

international conference

FT 2023

conference proceedings

Darko Lovrec
Vito Tič
Editors



University of Maribor Press

Fluid Power 2023
Fluidna Tehnika 2023

MARIBOR, 20.-21. SEPTEMBER 2023



University of Maribor

Faculty of Mechanical Engineering

International Conference Fluid Power 2023

Conference Proceedings

Editors

Darko Lovrec

Vito Tič

September 2023

Title	International Conference Fluid Power 2023
Subtitle	Conference Proceedings
Editors	Darko Lovrec (University of Maribor, Faculty of Mechanical Engineering) Vito Tič (University of Maribor, Faculty of Mechanical Engineering)
Review	Darko Lovrec (University of Maribor, Faculty of Mechanical Engineering, Slovenia), Vito Tič (University of Maribor, Faculty of Mechanical Engineering, Slovenia), Niko Heraković (University of Ljubljana, Faculty of Mechanical Engineering, Slovenia), Željko Šitum (University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia), Milan Kambič (OLMA d.o.o., Slovenia), Franc Majdič (University of Ljubljana, Faculty of Mechanical Engineering, Slovenia), Juraj Benić (University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia), Joerg Edler (Technische Universität Graz, Austria) Marko Šimic (University of Ljubljana, Faculty of Mechanical Engineering, Slovenia), Riko Šafarič (University of Maribor, Faculty of Electrical Engineering and Computer Science), Almir Osmanovi (University of Tuzla, Faculty of Mechanical Engineering Tuzla, Bosnia and Herzegovina), Edvard Detiček (University of Maribor, Faculty of Mechanical Engineering, Slovenia)
Technical editor	Jan Perša (University of Maribor, University Press)
Cover designer	Vito Tič (University of Maribor, Faculty of Mechanical Engineering)
Graphic material	Authors & Lovrec, Tič, 2023
Cover graphics	Fluid Power conference, University of Maribor, Faculty of Mechanical Engineering
Conference	International conference Fluid Power 2023
Location and date	Hotel Habakuk, Maribor, Slovenia, 20 th – 21 st September 2023
Organizing committee	Vito Tič (University of Maribor, Faculty of Mechanical Engineering, Slovenia), Darko Lovrec (University of Maribor, Faculty of Mechanical Engineering, Slovenia), Dušan Raner (University of Maribor, Faculty of Mechanical Engineering, Slovenia), Mitja Kastrevc (University of Maribor, Faculty of Mechanical Engineering, Slovenia), Edvard Detiček (University of Maribor, Faculty of Mechanical Engineering, Slovenia)
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Published by **University of Maribor**
University Press
Slomškov trg 15
2000 Maribor, Slovenia
<https://press.um.si>, zalozba@um.si

Issued by **University of Maribor**
Faculty of Mechanical Engineering
Smetanova ulica 17
2000 Maribor, Slovenia
<https://fs.um.si>, fs@um.si

Edition 1st

Publication type E-book

Available at <http://press.um.si/index.php/ump/catalog/book/811>

Published at Maribor, September 2023



© **University of Maribor, University Press**
/Univerza v Mariboru, Univerzitetna založba

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CIP - Kataložni zapis o publikaciji
Univerzitetna knjižnica Maribor

621.22(082) (0.034.2)

FLUIDNA tehnika (konferenca) (2023 ; Maribor)

International conference Fluid Power 2023 [Elektronski vir] : conference proceedings : [Maribor, Slovenia, 20th - 21st September 2023] / editors Darko Lovrec, Vito Tič. - 1st ed. - E-zbornik. - Maribor : University of Maribor, University Press, 2023

Način dostopa (URL): <https://press.um.si/index.php/ump/catalog/book/811>
ISBN 978-961-286-781-2 (PDF)
doi: 10.18690/um.fs.5.2023
COBISS.SI-ID 164336131

ISBN 978-961-286-781-2 (pdf)
978-961-286-782-9 (softback)

DOI <https://doi.org/10.18690/um.fs.5.2023>

Price Free copy

For publisher Prof. Dr. Zdravko Kačič,
Rector of University of Maribor

Attribution Lovrec, D., Tič, V. (eds.). (2023). *International conference Fluid Power 2023: Conference Proceedings*. Maribor: University Press.
doi: 10.18690/um.fs.5.2023

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OPTIMIZATION OF AXIAL PISTON WATER PUMPS IN THE DEVELOPMENT PHASE

SLOBODAN SAVIĆ,¹ NENAD TODIĆ,¹ STEFAN CVEJIĆ²

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:

axial piston pump,
optimization,
development,
water lubrication,
sliding bearing

1 Introduction

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.

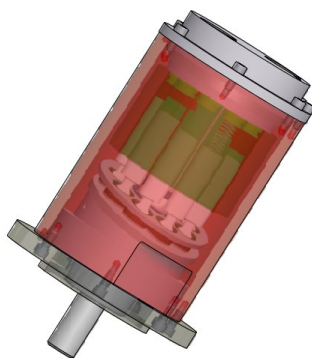


Figure 1: Axial piston water pump.

