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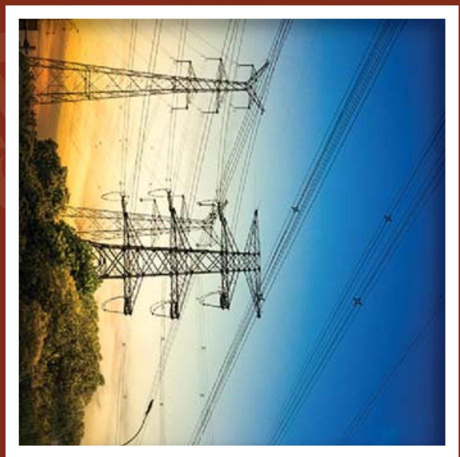

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SAVING ENERGY AND SUSTAINABLE DEVELOPMENT WITH WATER HYDRAULIC COMPONENTS AND SYSTEMS – OPPORTUNITIES, CHALLENGES AND OBJECTIVES

ABSTRACT

This paper describes the actual research activities related to development of water hydraulic components and systems. The main focus areas are discussed and the challenges and possible solutions of each subject are analyzed. Water quality aspects, component technology, control aspects and also applications are covered. Also some analysis about water hydraulics' possible role in climate change process and energy saving are presented. 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. 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. 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 using special material to operate with sea-water.

Modern water hydraulic technology is still new and there are a lot of problems to be solved in order to make the technique more widely available for power transmission.

Keywords: Water Hydraulic Technology, Piston Axial Pump, EnergySaving

Ušteda energije i održivi razvoj sa vodnim hidrauličnim komponentama i sistemima – prilike, izazovi i ciljevi

SAŽETAK

Ovaj rad opisuje stvarne istraživačke aktivnosti vezane za razvoj vodnih hidrauličkih komponenti i sistema. Razmatraju se glavna područja fokusiranja i analiziraju se izazovi i moguća rešenja za svaki predmet. Prikazani su aspekti kvaliteta vode, komponenata tehnologije, aspekti kontrole i aplikacije. Prikazane su i neke analize potencijalne uloge vodne hidraulike u procesu klimatskih promena i uštede energije. Trendovi potvrđuju da je dizajn vodnih hidrauličnih aplikacija prirodni pristup rešenju velikog broja glavnih problema zagađenja životne sredine i problema u industrijama, koji ne mogu prihvatiti kontaminaciju proizvoda i probleme rizika od požara i eksplozije. U radu je prikazano istraživanje trendova u razvoju i najbolje prakse u projektovanju vodnih hidrauličkih komponenata i sistema za upravljanje kretanjem vode pod niskim i visokim pritiskom, kao i otvorenih rešenja različitih industrijskih primena. Prodaja savremenih vodnih hidrauličkih komponenti i sistema prikazuje izuzetan rast. Važne industrijske primene i prednosti su predstavljene sa fokusom na procesne industrije kao što su prehrambena industrija, farmaceutski procesi, sistemi za gašenje požara vodom, visokopritisni čistači vode, sistemi za obradu drveta (obrade pilana i sušare) i industrijske pokretne mašine i komunalne mašine koji rade u osetljivom okruženju. Jedinstven proboj, sa uspehom razvoja, dizajna i implementacije, je proces koji se naziva Reversna osmoza (voda za piće iz morske vode) ostvaren novim klipno aksijalnim pumpama i ventilima koji koriste posebne materijale za rad sa morskom vodom.

Savremena vodena hidraulična tehnologija je i dalje nova i postoji veliki broj problema koji se moraju rešiti kako bi se tehnika postala dostupnija za prenos snage.

Ključne reči: Tehnologija vodne hidraulike, klipno aksijalna pumpa, ušteda energije

1 INTRODUCTION

Current technological efforts for water hydraulics are far less than those for oil hydraulics. However, the experience gained from oil hydraulics is very important for future water hydraulics research.

