentration of salts, to produce freshwater. The main process is reverse osmosis (RO).

Reverse osmosis (RO) is based on applying excess pressure to reverse the spontaneous process of osmosis, where water in solution moves across a semi-permeable membrane from lower solute concentration to the higher solute concentration. In RO plants, this excess pressure is applied by high pressure pumps which push seawater through semi-permeable membranes to obtain desalinated water [5]. Figure 1 shows a schematic diagram of the RO process. The major components of an RO plant are: the seawater intake system, feed pre-treatment facility, high pressure pumps, RO membranes, and brine disposal and post-treatment facility. The high-pressure pump is an important and precise component, and its operating state directly affects the performance of the RO system.

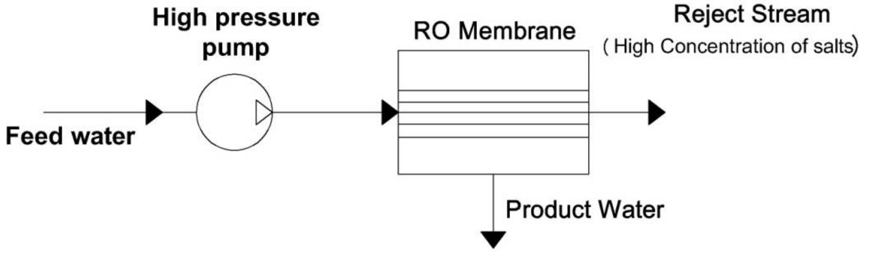


Fig. 1. Schematic Diagram of the Reverse Osmosis Process.

A special attention in this research was paid to development and experimental research of water high pressure hydraulic pumps MAP 10.2, Fig.2. [6]-[8]. There are some technological challenges to be met so that water hydraulic systems can become more competitive and more reliable compared to oil-hydraulic and pneumatic systems. Due to specific physical and chemical properties of water, the components and hydraulic systems have to be adapted for water hydraulics. Research of water hydraulic pumps involves material, pump design and pump testing, as well as service life testing [9]-[14]. Water hydraulic pump testing usually requires special equipment.

An axial piston pump is the most important component of water hydraulic systems. It is widely used in the fluid power industry because of its robustness, controllability, wide operating range and compact size. In order to develop water hydraulic axial piston pumps and motors, as the basic constructional parts of water hydraulic systems, it is necessary to use new materials and optimal structures to overcome rust, leakage, and low lubrication ability inherent in water. To improve the efficiency and reliability of water hydraulic axial piston pumps and motors, the bearing/seal parts that significantly affect their performance and reliability must be studied thoroughly [17]-[20].

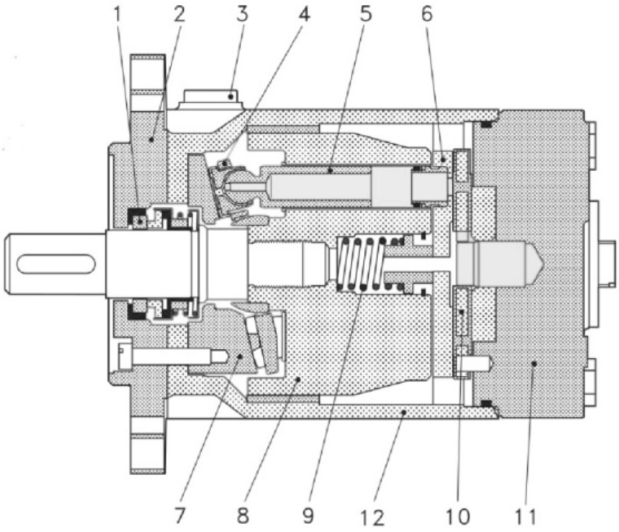


Fig.2 Axial piston pump MAP 10.2
1) Shaft sealing; 2) Mounting flange; 3) Bledding plugs; 4) Retaining ring; 5)Piston; 6) Valve plate; 7) Swash plat; 8) Cylinder barrel; 9) Spring; 10) Port plate; 11) Connecting flange; 12) Housing with bearing

INSTALLATION FOR EXPERIMENTAL RESEARCH

A comprehensive testing was carried out at the Research and Development Center RDC-PPT Namenska in Trstenik, the Republic of Serbia, in cooperation with the Faculty of Engineering of the University of Kragujevac and the company Miolma GmbH, Switzerland. The axial piston pump MAP 10.2 was tested using installation specially designed for the purpose of this experiment [21]-[25]. The installation used for testing of these water hydraulic components was designed combining the existing installation for testing hydraulic components for oil hydraulics and some elements of installations for water hydraulics.The hydraulic scheme of the test installation for the axial piston water hydraulic pump MAP 10.2 is shown in Fig. 3.

