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OIL LEAKAGE IN A VARIABLE-HEIGHT GAP BETWEEN THE CYLINDER BLOCK AND THE VALVE PLATE IN A PISTON PUMP

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Summary. The paper analyses the flow intensity of oil leakages in a variable-height gap between the cylinder block and the valve plate in an axial piston pump. The analysis is carried out for various zones of the valve plate depending on the inclination angle of the cylinder block and the dynamic viscosity coefficient of oil.

Key words: oil leakage, variable-height gap, piston pump.

INTRODUCTION

Due to their capability of operating at high pressures and powers, piston pumps are characterized by high values of energy efficiency coefficients, computed as the ratio of power to mass or volume [Osiecki 2004, Stryczek 1984]. Because of that they have found numerous applications in various branches of industry, especially in machines with complex functions, high efficiency and yield requirements. This, in turn, creates a demand for continuous development towards improving exploitation parameters of those machines by modernizing their construction.

In a pump operating in real conditions, due to variable moments resulting from hydrostatic load and relief forces, the cylinder block takes a non-parallel position with respect to the valve plate and the gap between them is of variable height [Ivantysyn and Ivantysynova 2001, Jang 1997, Kaczmarek and Rutanski 1982, Pasynkow 1976], as shown in Fig. 1.

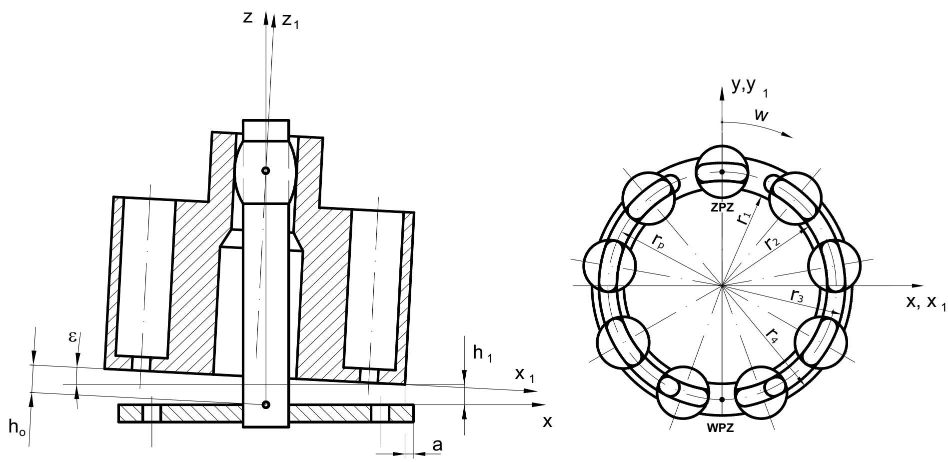

Fig. 1. Variable-height gap with a non-parallel cylinder block

During the pump's operation oil leaks outside and inside the valve plate, which affects, among other things, the volumetric efficiency of the pump [Jerszow and Kariew 1979, Zloto 2007].

In the present paper numerical methods are employed for determining the flow intensity of oil leaks in various zones of the valve plate in an axial piston pump.

COMPUTATION MODEL OF FLOW INTENSITY OF OIL LEAKS IN A VARIABLE-HEIGHT GAP

It was assumed that the gap between the rotating cylinder block and the valve plate is of variable height. Assumptions concerning the oil flow in the gap are as follows [Nikitin 1982, Osipow 1966]:

- the flow is laminar,
- the surfaces are rigid and do not undergo deformation,
- the gap's height is small and completely filled with oil,
- the tangent stress is Newtonian,
- the liquid is noncompressible,
- the liquid inertia forces are negligible.

A model of gap flows between the cylinder block and the valve plate is shown in Fig. 2.

