

ICMD 2016

57th International Conference of Machine Design Departments



FACULTY OF MECHANICAL
ENGINEERING
UNIVERSITY
OF WEST BOHEMIA

DEPARTMENT OF
MACHINE
DESIGN

Book of Proceedings

57th International Conference of Machine Design Departments



Department of Machine Design,
Faculty of Mechanical Engineering, University of West Bohemia in Pilsen

Orea Resort Horizont ***

September 7, 2016 – September 9, 2016

57th International Conference of Machine Design Departments (ICMD 2016)



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UNIVERSITY OF WEST BOHEMIA
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Department of Machine Design

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Papers classified by the scientific steering committee will be presented in parallel sessions relevant to the following topics:

- Machine Design
- Tribology
- Hydraulics, Fluid Mechanisms
- Engineering Analyses
- Modern Material and Technology
- Optimization and Design
- Product Innovation
- Experimental Methods and Measuring
- Nanotechnology
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Optimization Parameters of a Piston Radial Pump and Their Impact on Pressure and Pulsation Noise in Mobile Machine

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Abstract: Fundamental basis in developing the piston-radial pumps presents an experimental research and mathematical modelling of non stationary high dynamic hydraulic processes in the pump cylinder, discharge space and intake and discharge pipe line in the function of the action angle of the shaft. Based on the experimental research results and the results of the mathematical modelling, developing and application of the identification method of unknown parameters of a mathematical model, the computer RADIP program has been developed which enables sufficiently exact determination of some parameters of working processes of piston radial pumps.

Key words: piston radial pump, pump cylinder, mathematical modelling, hydrodynamic processes, mass flow, geometrical flow, experimental research, parameters, working processes, pulsation noise, mobile machine.

1. Introduction

The hydrostatic transmission system features with high power density, flexible connection, continuously variable transmission. Both axial and radial piston hydraulic pump are displacement machines, which are comprised a number of discrete pistons which reciprocate moving in the purpose of discharging fluid. Displacement machines make the discharge volume discrete. The output flow-rate ripples consequently. With the development of the application in industry, improving reliability, lowering the noise emission and offering maximum flexibility becomes the primary objective. Researchers pointed out that radial piston pump even behave better in suffering pressure impulsion longer life, if the pumps are well designed. In fact, leakage and

noise are inevitably in hydraulic transmission. Noise reduction in piston pumps has been the focus of the pump research. Many researches have taken several methods to make it quiet as possible as they can. It is recognized that the sudden change of pressure in controlled piston volume leads to sudden change of output pressure which produces a blasting sound.

The pressure change is caused by the sudden change of the fluid volume in piston chamber. To alleviate the noise emission, the piston chamber should be investigated. Modern design of a piston radial pump, based on computer aided design (CAD), requires description of the all processes and parameters in the pump. Complexity of hydrodynamic and dynamic processes in a piston-radial pump (pump cylinder, intake and discharge space, discharge valve and pipeline of high pressure) demands very studious physical and mathematical analysis the same processes. Fundamental basis, in order to solve this problem, presents experimental research, based on the ultra-speed measurement system, mathematical modeling of non stationary high dynamic processes and optimization technique. This way of solving the problem is only possible having the special computer program. Such program (RADIP) has been developed.

