OPTIMIZATION OF AXIAL PISTON WATER PUMPS IN THE DEVELOPMENT PHASE

SLOBODAN SAVIĆ,[1] NENAD TODIĆ,[1] STEFAN CVEJIĆ[2]

[1] University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia
ssavic@kg.ac.rs, ntodic@gmail.com
[2] University "Union-Nikola Tesla" of Belgrade, Faculty of Information Technology and Engineering, Belgrade, Serbia
etfot1@gmail.com

On the basis of theoretical and experimental studies, the appropriate structure of the sliding contact in the framework of the water hydraulic axial piston pump was designed. Load experiments for the developed water hydraulic axial piston pump were carried out on a water hydraulic component test installation. Experimental test results show that the volumetric efficiency and noise characteristics of the water hydraulic piston axial pump are significantly improved under hydrodynamic lubrication conditions compared to dry lubrication conditions. The conclusions obtained from these studies are very significant for further research and development of piston axial pumps of water hydraulics.

Keywords:
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optimization,
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water lubrication,
sliding bearing

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1 Intruduction

Axial piston water pumps serve as crucial components for water circulation, supply, and pressure generation in a wide array of applications. To meet the growing demand for efficient and reliable water transport, optimizing these pumps during their development phase is of paramount importance. This study focuses on identifying and addressing critical aspects that contribute to achieving enhanced pump performance, reliability, and longevity.

An important factor that defines the working characteristics of the pump is represented by different pairs of friction inside the pump. The most important couple is the sliding contact between the shaft and the bearings. In this connection, we note two important factors in the operation of the piston-axial pump of water hydraulics, lubrication and wear, as well as sealing and leakage. Various experiments were conducted using sliding contact components manufactured from PEEK material with different compositions. It was concluded that PEEK þ 10wt % CF, 10wt % polytetrafluoroethylene (PTFE) and 10wt % graphite give the most favourable properties for sliding contact operation under dry friction conditions.

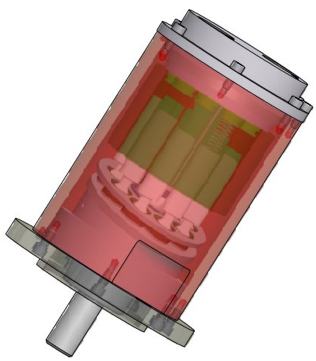

Figure 1: Axial piston water pump.
Source: own.

The wear mechanism of PEEK radial bearings operating in dry conditions was determined. The wear characteristics of EP and PEEK materials that can be used for sliding bearings inside piston-axial pumps of water hydraulics in conditions lubricated by dry and abrasive media were experimentally studied. It was found that the tested results differed significantly with different working fluids.

2 Key Parameters for Optimization

2.1 Piston Geometry

The geometry of pistons in axial piston pumps significantly influences fluid flow dynamics and efficiency. Optimizing parameters such as piston diameter, stroke length, and crown profile can lead to improved hydraulic efficiency and reduced frictional losses.

2.2 Cylinder Arrangement

The arrangement of cylinders within the pump, whether inline or swashplate, impacts the volumetric efficiency and overall performance. Evaluating the pros and cons of each arrangement and determining the optimal choice based on the specific application requirements is crucial.

2.3 Fluid Dynamics

Understanding the flow patterns and pressure distribution within the pump is essential for optimization. Computational Fluid Dynamics (CFD) simulations can provide insights into the effects of design changes on fluid behaviour, helping identify areas for improvement.

2.4 Material Selection

Choosing appropriate materials for pump components is vital to ensure durability and reliability. Materials must withstand the pressures, temperatures, and wear associated with pump operation while maintaining dimensional stability.

3 Results

The results of optimizing the parameters of the hydrodynamic processes of the axial piston pump are shown diagrammatically in Figure 2 (a to f) for different operating modes and for those used in experimental research.

