

Abstract

For the safe operation of pumps, it is essential to examine the operation parameters. Operation deviating from the operational parameters defined by the manufacturers would damage the pumps. The majority of specialists who are experts at pump technology and fluid mechanics are familiar with cavitation and aware of its detrimental effects. Firstly, in my study I will briefly present the cavitation as a phenomenon taking place during operation and its counting method. Then I state the results of our measurements carried out during the operation of a pump built in a system type Nocchi CB8038T. My goal is to call the attention to the proper way of the operation of centrifugal pumps, the cavitation generated during operation as a harmful phenomenon and its development examined in practice by us.

Keywords

operational parameters, cavitation, NPSH, centrifugal pump, Strouhal number, cavitation number, Reynolds number

1 Introduction

Operation not in conformity with the standards recommended by the manufacturer can result in a decline in performance or a failure of the pump. Cavitation is one of the phenomena which causes pump failure and whose development I monitored in my practical tests.

Before presenting my measurements, I find it important to give a short introduction to cavitation and the mathematical basis of its calculation to help a better understanding of the topic. I believe that publishing my experience contributes to the safe operation of pumps.

2 The description of the hydrostatic measuring system

The hydrostatic measuring system- Fig. 1- is suitable for research. The following features of hydraulic pumps can be measured, namely flow rate, pressure, speed and temperature. These parameters can be used to capture the characteristics that are used to evaluate the technical condition for operation. The pumps can be reassembled so that the system can be used to measure several types of pumps. I plan to incorporate a thermocouple element into the system, thus examining the phenomenon of heat-induced cavitation.



Fig. 1 The hydrostatic measuring system (Author compilation)

¹ Department of Mechatronics and Machine Design,
Faculty of Engineering Sciences,
Széchenyi István University,
H-9026 Győr, Egyetem tér 1, Hungary

* Corresponding author, e-mail: fecser.nikolett@sze.hu

The Table 1 shows the Technical Specifications of Measuring Equipment.

Table 1 Technical Specifications of Measuring Equipment (Nocchi, 2010)

| | Technical Specifications |
|--------------------------------------|--------------------------|
| Pump type | Nocchi CB8038T |
| Amount of Delivered Water | $Q_{max}=80$ l/min |
| Delivery Height | $H_{max}=30$ metre |
| Number of Impeller Vanes | $N=2$ pc |
| Electric Motor | $P=1.1$ kW, 3x400 V AC |
| Speed of Electric Motor | $n=2800$ rpm |
| Range Regulated by Frequency changer | $f=30-60$ Hz |

3 Phenomenon of cavitation

The available scientific literature provides several definitions for cavitation. Cavitation takes place when the gas bubbles developed in the fluid suddenly collapse. This process takes place at those locations in the pump where the pressure is subjected to the vapour-pressure of the pumped medium. Vapour-pressure of a fluid is a kind of pressure at which the fluid starts boiling or vapourising. (Sebestyén et al., 1978).

The cavitation is the partial evaporation of water in a flow system. A cavity filled with vapor is created when the static pressure in a flow locally drops to the vapor pressure of the liquid due to excess velocity. Two-phase flow is created in a small domain of the flow field. (Gulich, 2008).

Intense shock waves, various sound effects (cracking, flapping and sometimes howling sounds), changed fluid mechanics characteristics, significant decline of performance and mechanical errors belong to the detrimental effects of cavitation. Cavitation has a decisive effect on the pump's ability to suck as well. During the operation of the pump, the fluid entering from the suction pipe to the impeller has the lowest pressure here. When cavitation occurs at this location, the flow pattern of rotating pump wheel changes along with the pump characteristic curves. In the initial phase well-detectable noises develop, then continuously stronger and stronger shockwaves and vibrations are forming in the fluid and the travelling systems (Brenne, 1995; Franc and Michel, 2005).

Since the fluid has a minimum pressure at the leading edge of the impeller from the direction of the suction pipe, this is the location where cavitation may occur the earliest. The decrease of suction depth, applying suction pipes with a narrow diameter, resistance emerged in the suction pipe or an increase in the temperature of the fluid all contribute to the emergence of the phenomenon (Ganz, 2012).

Cavitation is divided into two classes: physical cavitation and mechanical cavitation.

Physical cavitation: a smaller type of cavitation occurs under normal operational conditions in holes or due to detachments

caused by collision. Its effects can be tracked down by noise and smaller erosive dissolutions. The effects are undetectable in the pump characteristic curves and do not cause reduction in transfer or a decline in efficiency.

Mechanical cavitation: causes "detachments" in the pump characteristic curves and the operation of the pump becomes chaotic (Józsa, 2013).

The mathematical basis of cavitation (Józsa, 2013).

