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The Influence of Cavitations Phenomenon and Water Hammer in Batlava Pumping Station

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ABSTRACT

Cavitations' phenomenon and water hammer fall in group of critical characteristics of turbo machinery and are a pernicious phenomenon that may occur during their exploitation. Water hammer appears in case when pressures change as a result of rapidly changing water flow velocity. As a preventive measure by water hammer is slowdown of the flow velocity of the water and all recommendations based on this purpose are categorized into: slowdown water flow velocity, protection from pressure drop, etc. In this paper are analyzed the phenomenon of cavitations' and water hammer through the mathematical model and based in the calculations are taken suitable measures in order to avoid such phenomena in the main drinking water supply system for residents of the city of Prishtina, Podujeva, Fushë Kosova and Obiliqi.

Keywords: Cavitations', water hammer, pumps, fluid flow velocity, tubes

1. INTRODUCTION

Cavitation as a phenomenon represents the formation of local vapor zones inside the fluid flow as a result of the transition of absolute static pressure to evaporation pressure. Cavitation occurs in water supply, pumps and other hydraulic equipment. Research has shown that fluid turbulence after bends and after various obstacles in the pipe fittings, cavitation is intense, corrosion is more pronounced, and the protective layers are more damaged.

Cavitation's' drastically affects the life of pumps. The consequences that appear in the pump in the case of cavitation phenomenon are: reduction of fluid flow, pronounced noise, vibrations. The water hammer is a consequence of the momentary increase in pressure, when it suddenly changes the direction or velocity of the fluid flow or when a valve rapidly or abruptly closes; in this case the flow of fluid through the pipes is stopped and the pressure energy is transferred to the wall of the pipes, valves or pump and consequently we have damage to the pipes, equipment, valves, pumps, etc. In this paper are analyzed the phenomenon of cavitations' and water hammer through the mathematical model and based in the calculations are taken suitable measures in order to avoid such phenomena in the main drinking water supply system for residents of the city of Prishtina, Podujeva, Fushë Kosova and Obiliqi.

2. DESCRIPTION OF STUDY

Cavitation means the phenomenon of the formation of local areas of steam (caverns) inside the flowing fluid as a result of the transition of absolute static pressure to evaporation pressure (temperature dependent).

In hydraulic turbo machines, in certain locations, pressure drops may occur conditions for reaching the boiling point at a temperature which is equal to the temperature of the suction fluid. This may have caused the gas phase (local boiling) to begin to appear in those places. Formed steam bubbles (caverns), including other gases in the mainstream move towards high pressure areas. As soon as they reach this area, condensation occurs rapidly and in the empty spaces (due to the change of specific volumes of steam and water) the liquid rushes from all sides. The target of this fluid movement is the center of the cavern and then - the shocks followed by local pressure increases, which can be several times higher than the baseline pressure. The pressure rise will be as large as the faster be the transition of the caverns from low pressure to high pressure.

Cavitation can occur in water supply, pumps and all equipment.

3. CHARACTERISTIC CASES FOR APPEARANCE CAVITATION

A hydraulic current machine will work without cavitation if the energy effect of the plant is greater than the energy effect of the machine (pump).

$$Y_{HA} > Y_H \tag{1}$$

When are:

Y_{HA} - the specific effect of plants in kg,

Y_H - the specific effect of the pump in kg.

3.1. The case when the water level is above the pump and it flows with gravity (Figure 1)

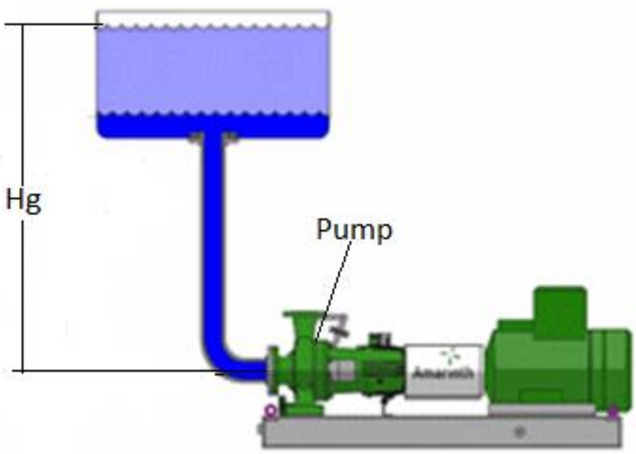

Figure 1: The case when the water level is above the pump

Abbreviation N.P.S.H. indicates the net power level in the pump inlet section, (Neto Positive Suction Head) [1]. In order for the pumps not to reach the cavitation phenomenon, the cavitation reserve of the plants in the suction pipe must be greater than the cavitation reserve of the pump.

