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Scientific paper

SUSTAINABLE DEVELOPMENT OF AGRICULTURE TECHNIQUES USING WATER HYDRAULIC COMPONENTS

ODRŽIVI RAZVOJ POLJOPRIVREDNE TEHNIKE KORIŠĆENJEM KOMPONENTI VODNE HIRAULIKE

Todic N.[1],Vulovic S.[1],Petrovic R.[2],Vujovic I.[3], Savic S.[1]

SUMMARY

This paper focuses on development of agriculture techniques using water hydraulic components. A special review of the developments is given on hydraulic power components, ie piston axial pump of water hydraulics. The main focus areas are discussed and the challenges and possible solutions of each subject are analyzed [1].Water quality aspects, component technology, control aspects and also applications are covered. Trends confirm that design of water hydraulic application is a natural approach to solve many of the major environmental pollution problem and problems in industries, which cannot accept contamination of products and problems of fire and explosion risk. The paper presents a research on trends in development and best practise in design of both low-pressure and high-pressure tap water hydraulic components and systems for motion control as well as open-ended solutions various industrial applications.

Key words: axial piston pump, water hydraulic, valve plate, cylinder block,

INTRODUCTION

The business sales history confirms that the use of modern water hydraulics shows a growing turnover per year. Important industrial applications and the benefits are presented with focus on process industries such as food industry, pharmaceutical processes, water mist fire fighting systems, high water pressure cleaners, water moisturising systems for a humidification, wood processing (sawmills and lumber drying processing), and industrial mobile machines and municipal machines working in environmentally sensitive surroundings [2]. A unique breakthrough with the success of development, design and implementation is the process called Reverse Osmosis (drinking water from sea-water) by novel dedicated axial pumps and valves

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using special material to operate with sea-water.

If we are thinking about the lifecycle of hydraulic oil and the costs related to every phase, the total sum will grow quite very high.We have to take into account all the investments related to drilling the oil, transportation, refining, marketing, delivery, use and disposal. Naturally it is impossible to find out just costs focused on hydraulic oil, because also other oil products are produced always at the same time. When comparing the supply of oil and water to each other, the difference is quite essential. Oil drilling is huge business, which needs big investments. For example the oil rigs have to be able to build in deeper water in the future. That means even bigger investments. Water is instead easily available and for example from sea water it is relatively easy to produce water for water hydraulic systems. One important factor globally is the packages for oil products. All the oil products are packed to barrels, containers, cans etc. The production of these packages requires a lot more extra energy than taking the water from tap [3]. The use of water in hydraulic system needs extra care considering the water quality. Microbiological growth is a phenomenon, which causes extra costs for maintenance and service. Also when using some additives for preventing microbial growth, some extra costs are generated. On the other hand storage of water is much easier and normally, when tap water is used, no storage costs are generated. Also, water doesn't wear out, so the fluid replacement can be less frequent than with oil. That is also very much according to sustainable development, because less energy is used for fluid replacement and the disposal is every time easier than with oil, which have to be transported to special disposal plants [4].

Energy efficiency of machines and systems will be also very important aspect in the future. The consumption of energy during system building, system use and system disposal have to be minimized. So the whole life cycle of the whole systems have to be considered. When thinking about water hydraulics, the situation is versatile. Due the material requirements of components, the system building costs are higher than oil hydraulics at present. The reasons for that are, for example, base materials and very small production quantities. In high pressure water hydraulics the price difference can be 3-5 times. However, in low pressures the price difference is decreasing [5]. The energy consumption per system can be evaluated to be higher, because the materials used are requiring longer machining times and more complicated processing that in oil hydraulics.