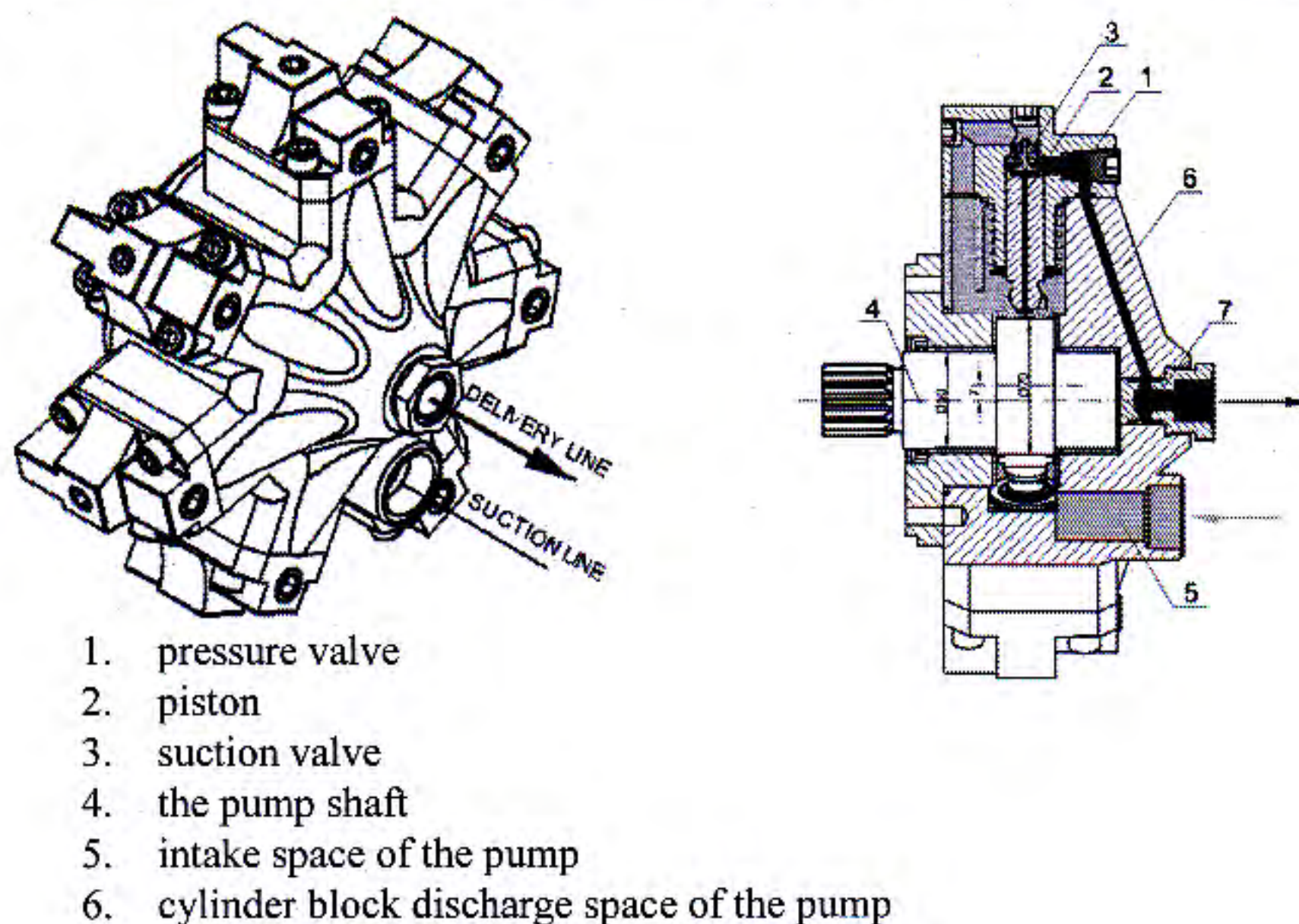


Fig 1. Construction and control spaces of a piston-radial pump

2. Mathematical Model

For mathematical modelling of hydrodynamic and dynamic processes in a piston-radial pump (pump cylinder, intake and discharge space, discharge valve and a pipeline of high pressure). Figure. 1, the following general suppositions have been adapted:

- a) Changes of the fluid state are pseudo stationary, except in the discharge pipeline;

- b) Kinetic energy of fluid in each control space, except in the discharge pipeline, is neglected.
- c) Fluid flow through clearances (crevices between the piston and cylinder, the flow through a split panel and discharge valve) is pseudo stationary;
- d) The processes in the control spaces are isothermic or isentropic;

2.1 Mathematical model of a pump process

Mathematical model is given for each element, considering the complexity of some processes and their mutual dependence as well as the need for further mathematical modelling. This makes programming module and their further improvement and monitoring much easier.

- mass flow through the opening 1, on the entrance place into the intake space of the pump of fluid, Figure 1:

$$\frac{dm_1}{dt} = \sigma_1 \mu_1 A_1 \sqrt{2\rho_s |p_u - p_s|} \quad (1)$$

where are: $\sigma_1 = 1$ for $p_u \geq p_s$, $\sigma_1 = -1$ for $p_u < p_s$

A_1 - geometrical flow section of the intake pipe.

- mass flow of fluid through the split pump organ during filling one of the pump cylinders:

$$\frac{dm_u}{dt} = \sigma_u \mu_u A_u \sqrt{2\rho_s |p_s - p_c|} \quad (2)$$

where are: $\sigma_u = 1$ for $p_s \geq p_c$, $\sigma_u = -1$ for $p_s < p_c$

A_u - geometrical flow section of the intake split organ

- mass balance of the intake space is:

$$\frac{dm_s}{dt} = \frac{dm_1}{dt} - \sum_{j=1}^{z_c} \frac{dm_{u,j}}{dt} \quad (3)$$

where are: $j=1, 2, \dots, z_c$ order number of cylinder, z_c the numbers of cylinders.