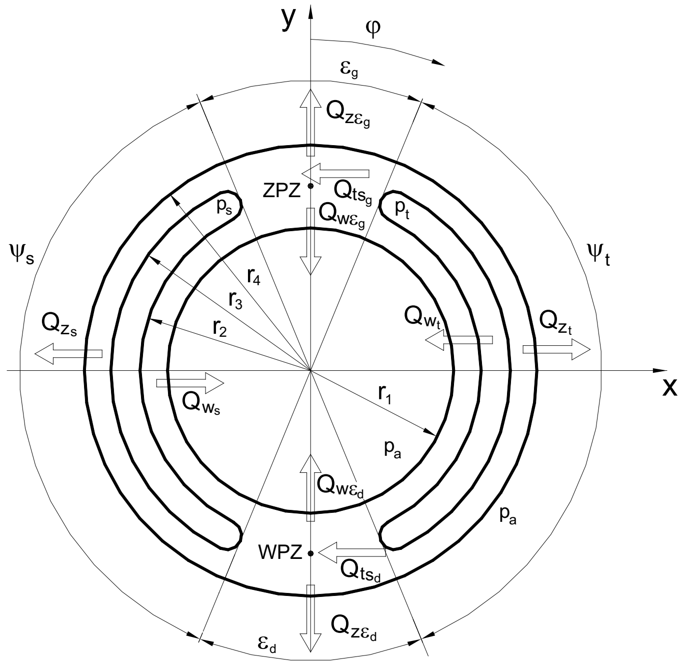

Fig. 2. Model of gap flows

In the pressure zone ψ_t and the suction zone ψ_s , the liquid flows outside the valve plate Qz_t and Qz_s, and into the valve plate Qw_t and Qz_s. In the upper and lower transition zones there are also centrifugal flows $Qz\varepsilon_g$ and $Qz\varepsilon_d$, as well as centripetal flows $Qw\varepsilon_g$ and $Qw\varepsilon_d$. Between the pressure and suction zones there are peripheral flows Qts_g and Qts_d.

In each of the zones the flow intensity of oil leaks was computed as the elementary product of the gap cross-section area and the mean flow velocity in accordance with:

$$Q = P\frac{1}{n}\sum_{i=0}^{n}\left(\upsilon_r\right)_{sri}, \tag{1}$$

where:
P – the total area of the gap cross-section,
n – the number of interpolation intervals,
$(\upsilon_r)_{\mathrm{sri}}$ – the mean flow velocity.

The cross-section area was obtained on the basis of the numerical method of squaring interpolated trapeziums [Majchrzak and Mochnacki 1994] according to:

$$P = l_n\left[\frac{h(r,\varphi_0)+h(r,\varphi_n)}{2}+\sum_{i=1}^{n-1}h(r,\varphi_i)\right], \tag{2}$$

where:
$h(r, \varphi)$ – the gap height at a given radius and angle,
φ_0 – the angle at the beginning of a given zone,
φ_n – the angle at the end of a given zone,

n – the number of intervals in the method of squaring interpolated trapeziums,
l_n – the length of an interval in the numerical method.
The gap height for a given cross-section was obtained from:

$$h = -r\sin\varphi \cdot \cos\delta \cdot tg\varepsilon - r\cos\varphi \cdot \sin\delta \cdot tg\varepsilon + Rtg\varepsilon + h_1, \tag{3}$$

where:
r – the current radius of a given cross-section,
φ – the angle of a given flow cross-section,
ε – the inclination angle of the cylinder block,
δ – the angle between the axis x and the smallest height h_1 of the gap,
R – the radius of the cylinder block.

The accuracy of results obtained in the computation model depends on the number n of intervals in the numerical method of squaring interpolated trapeziums [Zloto and Nagorka 2009]. Fig. 3 presents the accuracy of results depending on the assumed number of intervals: the more intervals, the more accurate the results.