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The use of water instead of oil is offering benefits, when considering energy consumption. The pressure losses in pipes and components are smaller with water than oil, which is clear benefit, with large flows and long pipes. On the other hand the leakages could easily be higher with water [6]. This, of course, leads to use of smaller clearances and seals, which can increase friction and that way energy consumption. However, the basic design and control principle of the system have very big role for the system energy consumption. If the basic design doesn't include relief function when needed, controllable pump rotation speed when needed or the control valve or block have to have small flow paths,the energy losses can rapidly increase. In accurate and fast control tasks with digital water hydraulics, also control algorithms can be optimized considering the minimizing of energy consumption [7]. When evaluating the system components disposal after the use, no significant differences between water and oil hydraulics can be found.

RESEARCH OF AXIAL PISTON PUMP OF WATER HYDRAULIC

The research and development challenges were to find engineering solutions to the specific problems in design and manufacturing of water hydraulic components and industrial systems

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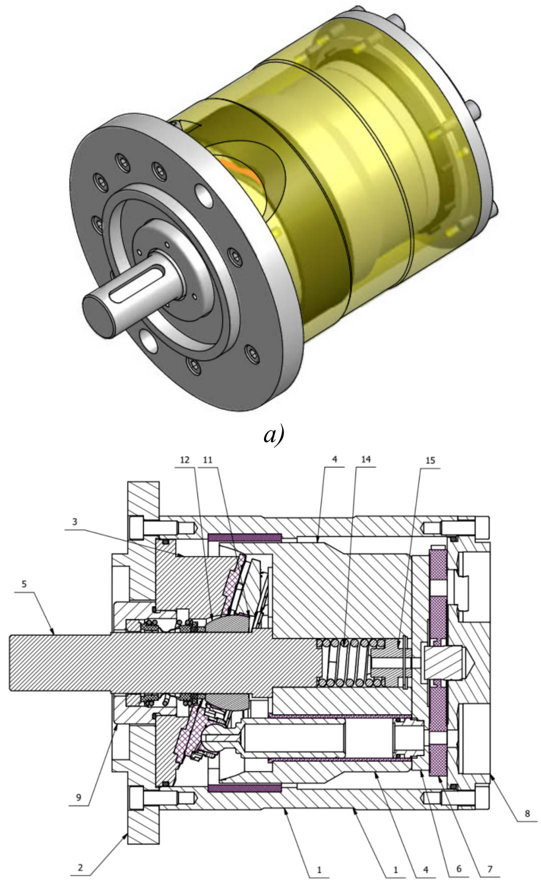
suitable for using pure tap water as the pressure fluid [8-9]. Current technological efforts for water hydraulics are far less than those for oil hydraulics. The experience gained from oil hydraulics is very important for future water hydraulics research. Fig.1 shows axial piston pump, in which the valve plate and swash plate are fixed, the shaft drives the cylinder block rotation and the pistons reciprocate in it when the axial piston pump operates. There are three friction pairs in axial piston pump, that is, cylinder block/valve plate, slipper/swash plate and piston/plunger cavity. The cylinder block-valve plate plays important role in axial piston pump because its failures predominate in maintenance [10-12].

The axial piston pump usually contains 7 or 9 pistons in the rotating cylinder block. The pistons execute linear movements into the cylinders. During one revolution the pistons execute the full stroke. The pistons are connected to the swashplate with slippers, which allows rotating motion against the swashplate. The swashplate has an inclination angle which defines the stroke of the pistons. The theoretical flow of the pump is worked out with the piston area, stroke of the pistons, number of the pistons and the rotation speed of the cylinder block. The valve plate realizes the connection of the piston chambers to the suction and pressure ports. The swashplate and the valve plate are fixed and the cylinder block is the rotating part.



b)

Fig. 1. The axial piston pumps of high pressure (model A180M464.10.10)
a) 3D model, b) Cross-sectional view :
1-Housing with bearing, 2-Mounting flange, 3-Swash plate, 4-Cylinder barrel, 5-Shaft, 6-Cylinder barrrel plate ,7-Valve plate, 8-Cover, 9-Nut, 11-Distancer, 12-Spherical ring, 13-Piston, 14-Spring,15-Spring holder

Axial piston pump of water hydraulic are pumps of high pressure. The high-pressure pumps have versatile applications in land-based, marine or offshore plants. This pumps are designed for Reverse Osmosis .