Engineering relationships between water and oil are significantly different and cannot be overcome or trivialized by simple modification of design parameters from oil hydraulics. Water hydraulics should be regarded as a new evolving technology. It has certainly brought in challenges as well as opportunities for the engineers and manufacturers. When the current drawbacks are resolved through advances in technology, modern water hydraulics will have a wider spectrum of application fields than oil hydraulics presently has.

The earliest hydraulic systems used water as hydraulic fluid. This restricted the working temperature range and caused corrosion as well as lubricating problems. It was not until the late 1920's that mineral hydraulic oils were introduced. Consequently, the oil became the main pressure medium of hydraulic applications. Recently, the demand for using pure tap water as a pressure medium in hydraulic applications has increased due to its availability, easy maintenance, its low cost and its high safety levels against pollution and fire hazard.Water hydraulics can be used in new application areas such as food processing, pulp and paper industry, medicine, glass making, coal mining and nuclear industry [1].

Water is characterized by very low viscosity in comparison with mineral hydraulic oils [2]. Key problems should be considered in water hydraulic system. First, the very low viscosity must increase the difficulty of developing hydrodynamic film between friction pairs, and the very small change of water's viscosity with pressure means that elastohydrodynamic lubrication with hard materials is unlikely to occur [3]. The low viscosity is accompanied with poor lubricities of water. Poor lubricities can cause corrosive wear and erosion problems. Secondly, it is to be noted that water (especially seawater) is electrically conductive and may act as an electrolyte when impurities or certain additives are present. In such cases the electrolyte corrosion may arise. Metallic materials to be used in connection with the water pressure medium should comply with the electrochemical series. Water piston pump (motor) has been developed in some developed countries, such as USA, UK, Japan, Denmark, Germany and Finland [4-5].

In water hydraulics a lot of interesting applications have been developed and researched. The application mentioned below makes clear that water hydraulics is no longer restricted to stationary applications.

(a) Ocean exploration engineering

When seawater hydraulics is used in the subsea control system, the power source and seawater pump could be positioned near the working place, requiring only electrical power from the surface. There would be no need for the flow and return of hydraulics fluid, and possibly no need for the expensive umbilical at all if the system were controlled remotely. The financial benefits would be significant.

(b) Metallurgical industry and mining

Non-flammability is of paramount importance in high-temperature and mining applications The use of water hydraulics instead of conventional fire resistant hydraulics in metallurgical industry (converter, furnace and aluminum productions), plastics processing facilities, nuclear industry and power in mine, not only avoid the risk of fire, also reduce operating cost and pollution to environment.

(c) Paper cutting

Quite a new development is a water jet cutting system for the paper machine. In the paper machine, the edge of the fast paper line has to be cut. Traditional way is to use steel cutters, but due to their unreliable operation, the use of water jet for cutting is raising more and more interest. In other words, the problem is that the steel cuttings are wearing quite much and have to be changed very often. Other alternative is to use water jet cutting.

(d) Waste packer lorry

In Sweden there is an interesting mobile application operated with water hydraulics. That is a waste packer lorry. The waste lorry is a daily operated vehicle and the hydraulic system must be designed for outdoor temperatures of –10 to +40ºC. Therefore, the tap water is frost protected by 35% food grade propylene glycol. This fluid is classified as a non-hazardous to humans and the environment [6] .

2 SUSTAINABLE DEVELOPMENT WITH WATER HYDRAULIC COMPONENTS AND SYSTEMS

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. 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.

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. 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.

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. 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. When evaluating the system components disposal after the use, no significant differences between water and oil hydraulics can be found.