Manometric suction head value

$$H_{sm} = \frac{P_0 - P_1}{\rho \times g} = A_0 - h_1 = H_{sg} + h'_s + h_c \quad (1)$$

Pressure at blades entering

$$h_1 = \frac{P_1}{\rho \times g} \quad (2)$$

Saturation vapor pressure at given temperature

$$h_g = \frac{P_g}{\rho \times g} \quad (3)$$

Geodetic suction height

$$h_c = \frac{c_1^2}{2g} \quad (4)$$

$$NPSH_{pump} = \Delta_n + h_c \quad (5)$$

$$NPSH_{system} = A_0 - H_{sg} - h'_s - h_g \quad (6)$$

The condition of a cavitation-free operation:

$$NPSH_{system} \gg \gg \gg NPSH_{pump} \quad (7)$$

4 Measurement of cavitation

Fig. 2 shows the pipeline track of the measurement, which I selected in my examination.

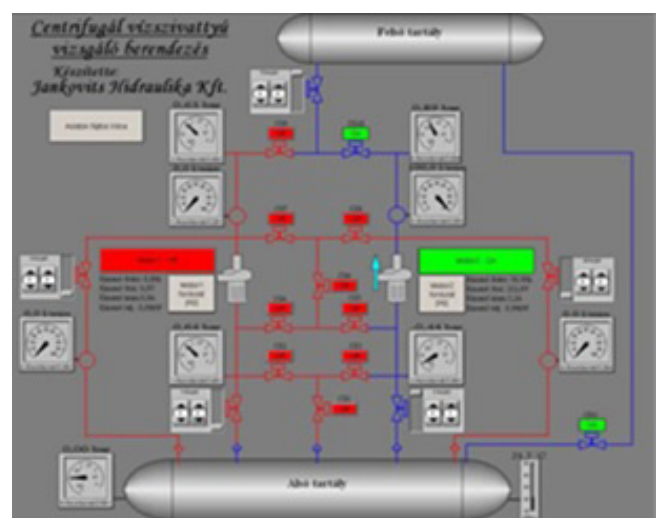


Fig. 2 The pipeline track of the measurement

Table 2 shows the flow rate and the elevation head of the Nocchi pump.

Table 2 The calculated data of Nocchi pump [Author compilation]

| Motor Frequency [Hz] | Flow rate [l/min] | Elevation head [m] |
|----------------------|-------------------|--------------------|
| 50 Hz | 0 | 37.41 |
| | 10 | 36.09 |
| | 20 | 34.76 |
| | 30 | 33.13 |
| | 40 | 30.89 |
| | 50 | 28.75 |
| | 60 | 26.30 |
| | 70 | 23.14 |
| | 80 | 20.59 |
| | 90 | 17.64 |
| | 100 | 13.66 |
| | 100 | 10.25 |
| | 100 | 6.30 |

Fig. 3 shows the flow rate and the elevation head of the Nocchi pump. At 100 l/min the elevation head of pump sharply goes down from 13.66m to 6.30m.

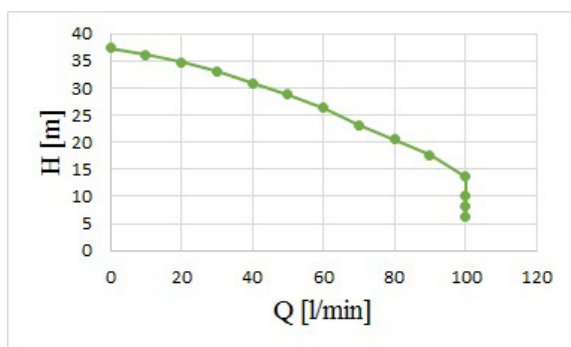


Fig. 3 H-Q curve of Nocchi pump (Author compilation)

Table 3 shows the flow rate and the performance of the Nocchi pump.

Fig. 4 shows the flow rate and the performance of the Nocchi pump. At 100 l/min the performance of pump sharply goes down from 0.97kW to 0.65kW

Table 4 shows the flow rate and the efficiency of the Nocchi pump.

Fig. 5 shows the flow rate and the efficiency of the Nocchi pump. At 100 l/min the efficiency of pump sharply goes down from 20.55 % to 13.55%.

Table 5 and Fig. 7 shows the elevation head and the NPSH of the Nocchi pump.

Fig. 6 shows the elevation head and the NPSH of the Nocchi pump.