The basic drive component of the test installation is a hydraulic test stand BAC 2063. The test stand BAC 2063 is used for testing hydraulic components such as pumps, hydraulic motors, directional control valves and other valves which use mineral hydraulic oil as the working fluid. For the test installation designed for the purpose of this experiment, the test stand BAC 2063 was used as the drive component to power the axial piston water hydraulic pump.

Water was used as the working fluid. The pump was supplied from the city public water supply through the water supply connection. The pressure at the pump inlet was always within the range determined by the research plan. The pump load at the outlet was regulated through the tap (7) shown in Fig.2. The pump outlet load is determined by the pressure in the discharge pipeline. The value of this measuring quantity was also within the range defined by the initial research plan (0-80 bar).

The following quantities were measured:

- The rotational speed of drive shaft n
- The pressure p_i at the pump outlet

- The pressure p_u at the pump inlet
- The fluid flow Q
- The torque M of the pump drive shaft.

The pressure was measured using measuring transducers without measuring tapes P3MA, manufactured by Hottinger, with the measuring range from 100 to 500 bar, accuracy class 0.1 and transmission range 100 kHz. The flow was measured by the flow meter RE 3-300, manufactured by Hydrotechnik, with the range of 15-300 lit/min, accuracy class 0.2. The torque and the number of rotations of the pump drive shaft were measured by the measuring transducer T30FN, manufactured by HBM, with the measuring range of 3000 rpm and 500 Nm, accuracy class 0.2. The measuring transducer T30FN was installed between the electric motor and the gearbox of the pump drive shaft. This measuring transducer is an integral part of the test stand BAC 2063. For data acquisition, a universal acquisition system QuantumX MX840B produced by HBM, with accuracy class up to 0.01, was used. This system employs MX Assistant and enables a continual measurement and calculation of the characteristic parameters of the pump working cycle in real time. The system QuantumX has 8 channels with 24-bit A/D converters per channel and simultaneous measurement on 8 channels. For the purpose of this experiment, simultaneous measurements were done on 5 channels. The sample rate is 192 kHz per channel. The software enables measurement of cyclic and non-cyclic fast-changing processes with graphic representation. The statistics of the data changed in the process are displayed in graphics. The acquired data can also be exported into different file types for further analysis.

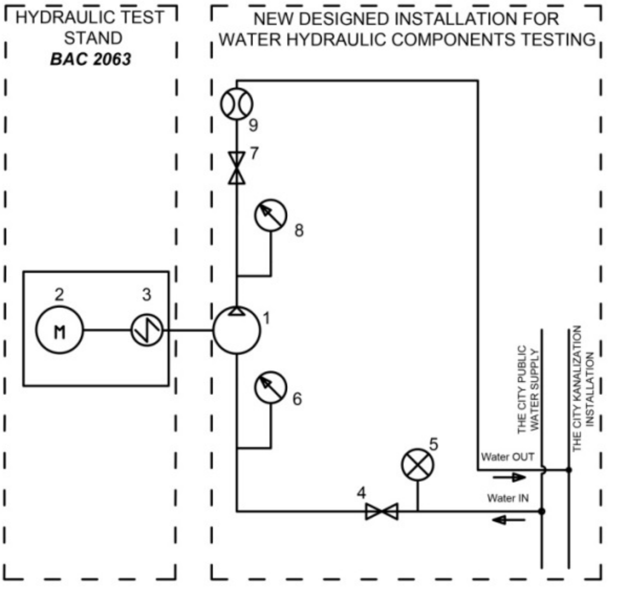
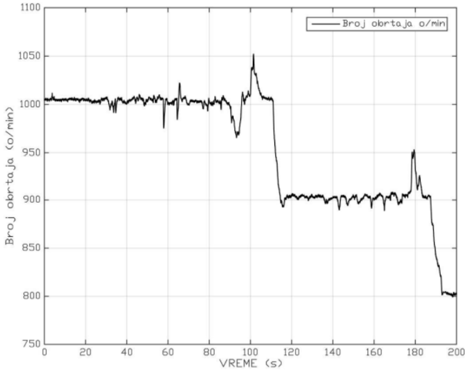


