STAGES OF NOISES AND VIBRATIONS TO A BUTTERFLY VALVE IN WORKING WITH CAVITATION

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S-au măsurat nivelul de zgomot (dB) şi vibraţii (mm/s²) la funcţionarea în cavitaţie a unui robinet fluture Dn100Pn6. S-au selectat secţiunea şi punctele de măsură pentru ambii parametri şi s-au măsurat nivelele lor pentru diferite stadii de dezvoltare ale fenomenului de cavitaţie. S-a constatat existenţa unui minim atât la vibraţii cât şi la zgomote, la un anumit stadiu de dezvoltare. De asemenea, s-au comparat calitativ rezultatele obţinute experimental cu cele publicate de firmele producatoare de robinete industriale.

The levels of noise (dB) and vibrations (mm/s²) were measured to a butterfly valve (Dn100Pn6) in working with cavitation. The section and points of measurement were selected for the parameters that we considered, noise and vibration. The measurements were made for different stages of the cavitation phenomena development. The diagrams display a minimum value in the diagram of noise and vibration versus flow rate. This point of extreme value is meeting a certain stage of cavitation phenomena development. The results were compared with the results of commercial booklets of industrial valve producers.

Key words: cavitation phenomena, vibrations, noise, butterfly valve

1. Introduction

In the present we have not a physic and mathematical model of the entire description for the cavitation phenomena that mean stages of apparition, evolution and implosion. For this reason the researches of cavitation phenomena have an experimental character with excepting of the implosion phenomena [1], [2]. A study of cavitation phenomena in pipelines, fittings, bearings and other technical components is practically lacking in the older treatises [2] and better represented in the recently ones [1]. Here, the results are referring to the incipient stage of cavitation phenomena.

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In the paper six stages of cavitation development were defined, acoustically characterized [3] as:

- NON (N) stage,

- INCIPIENT (I) stage characterized by specific noises (snaps) quasi random, hardly determinable with the ear,

- LIGHT (L) stage, low intensity, continuous noises, undeterminable at distance,

- MODERATE (M) stage, continuous noises, determinable at distance,

- HEAVY (H) stage, acute, continuous noises, determinable in all the laboratory,

- VERY HEAVY (VH) stage, very acute, continuous noises, with different intensities,

-SUPERCAVITATION (S) stage, difficult to sonorous evaluate/ differentiate from the VH stage, in which at the rise of the pressure drop on the valve, the flow rate remains constant (choking flow).

Figure 1 presents the diagram for different stages of working in cavitation of a butterfly valve, where "delta p [bar]" is the valve pressure drop and the "Q [m^3/h]" is the valve flow rate.
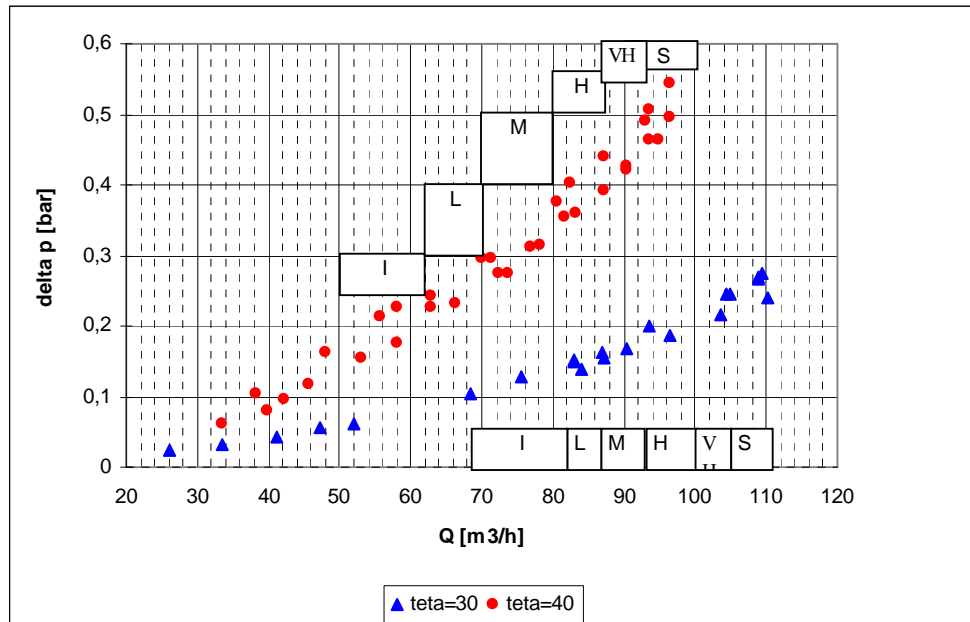

Fig.1. The working in cavitation diagram for a butterfly valve D100, Pn6

For every stage the level of noise and vibration to be able to develop a methodology of a non-intrusive evaluation of the cavitation phenomena have been determinated.