Table 3 The calculated data of Nocchi pump (Author compilation)

| Motor Frequency [Hz] | Flow rate [l/min] | Performance [kW] |
|----------------------|-------------------|------------------|
| 50 Hz | 0 | 0.55 |
| | 10 | 0.60 |
| | 20 | 0.66 |
| | 30 | 0.71 |
| | 40 | 0.76 |
| | 50 | 0.81 |
| | 60 | 0.84 |
| | 70 | 0.88 |
| | 80 | 0.91 |
| | 90 | 0.94 |
| | 100 | 0.97 |
| | 100 | 0.85 |
| | 100 | 0.80 |
| 100 | 0.65 | |

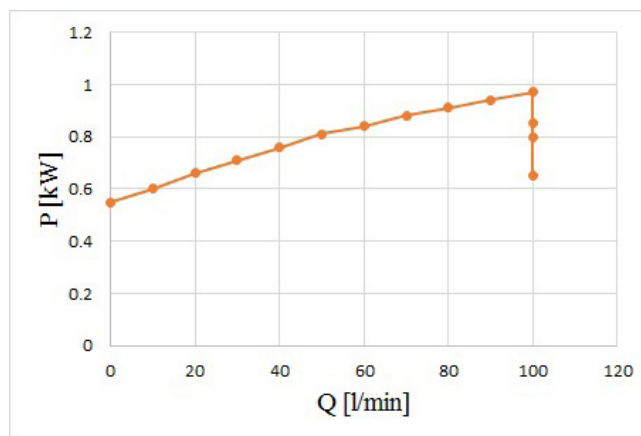


Fig. 4 P-Q curve of Nocchi pump (Author compilation)

Table 4 The calculated data of Nocchi pump (Author compilation)

| Motor Frequency [Hz] | Flow rate [l/min] | Efficiency [%] |
|----------------------|-------------------|----------------|
| 50 Hz | 0 | 0.00 |
| | 10 | 9.83 |
| | 20 | 16.97 |
| | 30 | 22.89 |
| | 40 | 26.58 |
| | 50 | 29.01 |
| | 60 | 30.71 |
| | 70 | 30.50 |
| | 80 | 29.50 |
| | 90 | 26.20 |
| | 100 | 20.55 |
| | 100 | 18.99 |
| | 100 | 16.50 |
| 100 | 13.55 | |

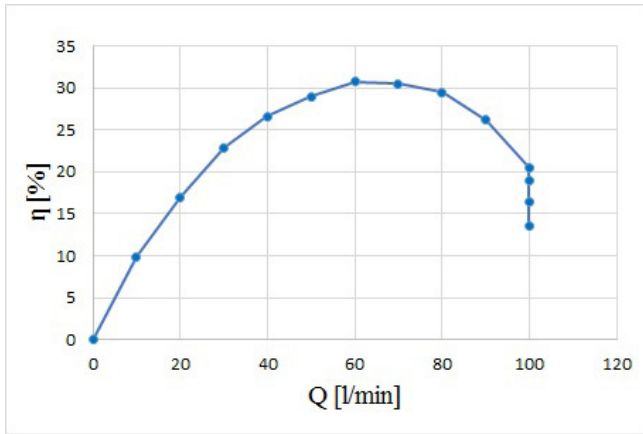


Fig. 5 η-Q curve of Nocchi pump (Author compilation)

Table 5 The calculated data of Nocchi pump [Author compilation]

| Motor Frequency [Hz] | Elevation head [m] | NPSH _{pump} [m] |
|----------------------|--------------------|--------------------------|
| 50 Hz | 5 | 0.005747 |
| | 8 | 0.005747 |
| | 10 | 0.005747 |
| | 12.6 | 0.005747 |
| | 13.5 | 0.006747 |
| | 13.66 | 0.007747 |
| | 13.66 | 0.008784 |
| | 13.66 | 0.012498 |
| | 13.66 | 0.016885 |
| | 13.66 | 0.021958 |
| | 13.66 | 0.027706 |
| | 13.66 | 0.034124 |

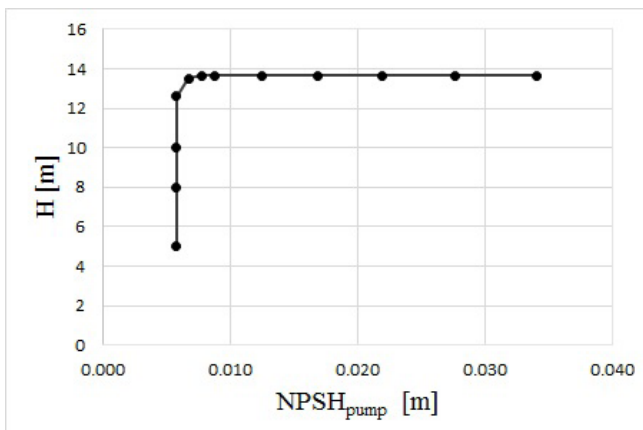


Fig. 6 H-NPSH_{pump} curve of Nocchi pump

Thoma's cavitation number

$$\sigma = Th = \frac{NPSH_r Q}{H_Q} \quad (10)$$

Table 6 shows the Strouhal and Thoma's cavitation number of the Nocchi pump.

