TRANSACTIONS OF THE INSTITUTE OF FLUID-FLOW MACHINERY

No. 136, 2017, 47–54

Krzysztof Karaśkiewicz and Łukasz Złoty*

Influence of radial flow impeller balance holes on the net positive suction head for rotodynamic pumps

Institute of Heat Engineering, Faculty of Power and Aeronautical Engineering, Warsaw University of Technology, Politechniki 1, 00-661 Warsaw, Poland

Abstract

The influence of balance holes of rotodynamic pumps on the net positive suction head is not fully clear. The lack of available information on the subject leads to the situations when deterioration in suction properties of the pump due to the presence of balance holes is recognized during pump test phase. Usually some holes are arbitrarily plugged. The paper analyses the influence of balance holes on net positive suction head characteristics. The measurement data are presented.

Keywords: Balance holes; Net positive suction head (NPSH); Centrifugal pumps; Cavitation

Nomenclature

H, h	–	dimensional and dimensionless pump head
N	–	number of measurement points on characteristic
Q, q	–	dimensional and dimensionless pump flow
n_q	–	pump specific speed
η, τ	–	dimensional and dimensionless pump efficiency
σ	–	average deviation between measured characteristics
NPSH3	–	net positive suction head value calculated as 3% drop of pump head

Subscripts

bh	–	corresponding to impeller with balance holes
BEP	–	corresponding to best efficiency point for hole-less pump impeller

*Corresponding author. E-mail address: lukasz.zloty@itc.pw.edu.pl

1 Introduction

When selecting a pump for a pumping system, the NPSHR (net positive suction head required) should meet the requirement: NPSHR < NPSHA (net positive suction head available) and thus be sufficiently low. Use of the pump balance holes usually worsens the NPSHR over a pump without holes, but is the cheapest way to reduce axial thrust. Also in this case, risk of occur a cavitation erosion could be higher – this subject was discussed in [7]. When NPSHR guaranteed is unexpectedly high, ad hoc practice of the manufacturer is to plug a part of the holes. Axial thrust must increase after this operation. Thrust bearings may be slightly overloaded in multistage pumps and even more in single-stage pumps. The designer should predict that but the relationship between NPSH and balance holes parameters is lacking in the literature [1–4] as a consequence, the impact of holes on NPSH cannot be quantified.

2 Test stand

Analyzed measurements in the paper was based on the experimental data. Test stand is built on single-stage in-line centrifugal pump with specific speed close to $n_q = 30$. Impeller is installed on electrical motor shaft. Pump casing with volute channel is assembling to motor flange. Schematic diagram of the stand used to research is presented in Fig. 1. Pump was installed horizontally. Nominal pump unit rotor speed was around 2940 rpm. The pump has a typical radial shroud impeller with 6 blades. The pump impeller with balance holes is shown in Fig. 2, all dimensions are given in millimeters. Diameter of the impeller blades and shroud are equals. Pipelines, valves and tank were connected via created closed loop system. In that case decreasing value of pressure in tank provides lower NPSHA. This setting of water tank pressure level was used to induce cavitation phenomena in the pump.

3 Measurements

To investigate how applying balance holes in pump impeller influence on NPSH value, laboratory test have been performed. The experiment was divided into two separate tests. In the first test, the results obtained include a cavitation curve of the pump impeller without balance. In this case the lowest NPSH value was expected. In the second case, made in the impeller, two $\phi = 0.006$ m balance holes were at a 0.055 m pitch diameter as shown in Fig. 1. All NPSH3 characteristics for 3% drop of pump head were measured for almost the same flow rate values. Rotational speed, power consumption and water temperature was also checked during the tests. The study was conducted in accordance with ISO 9906 standards [8].

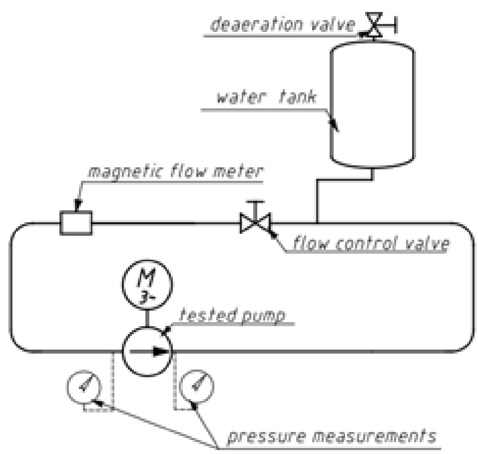

Figure 1. Schematic diagram of laboratory test stand.

