M.A.Promtov, M.V.Monastirski

INFLUENCE OF FORM AND PRESSURE PULSE AMPLITUDE STIMULATING CAVITATION ON REGULARITIES OF CAVITATION BUBBLE RADIUS CHANGE

Tambov State Technical University
106, Sovetskaya St., Tambov, 392620, Russia.
Tel. (0752)72-20-24; Fax: (0752)72-20-24;
E-mail: ***postmaster@decin.tstu.ru***

The analysis of numerical decisions of the differential equation of cavity pocket dynamics, at disturbance pressure pulses in the liquid, which can be obtained in the device of a hydrodynamic hooter type is presented in the given work. Based on the pulse prescribing in the definite form, the kinematical parameters of the cavity pocket are analyzed. It is shown, that the pulse form change results in pressure, generating by a bubble, value change and in cavitation bubble radius amplitude change.

Cavitation bubble dynamics depends on parameters describing the liquid state, on the way the liquid tension stresses are created, which result in cavity pocket formation. The behaviour of a cavitation bubble, formed when harmonic waves pass through the liquid, is very well known now. The more complicated problem is a problem of the cavitation bubble, generating anharmonic waves or close to shock waves, dynamics description.

Let's consider dynamics of the separate cavitation bubble, formed in the stator channel of hydrodynamic radiant of the rotary pulse cavitation device type (RPCD). RPCD operation peculiarity is that the time of rotor and stator channels t_1 overlapping is several times is less than that t_2 of stator channels overlapping. Hence at rotor and stator channels overlapping the overpressure short-time pulse is radiated into the stator channel and at stator channel overlapping the underpressure causing cavitation is generated. At big relations t_2/t_1 some “re-oscillations” in one and the same point of the stator channel are possible with the phase of overpressure and underpressure (rather static) [1].

The cavitation bubble behaviour in the RPCD channel radiated by pulse pressure is considered in works [2,3]. However in the given research the function *P(t)*, describing the pulse pressure in the stator channel t_1, is taken at the time when the stator channel t_1 is opened. That is, it is accepted, that at the time interval t_2, when the stator channel is closed by the rotor wall, the pressure is counterbalanced and is equal to static. The experimental research [1] shows that such assumption is not true.

The objective of the given work is in the analysis of cavitation bubble dynamics in the RPCD channel for whole pressure oscillation period, that is for the time:

$$T = t_1 + t_2 = \frac{2 \cdot a}{\grave{u} \cdot R_r} + \frac{b - a}{\grave{u} \cdot R_r} ,$$

where: *a* is rotor and stator channel width, m; *b* is the distance between the nearest points of adjacent channels, m; *w* is the rotor angular velocity, s^{-1}; R_r is the radius of rotor external surface, m.

We shall investigate cavitation bubble dynamics with the help of the Herring’s equation [4]:

$$R \cdot \frac{d^2R}{dt^2} + \frac{2}{3} \cdot \left(\frac{dR}{dt}\right)^2 + \frac{1}{r} \cdot \left[P - P_v - P(t) + \frac{2 \cdot d}{R} + \frac{4 \cdot m}{R} \cdot \frac{dR}{dt} - \left(P + \frac{2 \cdot d}{R_0}\right) \cdot \left(\frac{R_0}{R}\right)^{3g} \right] = 0 , \quad (1)$$

with the initial conditions $R\big|_{t=0} = R_0$, $\left.\frac{dR}{dt}\right|_{t=0} = 0$.

Here: *P* is the static pressure in the stator channel, Pa; *g* is a polytropic index for adiabatic process; R_0 is the initial radius of the bubble nucleus, m; *r* is the liquid density, kg/m^3; *s* is the dynamic viscosity coefficient, Pa*s; P_v is the saturated vapor pressure, Pa; *d* is the surface tension of the liquid, N/m; *P(t)* is the function describing the pressure pulse Pa.