- differential pressure equation in the intake pump space:

$$\frac{dp_s}{d\varphi} = \frac{E}{V_s \rho_s} \left(\frac{dm_1}{d\varphi} - \sum_{j=1}^{z_c} \frac{dm_{u,j}}{d\varphi} \right) \quad (4)$$

- differential pressure equation in the pump cylinder:

$$\frac{dp_c}{d\varphi} = \frac{E}{V_c} \left[\frac{A_c v_k}{\omega} + \frac{1}{\rho_c} \left(\frac{dm_u}{d\varphi} - \frac{dm_i}{d\varphi} \right) \right] \quad (5)$$

where are: $V_c = V_{c \min} + V_{cx}$; $V_{cx} = A_c \cdot x_k$; - immediate volume of the cylinder; the change of the volume of the pump cylinder caused by piston moving:

$$\frac{dV_c}{dt} = -A_c v_k \quad (6)$$

x_k - immediate displacement of the piston.

- mass balance of the discharge space is:

$$\frac{dm_v}{dt} = \sum_{j=1}^{z_c} \frac{dm_{i,j}}{dt} - \frac{dm_2}{dt} \quad (7)$$

where are: $j=1,2,\dots, z_c$ order number of cylinder, z_c the numbers of cylinders.

- mass flow streaming out of the discharge space into the discharge pipe is:

$$\frac{dm_2}{dt} = \sigma_2 \mu_2 A_2 \sqrt{2\rho_t |p_v - p_n|} \quad (8)$$

where are: $\sigma_2=1$ for $p_v \geq p_n$, $\sigma_2 = -1$ for $p_v < p_n$

A_2 - geometrical flow section of the discharge pipe line.

- differential pressure equation in the discharge pump space:

$$\frac{dp_v}{d\varphi} = \frac{E}{V_v \rho_v} \left(\sum_{j=1}^{z_c} \frac{dm_{i,j}}{d\varphi} - \frac{dm_2}{d\varphi} \right) \quad (9)$$

- mass flow through a concentric clearance between the cylinder and the piston:

$$\frac{dm_z}{dt} = \frac{\pi \cdot D_c \cdot \Delta r^3}{12 \cdot \eta \cdot x_k(\varphi)} \cdot (p_c - p_s) \cdot \rho_c \quad (10)$$

2.2 Modelling the streaming in the intake and discharge pipe line of the pump

During mathematical modelling of a process in a pump, it is also necessary to include and consider a series of suppositions for a process modelling occurring in the intake and discharge pipe line of the pump.

Equation Quantity Of Moving

The equation of continuity of pressed fluid with functions p , w , ρ at the isentropic change of the state:

$$\frac{\partial p}{\partial t} + w \frac{\partial p}{\partial x} + a^2 \rho \frac{\partial w}{\partial x} = 0 \quad (11)$$

where are: p and w – values of density and velocity of fluid per cross section of the pipe,

$$a = \sqrt{\left(\frac{\partial p}{\partial \rho} \right)_s}, \text{ the velocity of sound in the fluid,}$$

where are: $p = p(t, x)$ and $\rho = \rho(t, x)$ functions of time t and coordinate x .

Equation Quantity Of Moving

$$w \frac{\partial \rho}{\partial t} + \rho \frac{\partial w}{\partial t} + w \frac{\partial}{\partial x}(\rho w) + \rho w \frac{\partial w}{\partial x} + \frac{\partial p}{\partial x} = -f_r \rho \quad (12)$$

where is: f_r – friction force per mass unit.

3. Measuring results of working process

In the scope of performed experimental researches, the measuring of the pressure history in the cylinder, delivery chamber was done. The vibration of the pump housing was also measured depending on the pump driving shaft angle. All pressures and vibrations were measured simultaneously on each cca 0.09° step of the driving pump shaft (exactly 4.096 times per shaft rotation). As incremental angle encoder an optical encoder with 1.024 pulses per rotation was used. Pulses of the angle encoder were quadrupled by the interface for the angle encoder on the ADS 2000 system so that 4.096 pulses per shaft rotation were obtained. In order to see the repetition of the consecutive cycles with the unchanged working regime 10 consecutive cycles were measured. At the same time, a time interval from angle to angle was also measured in order to determine the variation of shaft speed and control of the incremental angle encoder. All the analogue signals (pressure, vibrations) were parallel converted into digital form by means of four (4) ultra speed A/D converters working simultaneously (parallel). The total number of measured data was $(4+1) \times 4.096 = 20.480$ per rotation (cycle), that is, 204.800 for ten consecutive cycles. The number 4.096 was not chosen by chance, but in order to use the fast Furrier's Transformation (FFT) of measured signals. Measurements were done for seven working regimes.