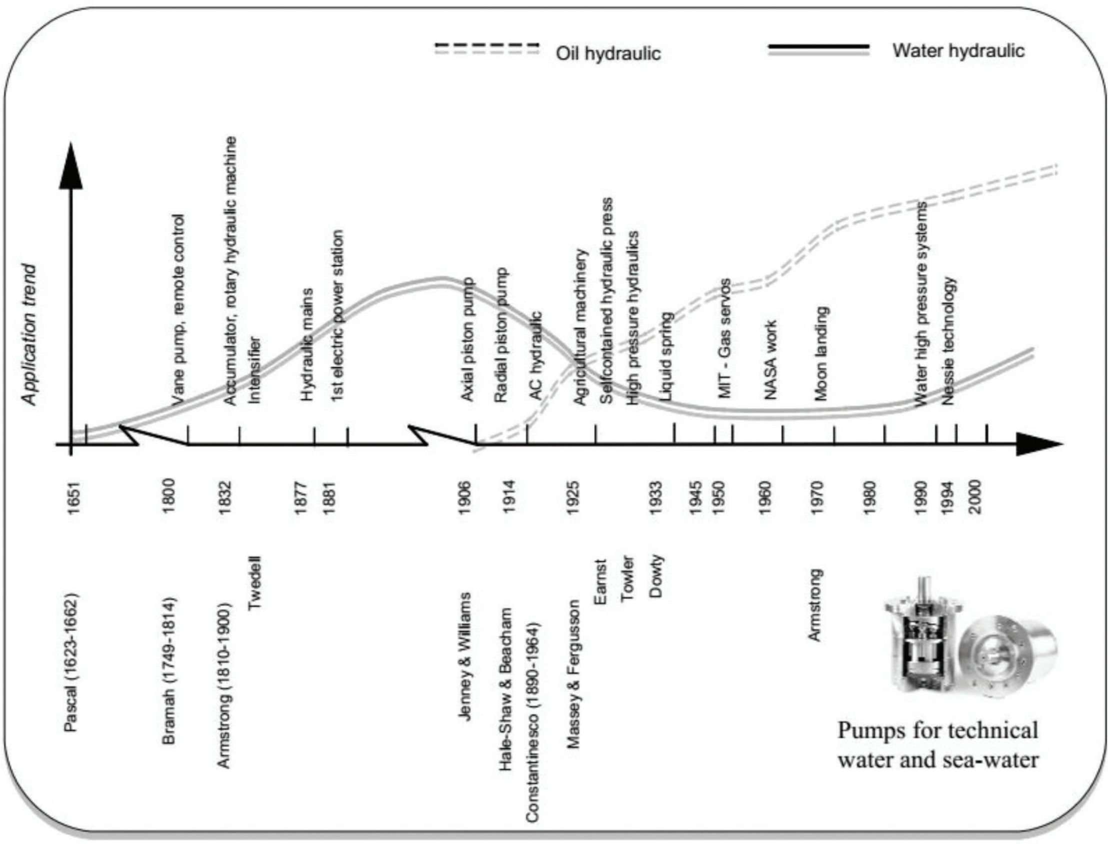

Fig.1. *The historical development of oil and water hydraulics*

3 DEVELOPMENT, RESEARCH AND DESIGN OF WATER HYDRAULICS COMPONENTS

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 suitable for using pure tap water as the pressure fluid [7]. Companies have water hydraulic components, systems and solutions on the market, and the number of products and the areas of application are increasing as illustrated in Fig.1. 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.

Moreover, the use of water hydraulic systems has not developed as fast as expected due to the lack of common goals and the components developed are scattered over a very large range of power levels, and missed sizes and types of components. The current market share of water hydraulics is believed to be less than 5%. As long as the quantity produced is small and one is still at the bottom of the learning curve, the price of the final component will be unfavorable [9]. Hence, while water is cheap, water hydraulic components are not. This will be resolved when more engineers and companies join in the development and use of this new technology. Recent sales growths are 50% to 100% per year. It is expected that water and oil hydraulics will co-exist in the near future with water filling in the niches where environment, health, fire and safely, product compatibility, etc. are important considerations. In the longer term, it is expected that water hydraulics will take over many of the existing oil hydraulic applications besides having new applications of its own [10].