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NUMERICAL ANALYSIS OF THE VALVE PLATE USING THE

FINITE ELEMENT METHOD (FME)

Numerical analysis of the valve plate was developed within the FEMAP (**F**inite **E**lement **M**odeling **A**nd **P**ostprocessing) software. In computer softver FEMAP created finite element model [13] . The valve plate is modeled using 3D tetra elements with midside nodes. The model consists of 307644 nodes and 205323 elements Fig 2.

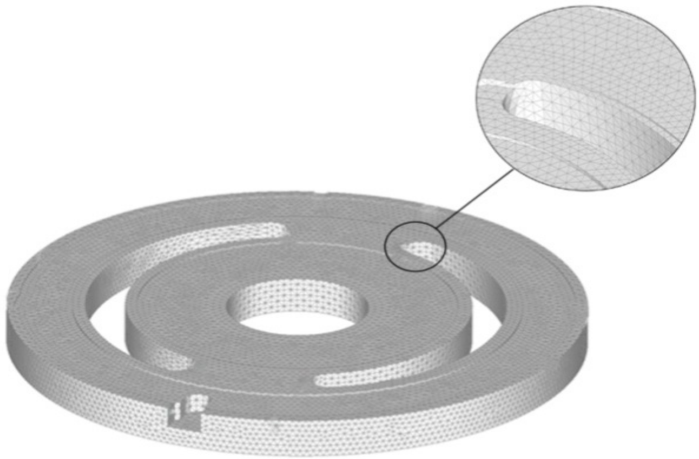
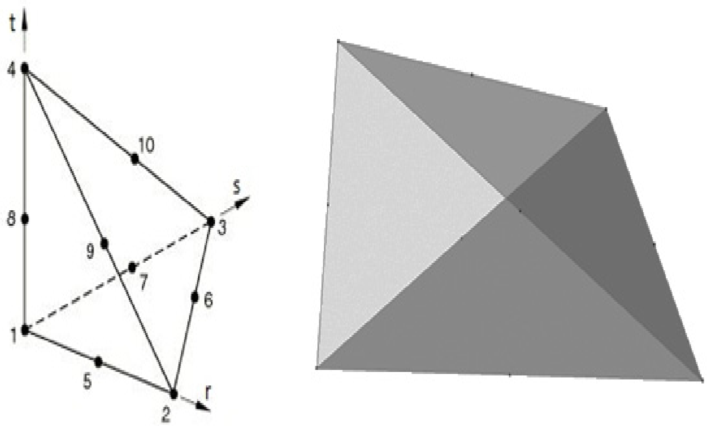


Fig.2.Valve plate modeled using 3d tetra elements (307644 nodes and 205323 elements)

The tetrahedron finite element with the nodes is shown in Fig.3, while the inerpolation functions are given in Table 1. [14]. Using the FEMAP softver, the mesh has been automated. The average length of the side of the tetrahedron is 1.5mm.



a) b)

Fig. 3. a)Coordinate system and nodal points b)Tetrahedron with 10 nodes

The positions of the integrable points of the tetrahedral finite element in the local coordinate system in the case of using five integration points are given in Table 2.

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Tab. 1. Interpolation functions of four to ten variable-number-nodes threedimensional tetrahedral element

$h_1=$	*1-r-s-t*	$-\frac{1}{2}h_5$	———	$-\frac{1}{2}h_7$	———	———	$-\frac{1}{2}h_{10}$
$h_2=$	*r*	$-\frac{1}{2}h_5$	$-\frac{1}{2}h_6$	———	$-\frac{1}{2}h_8$	———	———
$h_3=$	*s*	———	$-\frac{1}{2}h_6$	$-\frac{1}{2}h_7$	———	$-\frac{1}{2}h_9$	———
$h_4=$	*t*	———	———	———	$-\frac{1}{2}h_8$	$-\frac{1}{2}h_9$	$-\frac{1}{2}h_{10}$
$h_5=$	*4r(1-r-s-t)*						
$h_6=$	*4rs*						
$h_7=$	*4s(1-r-s-t)*						
$h_8=$	*4t(1-r-s-t)*						
$h_9=$	*4rt*						
$h_{10}=$	*4st*						