Let's enter dimensionless time t and dimensionless radius r. They are connected with variables t and R by the following relationships: $t = t \cdot T_0$, $R = r \cdot R_0$, where T_0 is the period of own bubble pulsations, s. That is determined from the Minnert's formula [4]:

$$T_0 = \frac{2 \cdot p \cdot R_0}{(3 \cdot g)^{0.5}} \cdot \left(\frac{r}{P + \frac{2 \cdot d}{R_0}} \right)^{0.5} . \tag{2}$$

Let's write down the equation (1) as dimensionless:

$$r \cdot \ddot{r} + \frac{2}{3} \cdot \dot{r}^2 + \frac{1}{r} \cdot A + \frac{\dot{r}}{r} \cdot B + r^{-3g} \cdot C = f(t) . \tag{3}$$

The constants A, B, C and function $f(t)$ are determined as follows:

$$A = \frac{2 \cdot d \cdot T_0^2}{r \cdot R_0^3};\; B = \frac{4 \cdot m \cdot T_0}{r \cdot R_0^2};\; C = -\frac{T_0^2 \cdot \left(P + \frac{2 \cdot d}{R_0} \right)}{r \cdot R_0^3};\; f(t) = \left(P(t \cdot T_0) + P_v - P \right) \cdot \frac{T_0^2}{r \cdot R_0^2} . \tag{4}$$

The equation (3) can be solved by numerical integration. Let's carry out the analysis of the equation (3) solutions at various methods of the function of pulse pressure *P(t)* presetting. Let's present function *P(t)* as piecewise-continuous function on the interval (0, T). T is the one cycle period of stator channel and rotor channels overlapping and overlapping by the rotor wall:

$$T = \frac{2 \cdot \text{ð}}{z_r \cdot \text{ù}} , \tag{5}$$

where z_r is the number of rotor channels.

In the given work the number of intervals, on which the function has its extremum changes from 2 to 5. On each interval the function *P(t)* is interpolated by the multinomial of the 2-nd degree: $P_i(t) = a_i t^2 + b_i t + c_i$, where i is the interval number, a_i, b_i, c_i are coefficients. Pressure pulse height and depth, generating in RPCD are proportional to the square of angular velocity of rotor [5] rotation. The pulse form circuit of the stimulating pressure is shown on Fig.1.

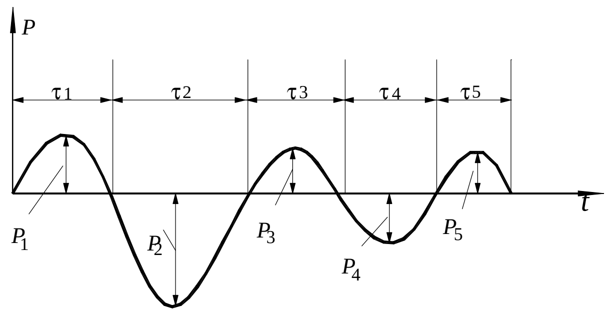

Fig.1. Pulse form circuit of stimulating pressure

All in all we set four pulse forms of stimulating pressure. The parameters for each pulse form have values:

1) At the pulse form 1: $P_1 = 0.5 \cdot w^2, P_2 = w^2, t_1 = \frac{P_2 \cdot \frac{1}{8} T}{P_1 + P_2}, t_2 = \frac{T}{8} - t_1, P_3 = P_4 = P_5 = 0$;

2) At the pulse form 2:

$$P_1 = 0.5 \cdot w^2, P_2 = w^2, t_1 = t_2 = \frac{1}{16} T, t_3 = t_4 = \frac{7}{24} T, P_3 = \frac{3}{14}(P_2 - P_1), P_4 = P_5 = 0;$$

3) At the pulse form 3:

$P_1 = 0.5 \cdot w^2, P_2 = w^2, P_3 = 0.25 \cdot w^2, t_1 = t_2 = \frac{1}{16}T, t_3 = t_4 = \frac{7}{24}T, P_4 = \frac{3}{14}(P_1 - P_2) + \frac{7}{24}P_3, P_5 = 0$;

4) At the pulse form 4:

$P_1 = 0.5 \cdot w^2, P_2 = w^2, P_3 = 0.25 \cdot w^2, P_3 = 0.225 \cdot w^2, t_1 = t_2 = \frac{1}{16}T, t_3 = t_4 = t_5 = \frac{7}{24}T, P_5 = \frac{3}{14}(P_2 - P_1) + (P_4 - P_3)$.