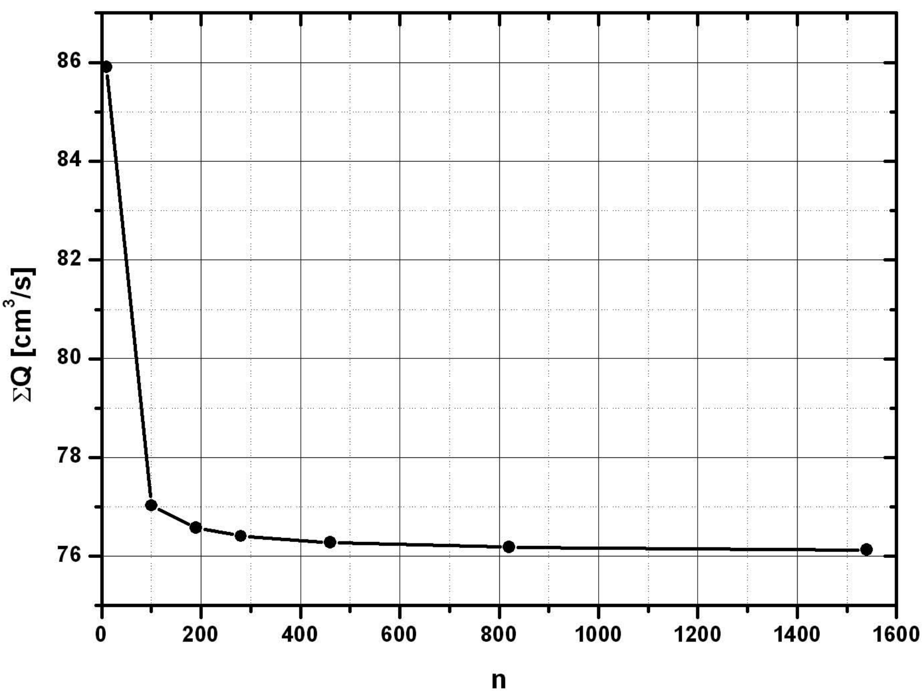

Fig. 3. Values of the flow intensity depending on the number of intervals assumed in the numerical method

The total flow intensity of oil leaks in a variable-height gap was computed according to the algorithm presented in Fig. 4.

