# ANALYSIS OF VALVE PLATE STRESS IN AN AXIAL PISTON PUMP

NENAD TODIĆ,[1] MAJA ANDJELKOVIĆ,[2]
RADOVAN PETROVIĆ[3]

[1] University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia
ntodic@gmail.com
[2] University "Union-Nikola Tesla" of Belgrade, Faculty of Information Technology and Engineering, Belgrade, Serbia
maja.andjelkovic@fpsp.edu.rs
[3] University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Kraljevo, Serbia
radovan4700@yahoo.com

Hydraulic pump is the heart of aircraft hydraulic system. Performance degradation based on mixed wear theory of aviation hydraulic piston pumps: its reliability and safety is very important; complicated structure; high pressure; high speed; strong vibration, multi field coupling, high reliability and long life. This paper establish detailed model based on mixed lubrication-wear mechanism. Experiment and validation indicate that the proposed mathematical model can reflect the integrated development process of hydraulic pump. Mechanical analysis of barrel-valve plate covers: film thickness, pressure distribution in different angles, contact pressure considering machined roughness, elastic and plastic deformation, comparison of contact force and fluid force, elastic and plastic deformation, viscosity and deformation compensation.

**Keywords:**
piston pump, experimental research, hydraulic system, pressure, mathematical modelling

University of Maribor Press

DOI https://doi.org/10.18690/um.fs.5.2023.17
ISBN 978-961-286-781-2

## 1 Intruduction

The distribution of pressure in the valve plates of an axial piston pump varies according to the phases of pump operation. The pressure schedule includes suction and discharge phases [1].

In the suction phase, the piston moves, creating a vacuum in the suction chamber. The port on the suction side is open so that the fluid can be sucked from the tank. In valve plates, the pressure is lower in the suction chamber to allow fluid to enter the pump.

The compression phase occurs when the piston moves forward, creating increased pressure in the pump's discharge chamber. The pressure port is open, while the suction port is closed. The pressure in the valve plates is higher in the pressure chamber so that the fluid is pushed through the outlet port to the hydraulic system.

This cycle is repeated during pump operation, creating an alternation between suction and discharge phases. The valve plate pressure distribution is designed to ensure efficient fluid suction during the suction phase and reliable fluid delivery during the push phase. Valve plate openings play a key role in controlling fluid flow direction and pressure distribution in stress analysis [2].

## 2 Determining the flow sections of the valve plate

The change in pressure is largely influenced by the smallest cross-section of the fluid flow formed by the valve plates and the rotating cylinder block. For simulation calculations, it is important to know the exact size of the flow passage opening on the high and low pressure side, depending on the angle of rotation. Due to the complex geometrical section, an analytical description of the cross-section is not possible. In the past, the cross section was measured and interpolated manually to obtain the surface profile. Using a 3D model of the valve plate, PAK is able to automatically calculate the smallest fluid cross-section for a complete revolution of the cylinder block (Fig. 1). [3]

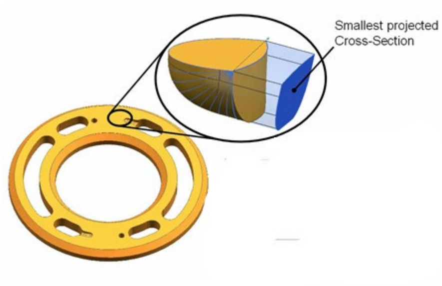


**Figure 1: Cross Section Area**
Source: own.

## 3 Systematic research of characteristic parameters

Predicting pump performance for a given design requires a simulation model that describes compressible and viscous fluid flow from the ports through the valve plates to the ventricles. Flow through lubrication gaps, which seal the chambers, must be considered. The change in pressure in the chambers is the result of the basic process of the pump and causes fluctuating forces and moments that lead to oscillating micro-motion of the moving parts of the pump's rotary group.

The influence of suction pressure *p*u on the gradient of pressure increase in the cylinder is shown in Figure 2 where steeper pressure gradients correspond to higher suction pressures. The size of the pressure pulsations in the pressure chamber is also affected by the suction pressure, in that lower suction pressures correspond to larger pulsations, Figure 3.

The influence of the number of revolutions of the drive shaft n on the flow of high-pressure pressure pulsations in the cylinder during the compression phase was observed, and it was noted that at a higher number of revolutions, larger pulsations appear, as a consequence of the influence of valve dynamics in this phase, Figure 4. The influence of the number of revolutions of the drive shaft on pressure pulsations in the pressure chamber is shown in Figure 5. It is noticed that at a higher number of revolutions, lower pressure pulsations appear in the pressure chamber.