So, the condition must be met:

$$(N.P.S.H)_{STAB} \geq (N.P.S.H)_{PUMP} \quad (2)$$

Where are:

- $(\mathrm{N.P.S.H})_{\mathrm{STAB}}$ - cavitation reserve of plants in the suction pipe (available, effective),
- $(\mathrm{N.P.S.H})_{PUMP}$ - is the smallest value of N.P.S.H by which the criterion of non-occurrence of cavitation is met. This value is a working characteristic of the pump provided by the manufacturer.

The cavitation reserve of the plant for our case is calculated according to the expression:

$$(N.P.S.H)_{STAB} = \frac{p_o - p_{av}}{\rho \cdot g} + \frac{c_e^2}{2} + H_g - \sum h_\xi = \frac{Y}{g} \quad (3)$$

Net energy is the absolute energy reduced by the evaporation energy of a fluid $\frac{p_{av}}{\rho \cdot g}$.

In the Batllava Pumping Station, installed pumps are with the same capacity. There are three pumps, with horizontal axles.

The necessary data for the calculation of the cavitation reserve are given separately for both cases: when only one pump Q = 0.5 m^3/s is working and case when two pumps are running simultaneously Q = 1.0 m^3/s.

The schematic representation of the pump system in Batllava is given in Figure 2.

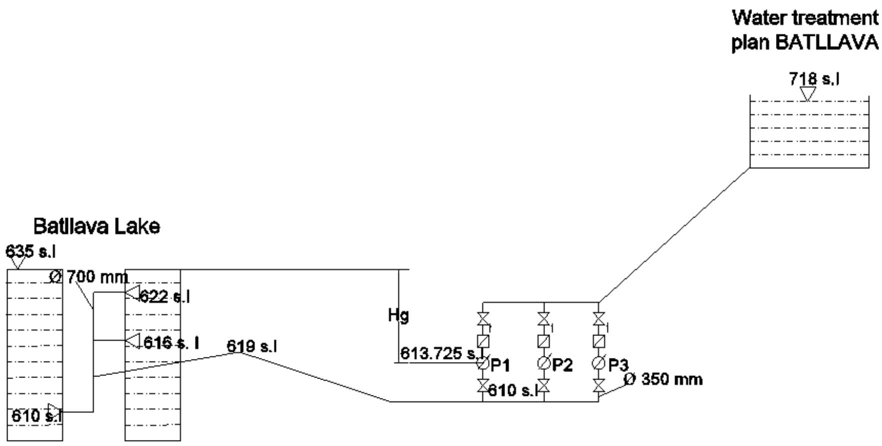

Figure 2. Schematic representation of pumps in Batllava

3.1.1. The case when works only one pump with maximum capacity (*Q* = 500 l/s or *Q* = 0.5 m^3/s)

The data necessary for calculation:

- ✓ $p_0 = 1\, bar = 1 \cdot 10^5\, Pa$
- ✓ $p_{av} = 0.016\, bar$ or $p_{av} = 0.016 \cdot 10^5\, Pa$
- ✓ $\rho = 1 \cdot 10^3\, kg/m^3$
- ✓ $g = 9.81\, m/s^2$

- ✓ $c_e \approx 0$,
- ✓ $(N.P.S.H)_{PUMP} = 11.2\ m$ (provided by the pump manufacturer)

By condition $(N.P.S.H)_{STAB} \geq (N.P.S.H)_{PUMP}$ respectively:

$$(N.P.S.H)_{STAB} = \frac{p_o - p_{av}}{\rho \cdot g} + \frac{c_e^2}{2} + H_g - \sum h_\xi \geq (N.P.S.H)_{PUMP} \quad (4)$$

From formula (3) we calculate the geodetic height:

$$H_g \geq (N.P.S.H)_{PUMP} - \frac{p_o - p_{av}}{\rho \cdot g} + \sum h_\xi \geq 2.79 \quad (5)$$