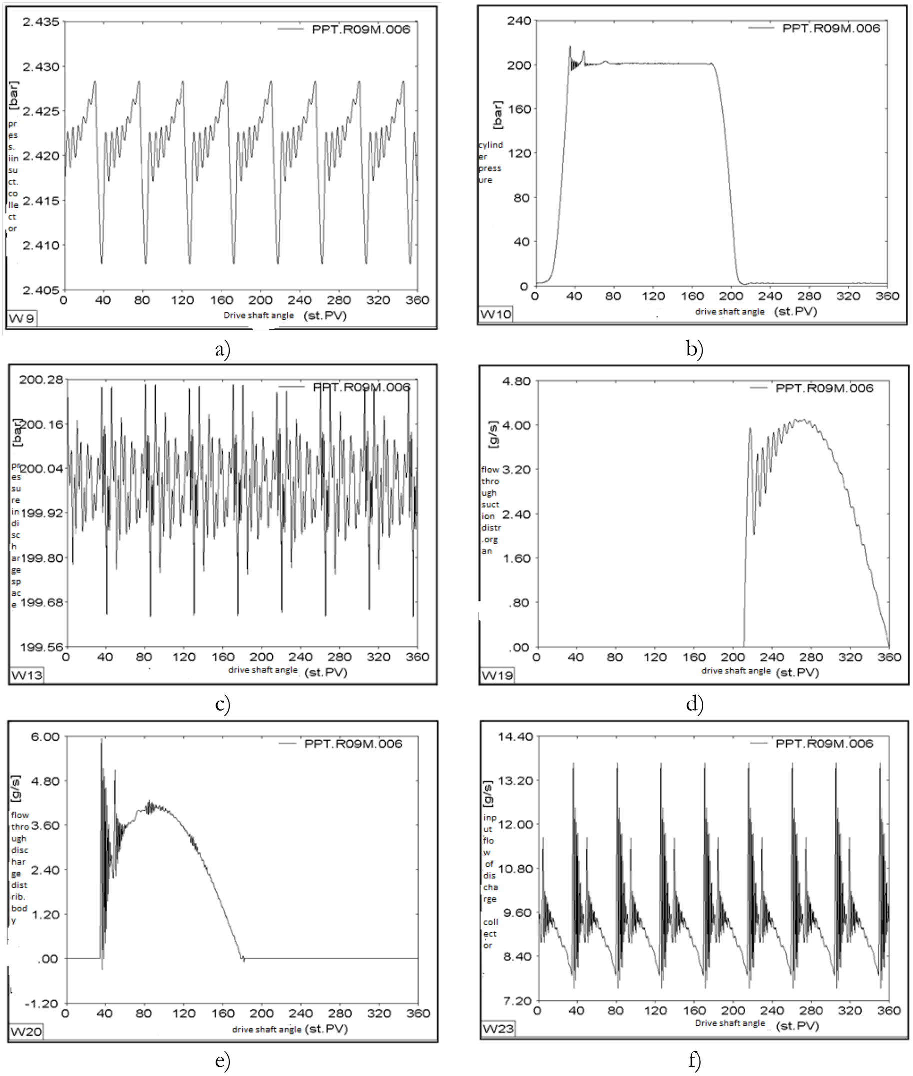

Figure 2 (a to f): Diagrams of characteristic parameters of the axial piston pump, for the operation regime: n = 875.6 min^{-1} and p = 200 bar.

Source: own.

From the diagrams in Figure 2, we can observe great similarity: pressure flow in the suction collector, pressure in the cylinder, pressure in the discharge chamber, flow through suction distribution body and flow through suction collector depending on the angle of a drive shaft in case of different operating modes of the axial piston pump.

The Table 1 shows numerical values of the initial and four optimized parameters of the axial piston pump, which significantly affect the level of cylinder delivery η_c.

Table 1: Initial and optimized numerical values of the four parameters, hydrodynamic processes of the axial piston pump

No	Name of the parameter	Analytical expression	Computer program	Dimension	Numerical values	
					initial	optimal
1.	Suction pressure	p_u	PU	Pa	2.68E5	2.71E5
2.	Parietal radius of the suction opening of distribution panel	R_2	R2U	m	5.1E-2	4.5E-2
3.	Angle of the suction phase beginning	a_2	ALM2G	°	29.77	27.1
4.	Spring rigidity of discharge valve	c_v	CVI	N/m	1104.7	1160

Value of discharge chamber, suction chamber volume, as well as the length of discharge pipeline do not have a significant effect on the maximum coefficient of cylinder delivery η_c . In further analysis, the attention is paid to the impact of initial and optimized parameters to the maximum coefficient of cylinder delivery η_c, for different operating regimes of the axial piston pump, which is shown in Table 2.

Table 2. Values of cylinder delivery coefficient η_c in case of initial and optimized parameters of axial piston pump for different operating regimes

No	Operating regime		Values of cylinder delivery coefficient η_c %		
	p bar	*nmin^{-1}*	Initial parameters	7 optimized parameters	4 optimized parameters
1.	50	800	93.6	96.2	95.8
2.	160	800	86.6	93.1	92.6
3.	180	800	85.3	92.1	91.7
4.	180	1000	85.3	92.1	91.7
5.	200	800	84.1	91.4	90.65
6.	200	875.6	84.1	91.4	90.65
7.	200	1000	84.1	91.4	90.65

4 Conclusion

Comparing the results of optimized parameters to the initial ones, the requirements for the analysis of the parameters of the construction of the distribution of working fluid are obvious in case when looking for an optimal solution to the construction of axial piston pump.

Optimizing axial piston water pumps during the development phase involves a comprehensive approach that considers various design and operational parameters. By focusing on piston geometry, cylinder arrangement, fluid dynamics, and material selection, engineers and researchers can create high-performance pumps that meet the demands of diverse applications. Embracing iterative design, simulation tools, and multi-objective optimization ensures the development of efficient, reliable, and robust axial piston water pumps for modern industries.

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