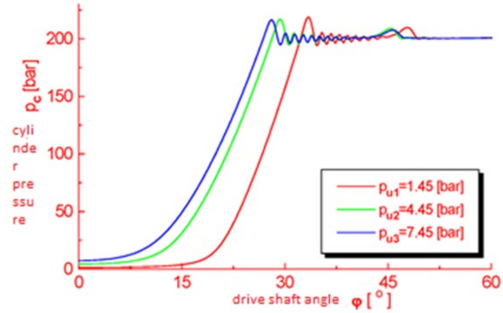


**Figure 2: Impact of the suction pressure $p_u$ to the gradient of pressure increase in the cylinder, $p_c$**

Source: own.

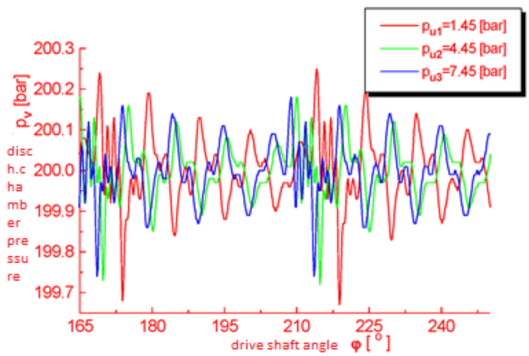


**Figure 3: Pressure flow in the discharge chamber $p_v$ during pressure change $p_u$ in the operating fluid**

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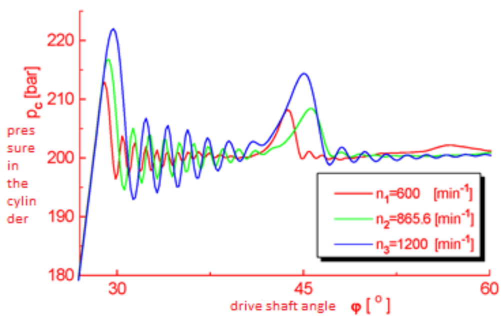


**Figure 4: Impact of the number of shaft revolutions nto the pressure pulsations flow in the cylinder, pc in the compression phase**

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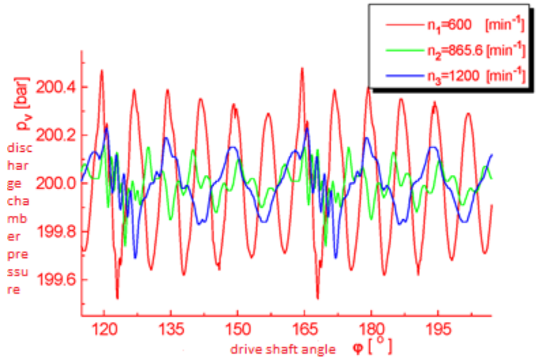


**Figure 5: Impact of the number of shaft revolutions $n$ to the pressure pulsation, $p_v$ in discharge chamber**

Source: own.

## 4 Conclusion

Almost all available models are based on measurements, but different methods are applied to obtain an analytical description.

The limit to the achievable accuracy of most of these models is given by the use of a relatively simple analytical expression, while a good fit of the measured curves is usually achieved only in a limited range of operating parameters.

The dependence of all important operating parameters such as pressure difference, velocity, displacement volume and temperature can be easily considered using the PAK software package. The software tool is based on Matlab.

### References

[1] Petrovic R.: „Matematičko modeliranje i identifikacija parametara višecilindričnih klipno-aksijalnih pumpi", doktorska teza, Mašinski fakultet Univerziteta u Beogradu, Beograd 1999.

[2] R. Petrović, N. Todić "Modeling and experimental research of characteristic parameters hydrodinamic processes of axial piston pumps with constant pressure and variable flow", p. 278 – 285, The 20 th International Conference on Hydraulics and Pneumatics, Prague, September 29 – October 1, 2008.

[3] R. Petrović, J.Pezdirnik, M.Živković „Mathematical modeling and identification of hydrodinamic processes of a piston radial pump" p.47-58, ISBN=978-961-248-290-9, Mednarodne conference Fluidna tehnika 2011, 15. In 16. September 2011, Maribor, Slovenija