Losses are calculated [2] by expressions:

$$\sum h_\xi = \sum h_{\xi\ loc.\ loss.} + \sum h_{\xi\ long.\ loss.} = \xi \cdot \frac{c^2}{2g} + \lambda \frac{l}{d} \cdot \frac{c^2}{2g} \quad (6)$$

where are:

l - pipe length, m,

d - pipe diameter, m,

λ - hydraulic coefficient of friction,

ξ - coefficient of local resistances,

c - the average velocity of the fluid at the point where the losses occur, m/s,

p_0 - pressure on the surface of the liquid in the tank, bar,

c_e - fluid velocity in the reservoir (~0), m/s.

$$\sum h_{\xi\ loc.\ loss} = \xi_1 \cdot \frac{c_1^2}{2 \cdot g} + \xi_2 \cdot \frac{c_2^2}{2 \cdot g} + \xi_3 \cdot \frac{c_3^2}{2 \cdot g} \quad (7)$$

$$\sum h_{\xi\ long.\ loss} = \lambda_1 \frac{L_1}{d_1} \cdot \frac{c_1^2}{2 \cdot g} + \lambda_2 \frac{L_2}{d_2} \cdot \frac{c_2^2}{2 \cdot g} + \lambda_1 \frac{L_3}{d_3} \cdot \frac{c_3^2}{2 \cdot g} \quad (8)$$

where are they taken:

$c_1 = \frac{Q_1}{A_1} = \frac{4Q_1}{\pi \cdot d_1^2} [\frac{m}{s}]$

$c_2 = \frac{Q_2}{A_2} = \frac{4Q_2}{\pi \cdot d_2^2} [\frac{m}{s}]$

$c_3 = \frac{Q_3}{A_3} = \frac{4Q_3}{\pi \cdot d_3^2} [\frac{m}{s}]$

$\xi_1 = \xi_{stainer} + \xi_{dyf.} + \xi_{btf.\ v} = 0.96$

$\xi_2 = \xi_{bend1} + \xi_{bend2} + \xi_{bend3} = 3.02$

$\xi_3 = \xi_{bend4} + \xi_{bend5} + \xi_{shib.v.} + \xi_{difu.} = 0.96$

$Q = Q_1 = Q_2 = Q_3$ = 500 l/s = 0.5 m^3/s

d_1 = 700 mm, L_1 = 9 m,

d_2 = 1000 mm, L_2 = 120 m and

d_3 = 400 mm, L_3 = 3 m.

$\xi_{stainer} = 0.1,\ \xi_{difu.} = 0.14,\ \xi_{btf.\ v} = 0.36,$

$\xi_{bend1} = 2.2,\ \ \xi_{bend2} = 0.32,\ \ \xi_{bend3} = 0.5,$

$\xi_{bend4} = 0.3,\ \ \xi_{bend5} = 0.3,\ \ \xi_{shib.v.} = 0.2,\ \ \xi_{dyf.} = 0.15$

$R_{e1} = \frac{c_1 \cdot d_1}{\upsilon},\ \ R_{e2} = \frac{c_2 \cdot d_2}{\upsilon},\ R_{e3} = \frac{c_3 \cdot d_3}{\upsilon}$

The viscosity of water in temperature t =15 ^{0}C is $\upsilon = 1.13 \cdot 10^{-6}\ m^2/s$.

Since the value of Reynolds R_e > 2300 [3] it is that the flow is turbulent then the coefficient of hydraulic friction is determined by the expression:

$\lambda = \frac{0.309}{log(\frac{R_e}{7})^2}$, [4] where these values come from $\lambda_1 = 0.012,\ \lambda_2 = 0.013, \lambda_3 = 0.011$

When one pump only works, the geodetic height of the water H_g from the free wide surface of the pump axis and in order not to reach the cavitation [5], 0.5 m height of the water must be added. Therefore, this size should be $H_g \geq 3.29$ m.

The altitude quota where the pumps are located (axis of the working circuit) is 613,725 m. The level of the lake to avoid cavitation is 613,725 + 3.29 = 617.02 m.

3.1.2. Case when two pumps are working with maximum capacity ($Q_1 = Q_2$ = 500 l/s = 0.5 m^3/s, $Q = Q_1 + Q_2$ = 1000 l/s = 1 m^3/s

$(\mathrm{N.P.S.H})_{\ Pump} = 8.2\ m$ When two pumps are working together with the maximum capacity provided by the manufacturer.