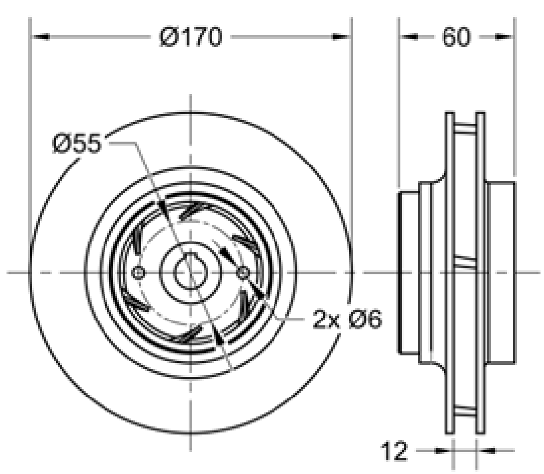

Figure 2. Drawing of the tested pump impeller with balance holes.

4 Results and discussion

The results of the experiment are presented in the form of pump characteristic curves. The calculated values were represented in a nondimensional form:

$$q = \frac{Q}{Q_{BEP}}\,, \tag{1}$$

$$h = \frac{H}{H_{BEP}}\,, \tag{2}$$

$$\eta = \frac{\tau}{\tau_{BEP}}\,. \tag{3}$$

To estimate the deviation between the measured pump curves, the following formula is used:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(h_i - h_{bh,i}\right)^2}\,. \tag{4}$$

Figure 3 shows that the presence of balance holes reduces the pump head. The average deviation value of the dimensionless head is about 3.2% of H_{BEP}. This may be a result of increased impeller volumetric losses. Some of the impeller energy is consumed by the circulation of the additional.

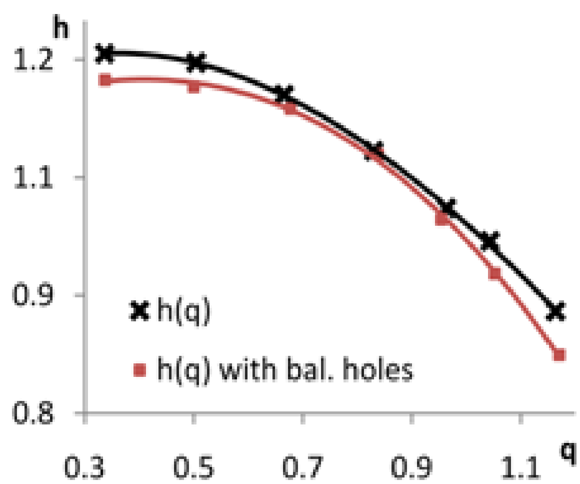

Figure 3. Dimensionless head-capacity characteristics for two cases.

Table 1. Measurement data for NPSH values.

q	NPSH3 [m]	NPSH3 with balance holes [m]	ΔNPSH3 [m]
0.331	1.149	1.680	0.531
0.488	1.860	2.250	0.390
0.651	2.636	3.320	0.684
0.816	3.419	4.060	0.641
0.922	4.031	4.740	0.709
1.023	4.660	5.587	0.927
1.124	6.337	6.700	0.363
Average NPSH increase:			0.606

This is also clear from Fig. 4. Decreasing head and raising volumetric loss leads to lower efficiency. This drop of efficiency is significant and shows the effect of balance holes on basic pump parameters such as head and efficiency. Calculated average deviation of η is nearly 3.1% of nominal η_{BEP}. In the pump design process this effect is very roughly estimated and sometimes not taken into account.

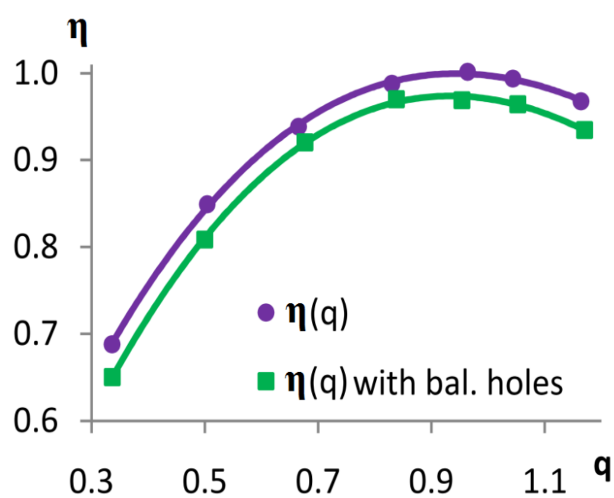

Figure 4. Dimensionless efficiency curves included two study cases.

These researches were focused on estimating impact of the balance holes on the NPSH value. Figure 5 shows the results of this study. The pump with impeller without balance holes provides improvement of cavitation characteristic approximately 0.6 m. In addition Tab. 1 presents NPSH measurement values for both investigated cases. One reason for the increase in NPSH is the increase in internal leakage. The Q flow through the balance holes estimated in [2] (formula

T.3.5.10) is $Q_s = 0.018 Q_n$ and according to [6] has almost the same value. In the case of impeller with holes, the flow rate through impeller can be estimated as $Q_n + Q_s = 1.018\, Q_n$ where subscripts n, and s denote nominal pump flow and flow through balance holes, respectively. According to the similarity law, NPSH is proportional to the square Q [2]:

$$\mathrm{NPSH} \sim Q^2 \,, \tag{5}$$

hence

$$\frac{\mathrm{NPSH}_{\text{with bal. holes}}}{\mathrm{NPSH}} = \left(\frac{Q_n + Q_s}{Q_n}\right)^2 \,, \tag{6}$$