2. Flow rate coefficient and cavitation coefficients

The hydrodynamic qualities of a valve are given by the following parameters:

a) the flow rate coefficient K_v or the velocity head loss coefficient ζ are defined as

$$Q = K_v \sqrt{\Delta p}, \qquad \Delta p = \zeta \rho \frac{v^2}{2}. \qquad (1)$$

The coefficient K_v is a dimensional one and in the commercial booklets is given as m³/h for a pressure drop of $\Delta p = 1$ [bar] having as a working fluid, the water. The velocity head loss coefficient ζ is dimensionless, ρ is the liquid density and v is the average upstream velocity of the valve.

b) the cavitation coefficients; the most used cavitation coefficients are:

Thoma cavitation coefficient

$$\sigma = \frac{p_{am} - p_v(t^\circ)}{\rho v^2 / 2} \qquad (2)$$

or the coefficients defined upstream and/or downstream of the valve

$$K_f = \frac{\Delta p}{p_{am} - p_v}; \quad K_d = \frac{p_{am} - p_v}{p_{av} - p_v}; \quad K_m = \frac{\Delta p}{p_{av} - p_v}, \qquad (3)$$

where p_{am}, and p_{av} are upstream and downstream absolute pressures of the valve, p_v is the equilibrium vapour pressure and Δp is the pressure drop on the valve. The coefficients defined by (3) are not independent:

$$K_d = \frac{1}{1 - K_f}, \qquad K_m = \frac{K_f}{1 - K_f} \qquad (4)$$

and these were defined from practical point of view. So, if K_f, K_d, K_m are known for an incipient cavitation stage it could be know the upstream or downstream pressure at a given flow rate for a known type of valve.

c) the level of noise which could be reduced in the standard limit of working [4].

3. Theoretical base of the cavitation coefficients and the evolution of the cavitation phenomena

The method generally established in [1] for a butterfly valve was applied. Considering the Bernoulli relation in permanent movement between the points M_0 and M, Figure 2, it was obtained:

$$\frac{p_0}{\gamma} + \frac{v_0^2}{2g} + z_0 = \frac{p_M}{\gamma} + \frac{v_M^2}{2g} + z_M + h_p. \tag{5}$$
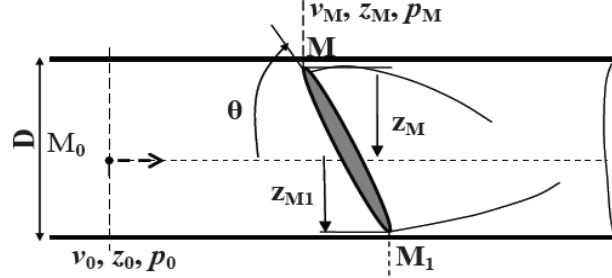

Fig. 2. The defining scheme for the cavitation coefficient

Were defined the reserve coefficient of cavitation, σ_{rez}, as:

$$\sigma_{rez} = \frac{p_{\min} - p_v}{\rho v_0^2 / 2}, \tag{6}$$

and the installation's coefficient of cavitation

$$\sigma_{inst} = \frac{p_0 - p_v}{\rho v_0^2 / 2} \tag{7}$$

The valve's coefficient of cavitation will be defined as

$$\sigma_c = \frac{v_{\max}^2}{v_0^2} - 1 + \frac{z_M - z_0}{v_0^2 / 2g} + \frac{h_p}{v_0^2 / 2g}, \tag{8}$$

if it will be considered that $p_M = p_{\min}$ and $v_M = v_{\max}$.
From the relations (6), (7) and (8) it will be obtained that

$$\sigma_{rez} = \sigma_{inst} - \sigma_c. \tag{9}$$

From relation (9) results the following stages [1]:
- $\sigma_{rez} > 0$, $\sigma_{inst} > \sigma_c$, non - cavitation
- $\sigma_{rez} = 0$, $\sigma_{inst} = \sigma_c$, incipient cavitation
- $\sigma_{rez} < 0$, $\sigma_{inst} < \sigma_c$, developed cavitation (industrial)
- $\sigma_{rez} << 0$, $\sigma_{inst} << \sigma_c$, super - cavitation.