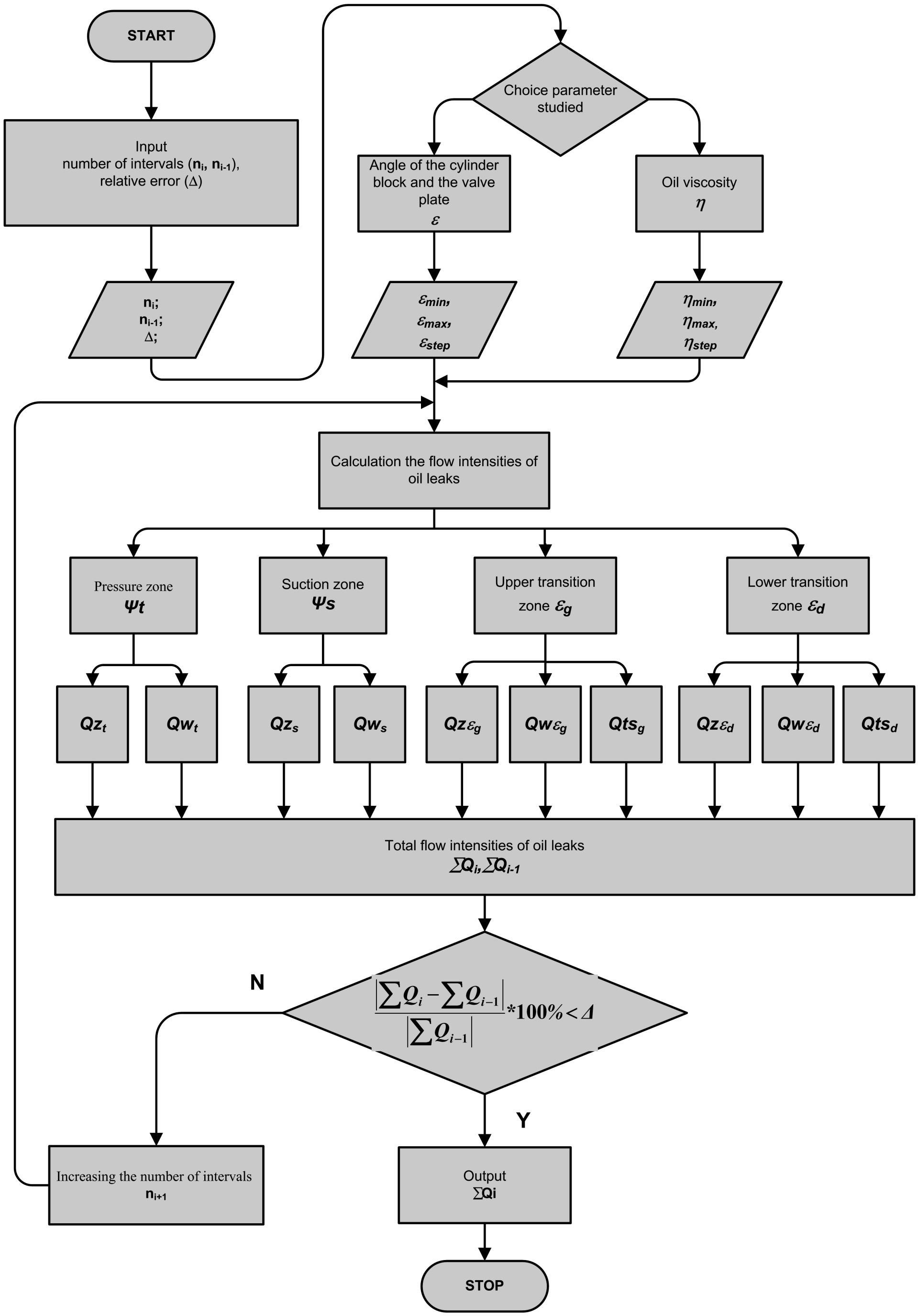

Fig. 4. Algorithm for numerical computation of the leak flow intensity

RESULTS OF COMPUTATIONS CARRIED OUT IN THE STUDY

The above-described computation model was utilized for the analysis of the total leak flow intensity depending on the angle ε of the cylinder block inclination and the dynamic viscosity coefficient η of oil.

The following data was assumed in the model:

- the pressure in the pressure zone $p_t = 32$ MPa,
- the pressure in the suction zone $p_s = 0.1$ MPa,
- the pressure outside and inside the valve plate $p_o = 0$ MPa,
- the angular velocity of the cylinder block $\omega = 157$ rad/s,
- the angle $\delta = 0{,}785$ rad with respect to the axis x of the smallest gap height h_1,
- the angle of the cylinder block inclination with respect to the valve plate $\varepsilon = 0{,}000523$ rad,
- the minimal gap height $h_1 = 2 \times 10^{-6}$m,
- the characteristic radiuses of the valve plate of a pump are $r_1 = 0{,}0284$ m, $r_2 = 0{,}0304$ m, $r_3 = 0{,}0356$ m i $r_4 = 0{,}0376$ m.

Fig. 5 presents the percentage shares of oil leak intensity in the particular zones of the valve plate. As can be seen, the greatest leaks are in the upper transition zone of the valve plate, and the smallest at the suction zone.

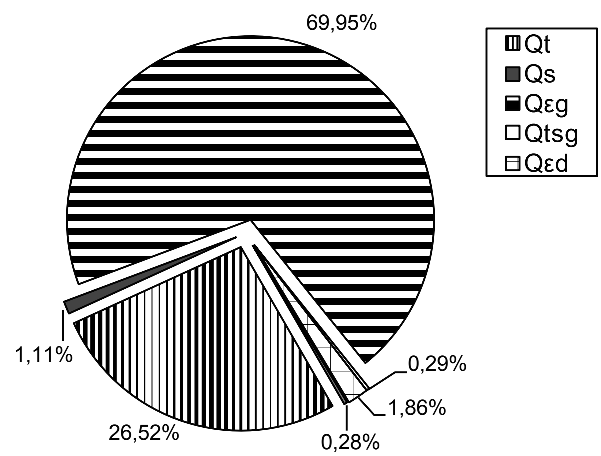

Fig. 5. Percentage shares of oil flow intensities at the particular zones of the valve plate

Figs. 6 and 7 show total values of oil leak flow intensity depending on the inclination angle of the cylinder block and on the dynamic viscosity coefficient of oil, respectively.