4. Conclusion

It is not possible to give a precise determination of parameters of hydrodynamic processes of a piston radial pump neither experimentally nor by a mere mathematical modelling only. Sufficiently exact parameters can be obtained by combining the application of measuring the pressure flow in the cylinder, mathematical modelling of a real hydrodynamic process and the method of nonlinear optimisation which enables, at the same time, the determination of systemic measuring errors and unknown parameters. Further research is possible in the construction of the piston-radial pumps with a bent cylinder block and splitting of working fluid by means of a split panel. Mathematical model would be, in that case, expanded by a dynamic cylinder block and a hydrodynamic processes in clearances between the cylinder block and the split panel. The instantaneous pressure inside the piston chamber is investigated. Because the pressure and the flow rate are coupled, the leakage located in the friction pairs is also analysed. The discharge pressure pulsation is calculated and present in this paper. The

output pressure value can be detected by the pressure transducer. It can be utilized in the further research of detecting instantaneous flow rate ripple.

References

- [1] R.Petrovic,1999.Mathematical modeling and identification of multi cylindrical axial piston pump parameters. PhD Thesis, Faculty of Mechanical Engineering, 1999,Belgrade,Serbia.
- [2] M.Bergeman,1994.Systematische Untersuchung des Geräuschverhaltens von Kolbenpumpenwith ungeraderKolbenanzahl, Verlag Mainz, Wissenschaftsverlag, Aachen.
- [3] J.Ivantysyn,M.Ivantysynova,2001.Hydrostatic Pumps and Motors. Principles, Design, Performance, Modelling, Analysis, Control and Testing“.First English Edition. New Delhi, India: Akademia Books International.
- [4] B.Obrović,S. Savić, R. Petrović, 2011. Dissociated gas flow in the boundary layer along bodies of revolution of a porous contour. *High Temperature*, Vol. 49, No. 3 (2011), pp. 413-421. ISSN 0018-151X.
- [5] R.Petrović, 2009.Mathematical modeling and experimental research of characteristic parameters Hydrodynamic processes of a piston axial pump. *Strojnikivestnik – Journal of Mechanical Engineering*, Vol. 55, No. 4 (2009), pp. 224-229. ISSN 0039-2480.
- [6] R.Petrović,2009. Mathematical modeling and experimental verification of operating parameters of vane pump with double effect. *Strojnikivestnik – Journal of Mechanical Engineering*, Vol. 55, No. 1 (2009), pp. 26-32. ISSN 0039-2480.
- [7] R.Petrović,M.Živkovic,2012.Systematic research of characteristic parameters of the piston and identification of hydrodynamic processes of a piston radial pump. In: *Proceedings of the 12th International Conference "Research and Development in Mechanical Industry – RaDMI 2012"*, Volume 2, Vrnjačka Banja, Serbia, 13-17 September 2012.Vrnjačka Banja: SaTCIP Ltd., 2012, pp. 843-849. ISBN 978-86-6075-037-4.
- [8] W.Zheng,R.Petrović,M.Gašić,N.Todić, 2009.The influence of fluid compressibility on discharge flow in high pressure vane within vane type pump. In: *Proceedings of the 9th International Conference "Research and Development in Mechanical Industry – RaDMI 2009"*, Vol. 1, Vrnjačka Banja, Serbia, 16-19 September 2009.Vrnjačka Banja: SaTCIP Ltd., 2009, pp. 426-432. ISBN 978-86-6075-007-7.
- [9] R.Petrovic, M.Andjelkovic, M.Radosavljevic, N.Todic,2014,Experimental Research and Optimization of Characteristic Parameters of the Valve Plate of the Axial Piston Pump/Motor,Department of Designing and Machine Components, Faculty of Mechanical Engineering, CZECH TECHNICAL UNIVERSITY IN PRAGUE,organize 55th International Conference of Machine Design Departments (ICMD2014), the BEST WESTERN Hotel Grand, Beroun, Czech Republic September 9 –12.

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