Relation (9) has a theoretic base and differentiates σ_{ins} from σ_c, which depends on Froude number, Fr, by $\dfrac{z_M - z_0}{v_0^2 \cdot 2g} = \dfrac{2}{\text{Fr}}$, on Reynolds number, Re and on the relative roughness k/D by h_p, of distance L_{MM0}, at constant temperature.

$$\sigma_c = f\left(\mathrm{Fr}, \mathrm{Re}, k/D, L\right) \tag{10}$$

In the case of a butterfly valve Fig. 2) it was been observed that between the cavitation coefficients associated with the section from M, σ_M, and the section from M_1, σ_{M1}, exists the relation

$$\sigma_{rezM} < \sigma_{rezM1}, \tag{11}$$

respectively the cavitation begins in section M. Between the σ_c and K_v coefficients, respectively ξ will be a natural dependence: the valves with bigger values of K_v coefficient, respectively smaller values of ξ are less exposed to cavitation, at the same flow rate.

4. Experimental research

4.1 Experimental stand

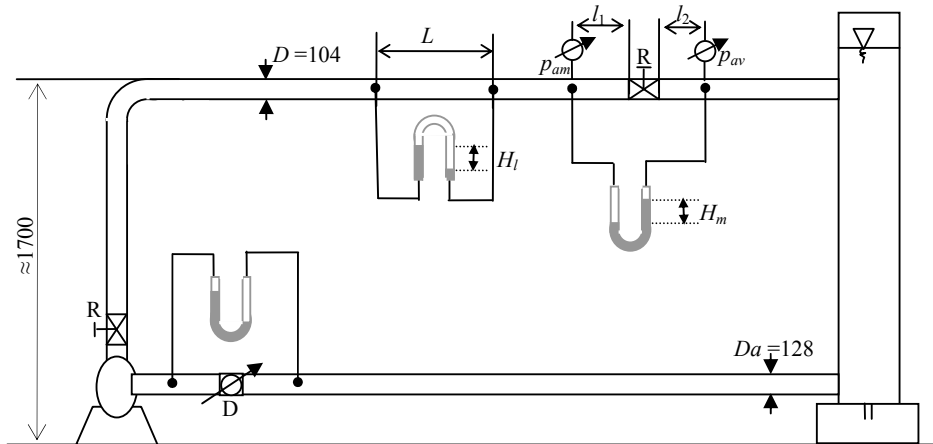The experimental stand is a hydrodynamic tunnel type with closed circuit.

Fig.3. Stand sketch; **R** – test valve, **D** – flow rate diaphragm, **H$_l$** – linear velocity head loss, **H$_m$** – velocity head loss measured upstream and downstream of the valve.

4.2 Measurements devices

Working fluid was tap water at 18 – 20 temperature degrees. The flow rates were measured with a diaphragm with pressure plug at D and $D/2$ (D, the diameter of the suction pipe). The upstream and downstream pressure of the valve were measured with an analogical differential manometer, first class precision and the valve pressure drop was measured with a mercury differential manometer. The levels of noises were measured with a sonometer (dB) and the vibrations were

measured with handheld portable data collector and analyzing instrument [6] and acceleration transducers having an amplitude range of 75 [g peak] and a sensitivity of 25 [mV/g].

4.3 Sections of measurements

The first measurements of the noise were made near the flange of the valve and at a distance of 0.5 meters of the valve at the same elevation. Better results were obtained when the measurements were made near the valve handle rode.

Two sections were fixed downstream of the valve for the vibrations measurement, at a distance of 2D and 3D reporting at the vertical axe of the valve. In every section was measured the level of vibration in four points of measurement placed as two diametric points in two perpendicular planes. Were obtained bigger values of vibrations in the upper site of the pipeline, on the vertical diameter and these values are confirmed by the (11) relation.

4.4 Experimental results

The coefficients of cavitation σ were calculated by Thoma's formulae for an open valve of 40^0, see Table 1.

Table 1

Cavitation coefficient for an open valve of θ = 40°

Q (m³/h)	Δp (bar)	K_v (m³/h)	p_{am} (bar)	p_{av} (bar)	σ (-)	Stage of cavitation (-)
33.6	0.062	133.9	0.15	0.08	-	N
45.7	0.117	133.4	0.2	0.08	-	N
62.86	0.243	127.5	0.335	0.085	62.62	I(L)
71.27	0.296	130.8	0.385	0.09	50.54	M
80.57	0.376	131.3	0.485	0.1	42.43	H
87.29	0.439	131.7	0.555	0.105	37.86	VH
93.54	0.506	131.4	0.63	0.11	34.57	VH
96.51	0.543	130.9	0.68	0.11	33.48	S
99.39	0.568	131.8	0.7	0,.12	31.5	S

