

## VOLUMETRIC LOSSES IN MULTI-SLOT SEALING OF BALANCE DISC IN HIGH-PRESSURE PUMPS

Andrzej WILK<sup>1</sup>, Kazimierz GOLEC<sup>2</sup>

1 Institute of Power Engineering and Turbomachinery, Silesian University of Technology,  
ul. Konarskiego 18, 44-100 Gliwice, POLAND;

2 Zakład Mechaniki Przemysłowej ZAMEP sp z o.o. ul. Udzieli 6, 44-100 Gliwice, POLAND  
E-mail: andrzej.t.wilk@polsl.pl

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The balance disc is used to balance the axial thrust in the high-pressure centrifugal pumps. The volumetric losses occurs in balancing system.

The quantity of the volumetric loss depends on the pressure difference between pressure at the inlet to the radial gap and the pressure under balance disc, and the dimensions of the radial gap, i.e. its diameter, length and width (Wilk S., 1984; Korczak A., 2005).

Assuming that during the flow through the axial gap pressure drop is linear, and despite a small loss of pressure at the inlet to the gap, height of the pressure under balance disc is given by the formula

$$H_t = \frac{F_c}{\pi \cdot g \cdot \rho \cdot \left[ \frac{1}{3} (r_w^2 + r_w r_z + r_z^2) - r_{sz1} \right]} \quad (1)$$

The work adopted one-dimensional calculating model supplemented by correction factors. On the basis of laboratory measurements (Wilk A., 2009) and theoretical analyzes (Wilk A., Wilk S., 2003) can be stated that such a model allows for obtain a satisfactory accuracy of calculations.

The relative volumetric loss in the balance disc is defined as

$$q_1 = \frac{Q_{sz1}}{Q} \quad (2)$$

A detailed analysis of this issue can be found for example in (Wilk A., 2003)

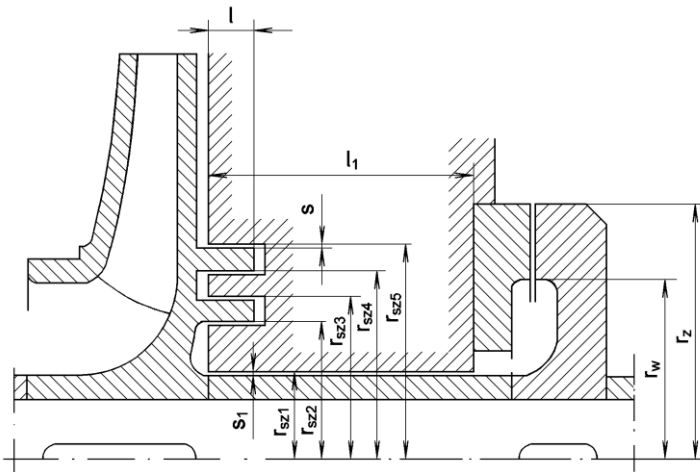
For example, it was calculated the relative volumetric loss in the high-pressure pump with the following nominal parameters: discharge  $Q = 0,0875 \text{ m}^3/\text{s}$ ; delivery head from one stage  $H = 80 \text{ m}$ ; rotational speed  $n = 1450 \text{ rpm}$ ; number of stages  $i = 10$ ; and dimensions of balancing system  $r_w = 0,155 \text{ m}$ ,  $r_z = 0,19 \text{ m}$ ,  $r_{sz1} = 0,07 \text{ m}$ ,  $l_1 = 0,195 \text{ m}$ ,  $s_1 = 0,00035$ .

Calculated relative volumetric loss is equal to  $q_1 = 0,063$ .

When the pump works with affluence, for example during series connection of pumps, the head of pressure at the inlet to the radial gap is increased by the head pressure of affluence. For example, during serial cooperation the 7-stage pump (first in serial connection, the head pressure of affluence  $H_n = 560 \text{ m}$ ) with a 10-stage pump (working as the second in a serial connection), relative volume loss increases to  $q_1 = 0,0921$ .

**Multi-slot sealing.** To reduce the volumetric losses in the system would increase the length of radial gap and reduce it's width.

Increasing the length of the gap increases the length of the shaft and the pump and thus increase the deflection of the shaft and the weight of the pump. Reducing the width of the gap would cause weakening of the sleeve.



Rys.1. Multi-slot sealing of balance disc

Way to reduce the volumetric losses in the axial thrust balancing system without having to increase the dimensions lengths, can be applied multi-slot sealing after the last impeller. This design solution was developed in Zakład Mechaniki Przemysłowej ZAMEP and is protected by the Polish Patent Office. Sample solution is shown in Fig. 1. After applying multi-slot sealing after last stage impeller increases the hydraulic resistance during flow of the liquid under balance disc and reduces the pressure acting on the rear disc of

last impeller resulting in reduced axial thrust acting on the rotating assembly.

For example, the relative volumetric loss was calculated for the following dimensions of the multi-slot sealing behind the impeller of last stage  $r_{sz2} = 0,08$  m,  $r_{sz3} = 0,09$  m,  $r_{sz4} = 0,1$  m,  $r_{sz5} = 0,11$  m,  $l = 0,025$  m,  $s = 0,00035$  m.

The calculated relative volumetric loss is  $q_1 = 0,0478$ . The speed of the fluid in the gap was also significant decreases from  $c_1 = 35,813$  m/s to  $c_1 = 27,178$  m/s.

During pump operation with affluence ( $H_n = 560$  m) the relative volumetric loss is equal  $q_1 = 0,0691$ .

**Conclusions:** 1. Application of the multi-slot sealing behind the last stage impeller in the high-pressure pump with balance disc can substantially reduce the volumetric losses in the balancing system without necessity of increasing the lengths of the pump.

2. Application of the multi-slot sealing behind the last stage impeller results in a significant reduction of liquid velocity in the gap and thus increases the sustainability elements of the balancing system.

#### Notation schedule:

$F_c$  - total axial thrust acting on impellers, N,     $H_t$  - pressure head under balancing disc, m,  
 $n$  - rotational speed, rpm,     $Q$  - pump discharge, m<sup>3</sup>/s,  
 $q_1$  - relative volumetric loss,     $Q_{sz}$  - volumetric flow rate in the gap, m<sup>3</sup>/s,

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