On Fig.2 the equation (1) solution for the 4-th pulse form and angular velocity of rotor pulse rotation 300 s^{-1} are given, R_0=5*10^{-4} m.

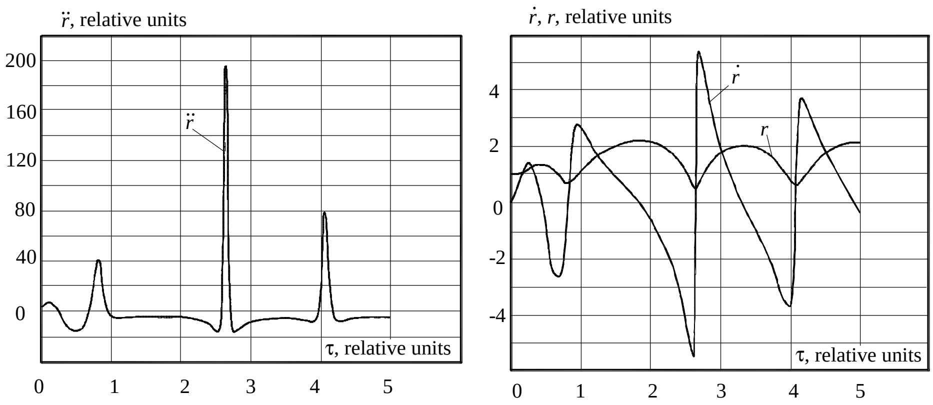

Fig.2. Dimensionless equation (1) solution

The change dependences of the bubble dimensionless radius and dimensionless acceleration of the bubble wall of pulse frequency of stimulating pressure $f = \frac{1}{T}$ (Fig.3) are constructed.

3 pulse forms 4 pulse forms

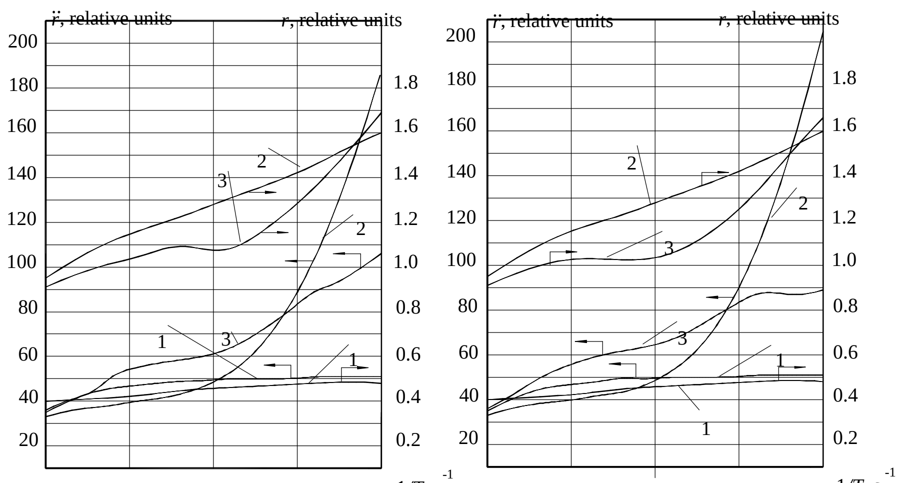

Fig.3. Change dependences of dimensionless radius r and dimensionless acceleration $\ddot{r}$ of the bubble wall for 1,2 and 3 pulsations of pulse frequency of stimulating pressure for 3 and 4 pulse forms respectivly.

Based on the received dependences it is possible to make conclusions, that:

1) At the pulse form change of stimulating pressure from the 1st form to the 4th the generated by a bubble cavitation pressure, which is proportional to a bubble wall acceleration increses.

2) At the pulse form change the radius change at pulsations increases.

3) Increase of dimensionless acceleration of the bubble wall for the 2nd pulsation with the pulse frequency increase is very well expressed.

The explanation of the 1st and 2nd items of the conclusion is that complicating the pulse form we are increasing the amount of energy feeded to a bubble, at the expense of additional changes of the external stimulating pressure. The explanation of item 3 is that with the pressure pulse frequency increase the pressure pulse period reduces and the bubble system is close to a resonance at the 2nd pulsation.

R E F E R E N C E S

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