The levels of measured noises and vibrations for different stages of cavitation phenomena evolution are displayed in Figure 4.
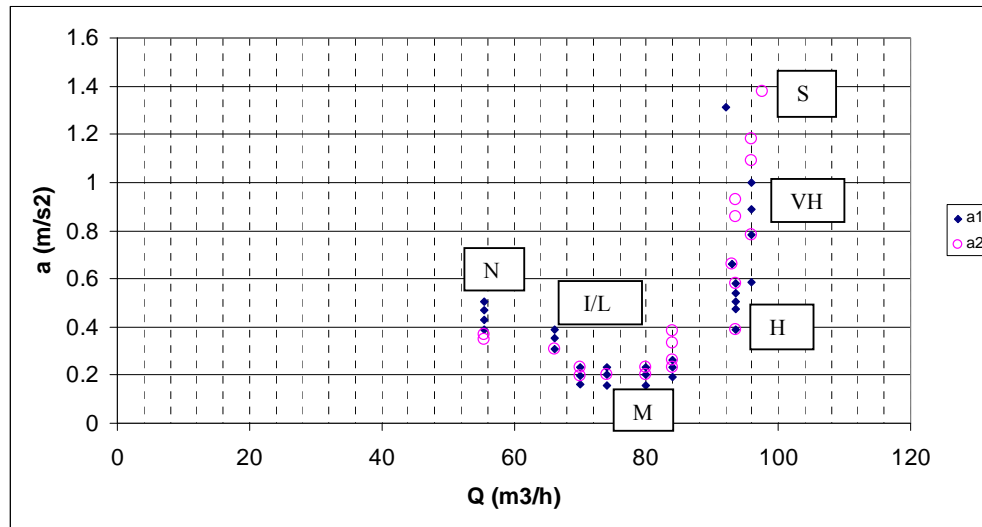
Fig. 4. Level of vibration in the all six stages of cavitation measured at the distances of 2D (a1) and 3D (a2) sections.
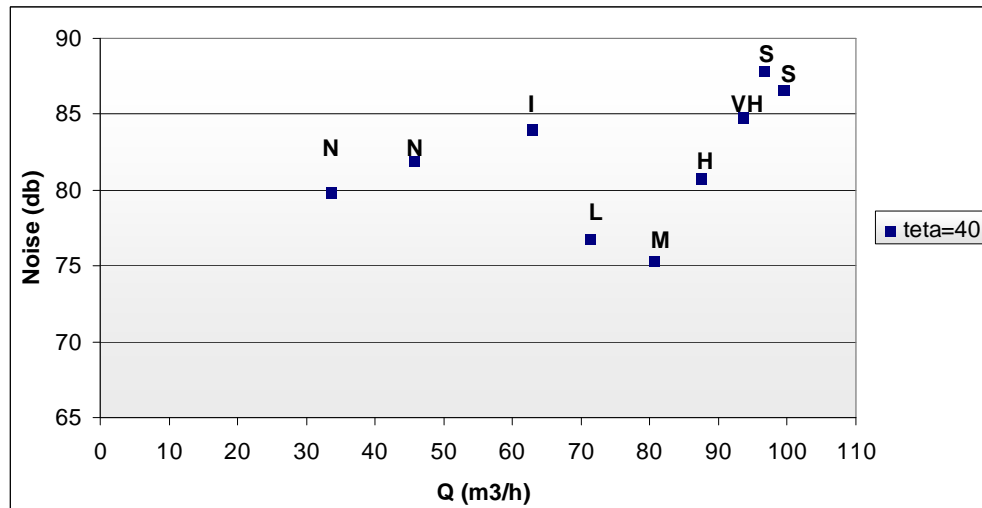

Fig. 5. Level of noise measured for each of the 6 cavitation stages

Measurements for the noise level are displayed in Figure 5.

The measured parameters, noise and vibration, have in their evolution a minimum extreme value which are characteristic for the MEDIUM (M) stage of the cavitation phenomena evolution. This behavior could be explained by the evolution of the physical phenomenon itself. In this stage (M) the cavitation is developed as vaporous linen cloths that are stationary in time (steady-state). At the advanced stages of the evolution (H, VH) are formed wakes of vaporous

which in their evolution are braking and detaching from the valve obturator. In this conditions the level of vibrations and noises are superior then in the stage M of cavitation phenomena evolution. In the case of the noise levels appeared the minimum extreme value of noise for the same M stage of cavitation at an appropriate value of flow rate as for the vibration extreme value.

5. Conclusions

Relation (9) will give us the first way to evaluate the stages of cavitation phenomena evolution.

Six stages of cavitation phenomena evolution are proposed; the evaluation of these stages are making by noises and vibrations measurements. The minimum values of noises and vibrations measurements are characterized by the M stage of cavitation phenomena evolution.

The existence of this extreme minimum value suggested us to promote a method which could make a qualitative evaluation of the development of cavitation phenomena.

Acknowledgements

R E F E R E N C E S

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