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.

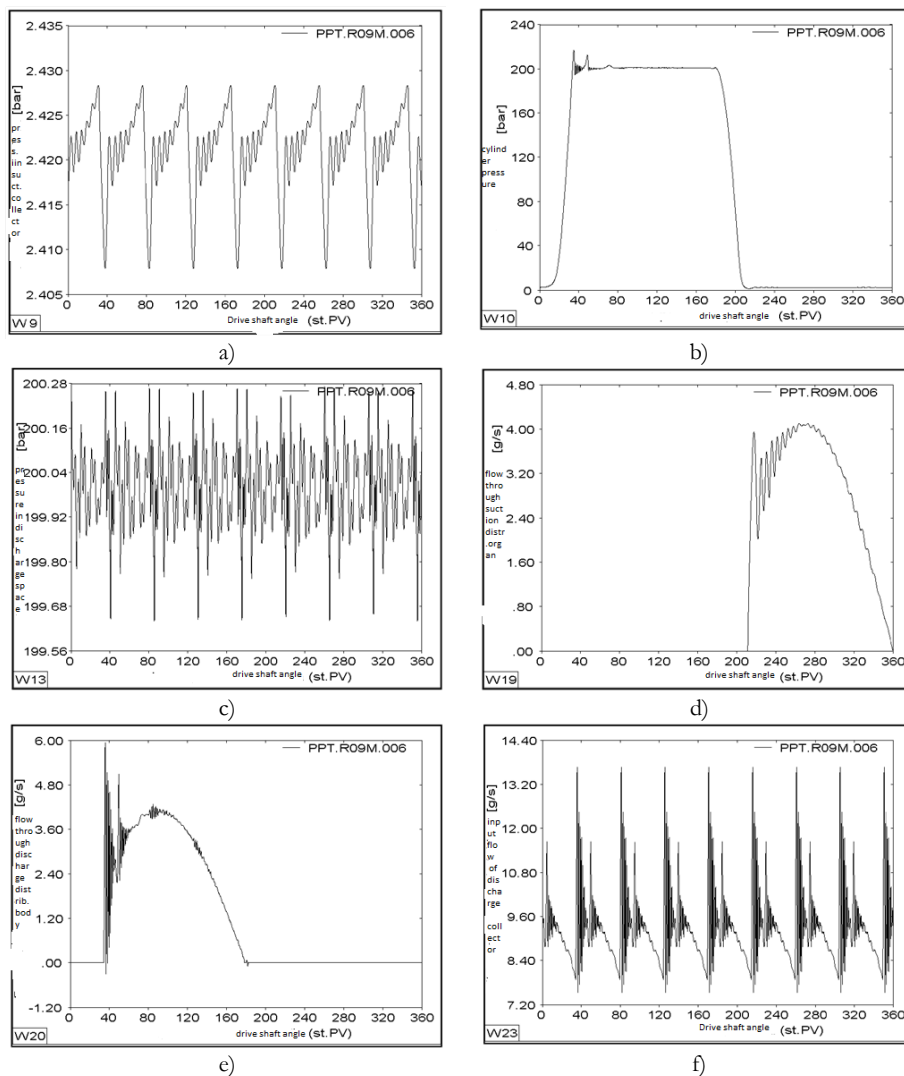


Figure 2 (a to f): Diagrams of characteristic parameters of the axial piston pump, for the operation regime: $n = 875.6 \text{ min}^{-1}$ and $p = 200 \text{ bar}$.

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_n	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	α_2	ALM2G	°	29.77	27.1
4.	Spring rigidity of discharge valve	c_p	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 %		
	$p \text{ bar}$	$n \text{ min}^{-1}$	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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INTERNATIONAL CONFERENCE FLUID POWER 2023

DARKO LOVREC, VITO TIČ (EDS.)

University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
darko.lovrec@um.si, vito.tic@um.si

The International Fluid Power Conference is a two-day event, intended for all those professionally involved with hydraulic or pneumatic power devices and for all those, wishing to be informed about the 'state of the art', new discoveries and innovations within the field of hydraulics and pneumatics. The gathering of experts at this conference in Maribor has been a tradition since 1995, and is organised by the Faculty of Mechanical Engineering at the University of Maribor, in Slovenia. Fluid Power conferences are organised every second year and cover those principal technical events within the field of fluid power technologies in Slovenia, and throughout this region of Europe. This year's conference is taking place on the 20th and 21st September in Maribor. The main focus of this year's contributions is on the components and system development in the field of fluid power technology.



DOI
[https://doi.org/
10.18690/um.fs.5.2023](https://doi.org/10.18690/um.fs.5.2023)

ISBN
978-961-286-781-2

Ključne besede:
fluid power technology,
components and design,
control systems and
testing,
fluids and tribology,
education



University of Maribor

Faculty of Mechanical Engineering