Considering the value of NPSH at nominal point NPSH = 4.66 m this gives a 0.17 m increase in NPSH. Comparing with that result, the measured value 0.5 m is higher so another reason for the increase in NPSH may be the influence of the stream coming from the balance holes on the pressure field at the impeller inlet. That stream creates complex vortex structure. This phenomenon is unfortunate that it occurs mainly at the inlet of the suction blade. As is well known, this part of impeller blade is most exposed on cavitation effect. A more detailed description of this case is in [5]. In paper [5] there is a CFD analysis for flow through rotating holes. The conditions near these holes are similar to the impeller holes of the pump tested. Figure 6 shows streamlines for fluid flow through rotating holes. As a result of the rotation a vortex in the hole appears and the flow pattern at the outlet of it is very complex. This may interfere with the flow field in the inlet of blade channel, cause additional losses and lower the pressure on the suction side.

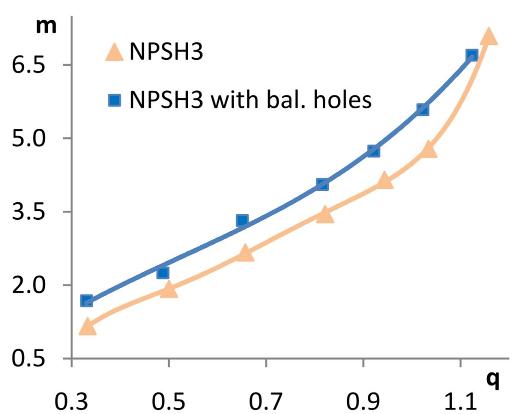

Figure 5. NPSH values means by meter in function dimensionless capacity for two study cases.

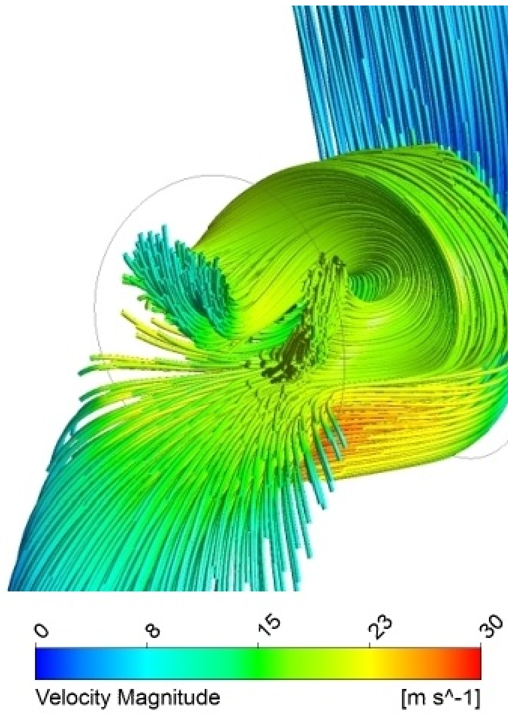

Figure 6. Streamlines flowing through rotating holes based on [5].

5 Conclusions

The paper presents an analysis of experimental data for the pump of specific speed $n_q = 29.7$. The tests were performed for impeller without holes and with two balance holes. A relatively high NPSH3 increase was achieved at a nominal point of more than 10%. Study shows that the impact of balance hole may be significant for NPSHR characteristics and that further studies are needed to capture quantitative relation between hole parameters and NPSHR increase.

Received in October 2017

References

[1] Jędral W.: *Rotodynamic Pumps.* PWN, Warsaw 2001.

[2] Gülich J.F.: *Centrifugal Pumps.* Springer-Verlag, Berlin Heidelberg 2008.

[3] Karassik I.J., Messina J.P., Copper P., Heald C.C.: *Pump Handbook Third Edition*, McGraw-Hill, 2001.

[4] Tuzson J.: *Centrifugal Pump Design.* John Wiley & Sons, 2000.

[5] Karaśkiewicz K., Złoty Ł.: *Investigations of turbulent flow through axial thrust balance holes in rotodynamic pumps*. Trans. Inst. Fluid-Flow Mach. **130**(2016), 57–69

[6] Wilk A.: *Flow Rate Coefficient Through the Exculpatory Holes in the Rotodynamic Pump.* PhD thesis, Silesian University of Technology, Gliwice 1998.

[7] Gireń B.G., Noińska-Macińska M.: *Cavitation erosion regimes — an attempt of deriving classification predictor*. Trans. Inst. Fluid-Flow Mach. **132**(2016), 3–15.

[8] PN-EN ISO 9906, June 2012, PKN, Warszawa 2012, ISBN 978-83-266-9738-8.