3.1. Materials Used for Research

Developments of water hydraulic axial piston machines have been made around world during the past three decades. The research involved material research, pump design and pump tests, including life time tests. The changes in design, material selections and power pack development are discussed. The design of the pumps, material of the pumps and test results are also discussed. The combination of stainless steel and coal fibre reinforced PEEK has proven to be successful in water hydraulic pumps [9-12]. Material selection, optimizing structure and manufacturing are recognized as the key problems. Material research is an important part of water hydraulic component research. The wear mechanism of ceramic-ceramic contact is fatigue and surface fracture. In stainless steel polymer combinations, the wear mechanism of the PEEK composites is fatigue when the load is lighter and micro-cutting and plastic deformation when the load is heavier. The conclusion is that metal-polymer combinations are more suitable to be friction pairs in water hydraulic piston pumps, but that ceramic-ceramic combinations also have potential. Companies have some patents concerning water hydraulic axial piston pumps. Key elements of the patents are the structure and materials of the slipper. Stainless steel and industrial plastics combinations are used in all the inventions [12-18].

3.2. Research of axial piston pump

Fig.2 shows the structure of 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.

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. Usually, the swashplate and the valve plate are fixed and the cylinder block is the rotating part

4 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

Material	PEEK 1	PEEK 2
Aditive	10% carbon, 10% graphite, 10% PTFE	
Young's modulus [MPa]	9500	3500
Poission ratio [-]	0.394	0.400
Density [kg/m3]	1480	1300
Tensile strength, Yield [MPa]	119	97
Compressive yield strenth [MPa]	152	118
Friction coefficient [-]	0.19	0.34

Table 1. *Material properties*

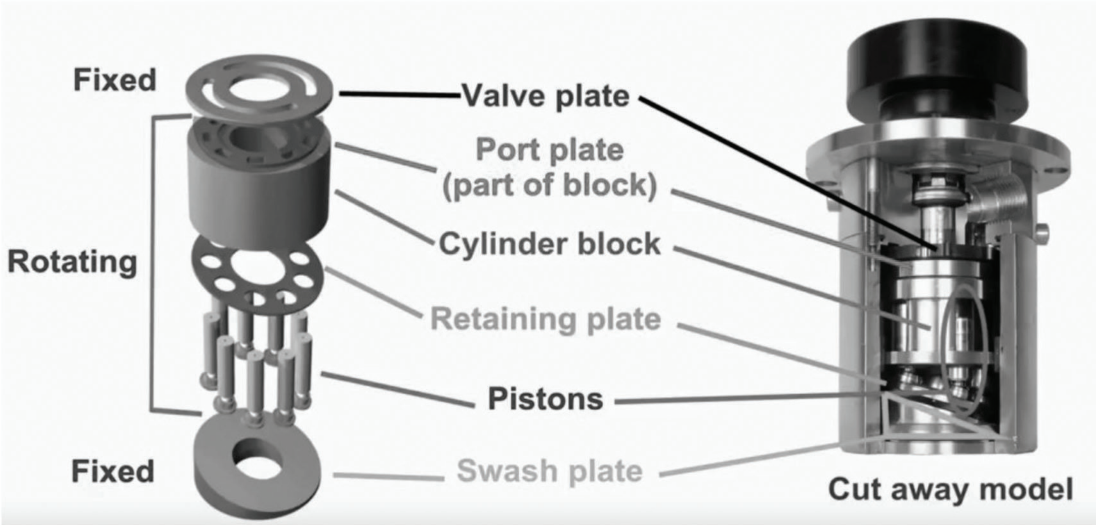

Fig 2. *Structure of axial piston pump*

components' characteristics so that they are not sensitive for fluid quality, temperature, pressure peaks, cavitation, erosion and wear. 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 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].

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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