The Fig.4 shows the tetra element in which maximum stress is achieved. This stress was achieved by using material PEEK [15-16]. The maximum displacement of the valve plate made of material PEEK is 5.86 microns. For the analyzed cases, stresses in the valve plate did not differ significantly. In further work, we will study the remaining parts of the pump.

Tab. 2. Five integration points - Positioning and weight coefficients

Points No.	*Position r_i (r,s,t)*	*Weights w_i*
1	$\left(\frac{1}{4},\frac{1}{4},\frac{1}{4}\right)$	$-\frac{2}{15}$
2	$\left(\frac{1}{6},\frac{1}{6},\frac{1}{6}\right)$	$\frac{3}{40}$
3	$\left(\frac{1}{6},\frac{1}{6},\frac{1}{2}\right)$	$\frac{3}{40}$
4	$\left(\frac{1}{6},\frac{1}{2},\frac{1}{6}\right)$	$\frac{3}{40}$
5	$\left(\frac{1}{2},\frac{1}{6},\frac{1}{6}\right)$	$\frac{3}{40}$

CONCLUSION

It can be concluded that the main challenges for wider usability of water hydraulics are reliability, controllability and price level-and at the same time. Reliability means that the components have to be able to work longer periods without service and without big risk for brake. It includes the control of water quality so that the components can operate with optimal pressure quality. It also includes the development of components' characteristics so that they are not sensitive for fluid quality, temperature, pressure peaks, cavitation, erosion and wear [17-18]. And it also means having successful references, where water hydraulics is operation on demanding and long time tasks. Controllability means that overall ability of water hydraulics to realize more accurate and dynamic control systems have to be improved. This can be done by developing better control

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valves, control methods and actuators. At the moment, fairly accurate position control systems can be achieved with low pressure by using servo valves or digital hydraulic controls. However, more challenges are in higher pressures (over 20 MPa), where the component supply is very limited. Also components and methods for realizing pressure controls are more needed in the future. The price level of water hydraulic components is certainly one big challenge. Low pressure water hydraulics is offering one possibility to achieve cheaper costs by using cheaper materials like polymers. However, in general the biggest factors are more expensive materials and small production amounts. Even the components and systems are technically perfect, the price level still affects strongly to machine builders choices [19].

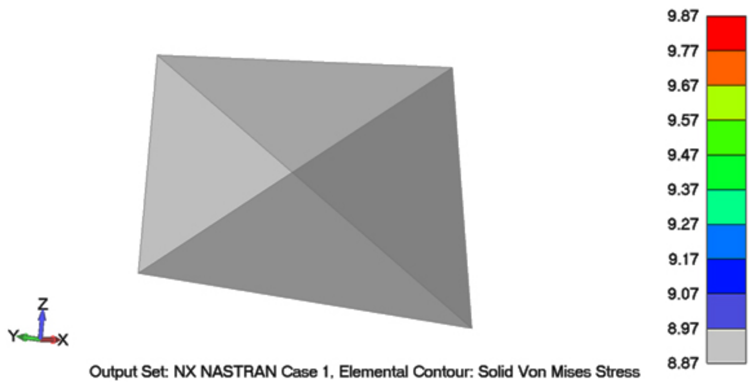

Fig. 4. Distribution of equivalent von Misses stress PEEK

Therefore increasing production amounts along with increasing practical applications, will slowly lead to decreasing price level of the components. And it is important that the machine builders remem As a conclusion it can be stated that at present water hydraulics already have many possibilities for building motion control systems and in the future there will be even more, when technical level is still increasing. The major benefits-environmental friendliness and fire safety-are strong drivers for water hydraulics' future development

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