By condition $(N.P.S.H)_{STAB} \geq (N.P.S.H)_{PUMP}$, we calculate

$$H_g \geq (\mathrm{N.P.S.H})_{\ Pump} - \frac{p_0 - p_{at}}{\rho \cdot g} + \sum h_\xi \geq 2.28 \tag{9}$$

Losses are calculated using the expressions

$$\sum h_\xi = \sum h_{\xi\ loc.} + \sum h_{\xi\ Long.} = \xi \cdot \frac{c^2}{2g} + \lambda \cdot \frac{l}{d} \cdot \frac{c^2}{2g} \tag{10}$$

Where are:

$$\sum h_{\xi\ loc.loss.} = \xi_1 \cdot \frac{c_1^2}{2 \cdot g} + \xi_2 \cdot \frac{c_2^2}{2 \cdot g} + \xi_3 \cdot \frac{c_3^2}{2 \cdot g} + \xi_3 \cdot \frac{c_3^2}{2 \cdot g} \tag{11}$$

$$\sum h_{\xi\ long.\ loss.} = \lambda_1 \frac{L_1}{d_1} \cdot \frac{c_1^2}{2 \cdot g} + \lambda_2 \frac{L_2}{d_2} \cdot \frac{c_2^2}{2 \cdot g} + \lambda_3 \frac{L_3}{d_3} \cdot \frac{c_3^2}{2 \cdot g} + \lambda_4 \frac{L_4}{d_3} \cdot \frac{c_4^2}{2 \cdot g} \tag{12}$$

Where the expressions are taken:

Expressions for further calculation are the same as those given below:

$c_4 = \frac{Q_4}{A_4} = \frac{4 \cdot Q_4}{\pi \cdot d_4^2}\ \frac{m}{s}$

$Q = Q_1 = Q_2$ =1000 l/s =1.0 m^3/s

$Q_3 = Q_4 = Q/2$ = 500 l/s =0.5 m^3/s

$$R_{e4} = \frac{c_4 \cdot d_3}{\upsilon}$$

The viscosity of water for temperature t = 15 ^{0}C is $\upsilon = 1.13 \cdot 10^{-6} m^2/s$.

Since the value of Reynolds R_e >2300 it is that the flow is turbulent then the coefficient of hydraulic friction is determined by the expression:

$$\lambda = \frac{0.309}{log(\frac{R_e}{7})^2}, \text{from come these values: } \lambda_4 = 0.011$$

When operating two pumps, the geodetic height of the water H_g from the free wide surface of the pump axis and in order not to reach the cavitation, 0.5 m of water level must be added. Therefore, this size should be $H_g \geq 2.78$ m.

The altitude quota where the pumps are located (axis of the working circuit) is 613,725 m. The level of the lake to avoid cavitation is 613.725 + 2.78 = 616.5 m.

4. CONCLUSION

From the whole research work it can be concluded that:

a) When only one pump works, the geodetic height of the water from the free wide surface of the pump axis, and in order not to come to the cavitation, 0.5 [m] of water reserve level must be added, therefore the geodetic height becomes: $H_g \geq$ 2.28 [m], then the level of the lake should be: 613.725 + 2.28 = 616 m and

b) When two pumps work, the geodetic height of the water from the free wide surface of the pump axis, and in order not to come to the cavity, a reserve water level of 0.5 [m] must be added, therefore the geodetic height becomes: $H_g \geq 2.75$ m, then the level of the lake should be: 613.725 −2.75 = 611 m

REFERENCES

[1] European Association of Pump Manufacturers. “Net Positive Suction Head for Rotodynamic Pumps: A Reference Guide”,

[2] Faculty of Engineering and Applied Science, “Mechanical and Materials Engineering”, Queens University

[3] Bohl, Wili: Stoemungsmaschinen 1 (Aufbau und Wirkungweise), Vogel Buchverlag,Wuerzburg, 1994,

[4] Charles Jackson and A. J. Campbell. Alignment of Rotating Machinery, Vibration Institute, Houston, Tex., 1991

[5] Stoffel, B: Turbomaschinen I, Technische Universitaet, Darmstadt, 2002.