Table 6 The calculated data of Pedrollo pump (Author compilation)

| Motor Frequency [Hz] | Strouhal number | Cavitation number |
|----------------------|-----------------|-------------------|
| 50 Hz | 0.000 | 0.000 |
| | 31.105 | 0.854 |
| | 15.552 | 0.427 |
| | 10.368 | 0.285 |
| | 7.776 | 0.214 |
| | 6.221 | 0.171 |
| | 5.184 | 0.142 |
| | 4.44 | 0.122 |
| | 3.888 | 0.107 |
| | 3.456 | 0.095 |
| | 3.10 | 0.085 |
| | 3.779 | 0.085 |
| | 3.779 | 0.085 |
| 3.779 | 0.085 | |

Fig. 7 shows the Strouhal and Thoma's cavitation number of the Nocchi pump

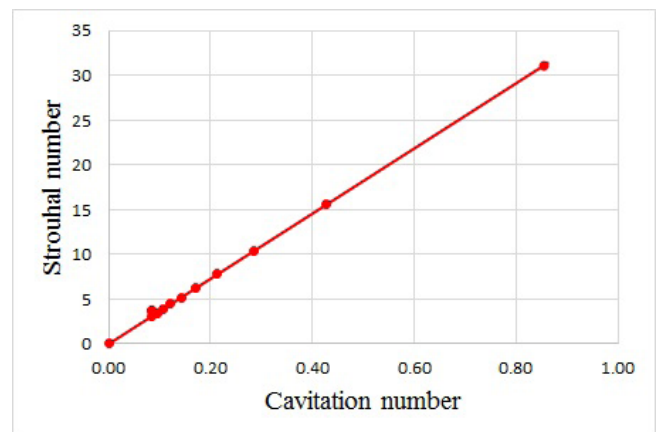


Fig. 7 S-C curve of Nocchi pump

5 Taking the S-C and S-R curve of the pump

The Reynolds number (Re)

$$Re = \frac{v \cdot d}{\nu} \quad (8)$$

The Strouhal number (St)

$$St = \frac{f \cdot D}{v} \quad (9)$$

Table 7 shows the Strouhal and Reynolds number of the Nocchi pump.

Fig. 8 shows the Strouhal and Reynolds number of the Nocchi pump.

5 Conclusion

Based on these results the next points can be stated as a conclusion:

- At 100 l/min the performance of pump sharply goes down from 0.97kW to 0.65kW. Cavitation has a significant effect on performance.
- Bubble cavitation by itself produced very broadband noise.

The goal of my research is to test different types of vortex pumps under laboratory conditions and to draw conclusions that may be appropriate for the development of a mathematical model (Kubota et al., 1992).

Table 7 The calculated data of Nocchi pump [Author compilation]

| Motor Frequency [Hz] | Strouhal number | Reynolds number |
|----------------------|-----------------|-----------------|
| | 0.000 | 0.000 |
| | 31.105 | 414.829 |
| | 15.552 | 829.659 |
| | 10.368 | 1244.488 |
| | 7.776 | 1659.317 |
| | 6.221 | 2074.147 |
| 50 Hz | 5.184 | 2488.976 |
| | 4.444 | 2903.805 |
| | 3.888 | 3318.635 |
| | 3.456 | 3733.464 |
| | 3.110 | 4148.293 |
| | 3.779 | 3414.045 |
| | 3.779 | 3414.045 |
| | 3.779 | 3414.045 |

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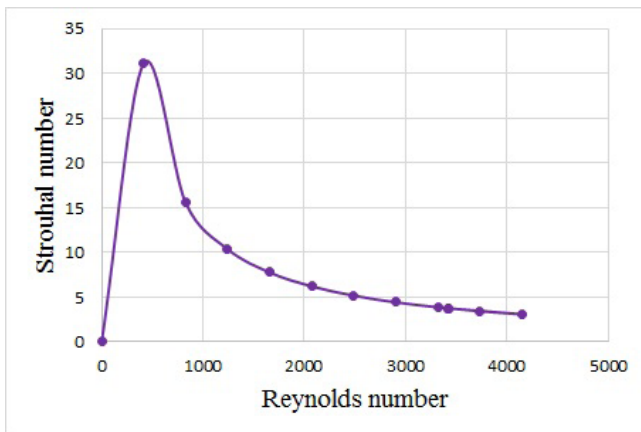


Fig. 8 S-R curve of Nocchi pump