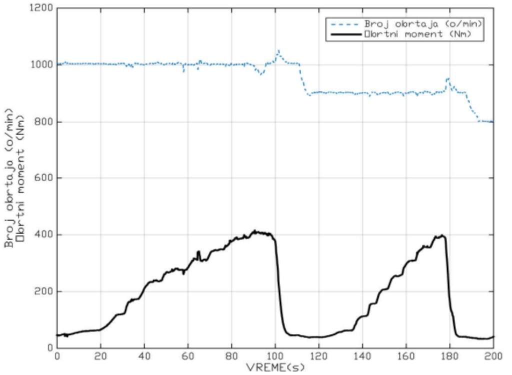
Fig.3. Hydraulic scheme of the installation for the axial piston pump MAP 10.2 testing
1-Axial piston pump MAP 10.2, 2-Electric motor 37kW, 3-Measurement transducer of the rotational speed and torque of the pump drive shaft, 4-Suction tap, 5-Manometar, 6-Pressure transducer at the pump inlet pipeline, 7-The tap at the discharge pipeline, 8-Pressure transducer in the discharge pipeline, 9- Turbine flow meter

RESULTS

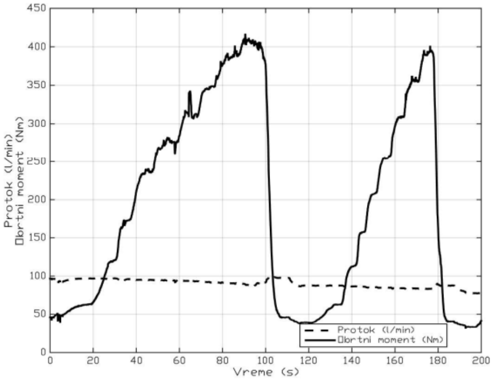
The test results are obtained for the following parameters of the pump: rotational speed of drive shaft, pressure at the pump outlet, fluid flow and the torque of the drive shaft, all measured as a function of time τ.



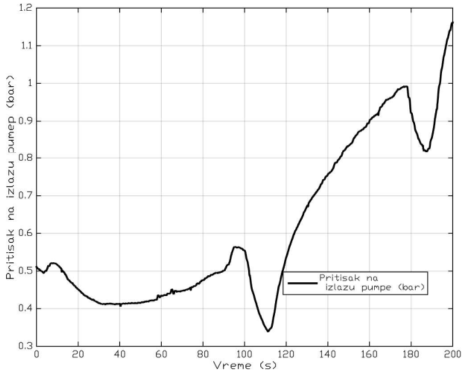
4a.



4b.



4c.



4d.

Fig. 4 Diagram of the pump operating parameters
4a. The rotational speed of the drive shaft n as a function of time τ
4b. The drive shaft torque M and rotational speed of the drive shaft n as a function of time τ
4c. Pressure p_i at the pump outlet as a function of time τ
4d. The change of the fluid flow Q and The drive shaft torque M as a function of time τ

The diagrams in Fig.4 show the interdependence of the four operating parameters of the water hydraulic piston axial pump. The diagrams were obtained using data processing software QuantumX Assistant, specially developed for this type of research. The acquisition of the working parameters was done in the 200 s interval. The rotation speed was varied from 1000 rpm to 800 rpm. The value of the rotation speed was changed every 100 s. During this period, the value of the rotation speed was unchanged, and during this time the value of the outlet pressure was varied from the minimum setpoint to the maximum setpoint of the pressure at the outlet of the pump. This procedure was repeated for each new value of the rotation speed.

CONCLUSION

It should be pointed out that the test obtained results are compliant with the experimental results for axial piston pumps given in papers [15] and [16]. The tests conducted in these studies were performed on a relatively expensive test equipment specially designed for water hydraulics testing.

The experimental test results presented in this paper are very important because they can be used for mathematical modelling and development of software for identification and optimisation of the pump working parameters. Designers will find these results especially valuable in designing new or improving the existing models of water hydraulic axial piston pumps.

The working parameters of the axial piston pump cannot be accurate enough if they are determined only by means of experiment or only by means of mathematical modelling. Accurate parameters can be determined through combination of experimental tests, mathematical modelling of the hydrodynamic process and methods of nonlinear optimisation. This way it is possible to identify measurement mistakes and unknown parameters.

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