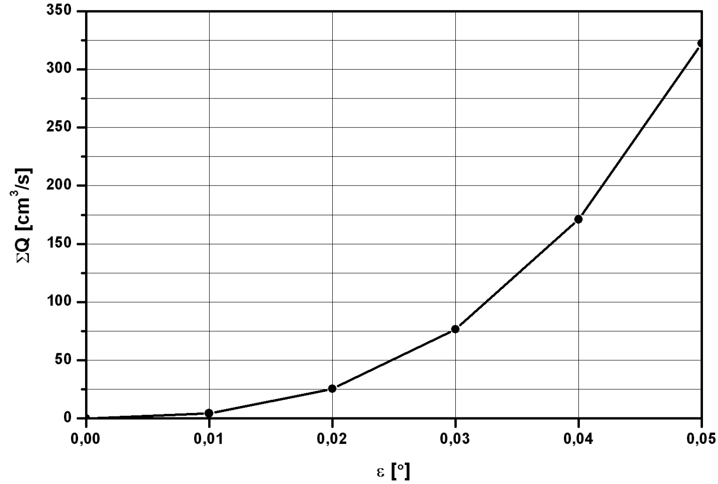

Fig. 6. Values of total flow intensities of oil leaks depending on the inclination angle of the cylinder block

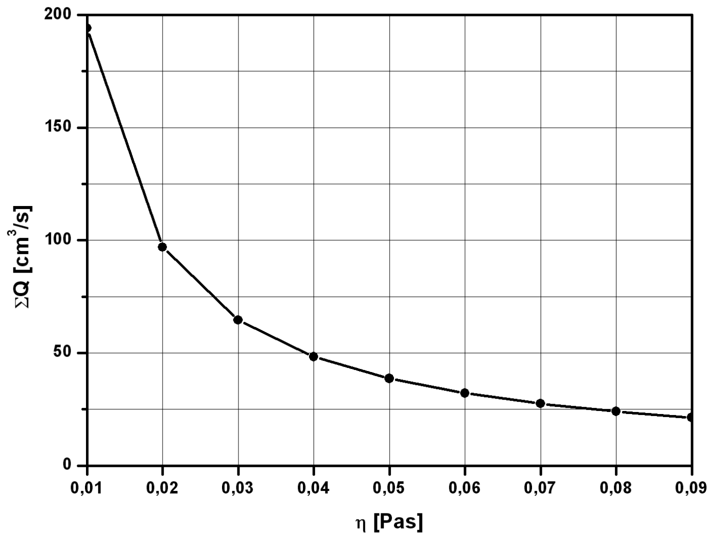

Fig. 7. Values of total flow intensities of oil leaks depending on the dynamic viscosity coefficient of oil

Figs. 6 and 7 depict the significant influence of the inclination angle of the cylinder block and of the dynamic viscosity coefficient of oil on the total values of oil leaks.

CONCLUSIONS

On the basis of the carried out study, the following conclusions can be formulated.

1. The developed computation model is suitable for the analysis of the flow intensity of oil leaks in the particular zones of the valve plate.

2. The highest percentage of the leak flow intensity occurs in the upper transition zone.
3. The impact of the cylinder block inclination angle and of the dynamic viscosity coefficient on the total values of leak flow intensity is significant.

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PRZECIEKI OLEJU W SZCZELINIE O ZMIENNEJ WYSOKOŚCI POMIĘDZY BLOKIEM CYLINDROWYM I TARCZĄ ROZDZIELACZA POMPY TŁOKOWEJ

Streszczenie. W pracy przedstawiono analizę natężenia przepływu przecieków oleju w szczelinie o zmiennej wysokości pomiędzy blokiem cylindrowym i tarczą rozdzielacza pompy wielotłoczkowej osiowej. Analizę przeprowadzono dla różnych stref tarczy rozdzielacza w zależności od kąta pochylenia bloku cylindrowego i współczynnika lepkości dynamicznej oleju.

Słowa kluczowe: przecieki oleju, szczelina o zmiennej wysokości, pompa tłokowa.