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THE CALCULATION PROCEDURE OF EXPERIMENTAL SONIC GENERATOR WITH TWO RESONATORS DESIGNED FOR WATER TREATMENT PROCESSES

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ABSTRACT

The design parameters such as nozzle slot, generator's slot, resonance chamber diameter, resonator neck length, inlet port diameter are required to determine the optimal operating parameters while using the sonic generator for water treatment. These parameters determine the optimal values of functional parameters that induce best results within the water treatment process. The design calculation achieves the necessary values of the operating parameters which are the supply air pressure, air mass flow, generators frequency.

KEYWORDS: sound waves, sonic generator, resonator, design parameters

1. Introduction

The sonic generator with two resonators is actually a Levavasseur type generator with two toroidal cavities. The paper presents the calculation method of the generator with two resonators and flat jet.

2. The sonic generator operation

The Levavasseur generator (fig.1) consists of two toroidal resonators of which one is generating and the other one is resonant [1]. The resonant cavity is out of phase with generating cavity that induces the increase of generators operating efficiency.
Further is analyzed the one-dimensional flow dynamics of air in a Levavasseur generator with flat jet. Thus the compressed air is allowed in the central port and accelerates in the convergent side formed by the resonators. The air jet arrived in the resonators opening is divided into three: a central jet and two side jets. The side jets follow the contour of cylindrical cavities and intersect the central jet at the cavity exit and so deviate the central jet from its flow direction.
Hence is achieved the air periodic discharge of cylindrical cavities which produces pressure pulsations with the frequency determined by the attachment rate of central jet on the resonator external edge.

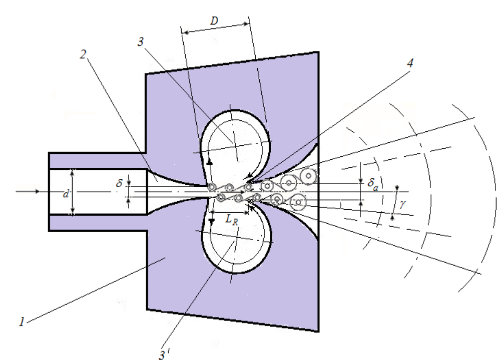

Figure 1. The flow scheme of sonic generator with two resonators : 1-base; 2-convergent nozzle; 3,3'-resonance cavities; 4-resonator edge; D-resonance cavity diameter; δ-convergent nozzle slot; δ_a- generator slot; L_R-resonator neck length; d-inlet port diameter

In turn the rate of jet attachment on edges is determined by the vortex produced by the external sides of central jet [2]. The equal cavities diameters determine the interference oscillations which ensure increasing amplitude that allows for the high frequency waves pulsing and also ultrasonic frequency.

3. The design parameters calculation

A basic criterion that describes the air-jet sonic generator’s operating is the Strouhal number [3] showed by the following equation:

$$Sh = \frac{f \cdot \delta}{v} \quad (1)$$

where: f-operating frequency, δ-nozzle slot, v-air jet speed.

The air jet speed according to air flow rate in the exit section of convergent nozzle is either sunsonic or critical. In subsonic regime the air flow rate from nozzle is determined by Saint-Venant formula [3]:

$$v = \sqrt{\frac{2k}{k-1} \cdot \frac{p_0}{\rho_0}\left[1 - \left(\frac{p_{at}}{p_0}\right)^{\frac{k-1}{k}}\right]}, \text{ m/s} \quad (2)$$

where: P_0=p+P_{at} is the supply absolute pressure, p- the supply gauge pressure, P_{at}-enviroment pressure

ρ_0- density of air tank (3),

$$\rho_0 = \frac{P_0}{R \cdot T_0} = 3{,}57, \text{ kg/m}^3 \quad (3)$$

the gas constant for air (4):

$$R=287 \text{J/(kg·K)} \quad (4)$$

the air tank temperature:

$$T_0=273{,}12+ t_o, \text{[K]} \quad (5)$$

k=1,4 adiabatic exponent of air.

If the total air pressure P_0 is higher than enviroment pressure P_{at} and the air flow is of (6):

$$\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}} = 1{,}72 ori \quad (6)$$

then the critical regime is installed in the exit section of the convergent nozzle [3].

The critical speed is determined by the formula:

$$v = a_* = \sqrt{\frac{P_0}{\rho_0} \cdot \frac{2k}{k+1}}, \text{ m/s} \quad (7)$$

The convergent nozzle slot is obtained using the frequency f, optimal Sh number and air jet speed v:

$$\delta = \frac{Sh \cdot v}{f}, \quad (8)$$

The nozzle slot width h is not a determinant parameter and for flat jets is recommended the ratio:

$$\delta / h > 6 \quad (9)$$

Then the cross section of convergent nozzle is:

$$S = \delta \cdot h \quad (10)$$

where: δ[m]- nozzle slot, h[m]- nozzle slot width.

The mass air flow for subsonic flow air through orifices and nozzles results from formula:

$$m = \rho_0 \cdot v \cdot S, \text{ kg/s} \quad (11)$$

where S is the exit section area of convergent nozzle.

The resonator neck length can be determined from equation (12):

$$L_R = n \cdot l_v - \frac{L_R}{a} \cdot f \cdot l_v \quad (12)$$

where: n- integer number of vortex (n=1 for symmetric vortex system, n=2 for the case of asymmetric vortex system), l_v-distance between vortex.

The frequency f is determined by the value Sh with the equation:

$$f = \frac{Sh \cdot v}{\delta} \quad (13)$$

The own frequency of resonator is determined by the equation:

$$f = \frac{a}{2\pi} \cdot \sqrt{\frac{S_R}{b \cdot V_R}} \quad (14)$$

where S_R-cross section area of resonance cavity opening, a- sound speed, b- resonance cavity opening depth, V_R- volume of resonance cyllindric cavity.

The volume of resonance cyllindric cavity with diameter D and depth h which is equal to convergent nozzle width is determined with the formula:

$$V_R = \frac{\pi \cdot D^2}{4} \cdot h \quad (15)$$

The crooss section area of rectangular opening of resonance cavity will be:

$$S_R = L_R \cdot h \qquad (16)$$

where: L_R, h is the length and width of opening. The formula for calculation of opening depth of resonance cavity is:

$$b = \frac{\delta_a - \delta}{2} = L_R \cdot tg\gamma \qquad (17)$$

where: tg γ = tg (10-15)0 = 0,2-0,25.
Thus the resonance cavity diameter is:

$$D = \frac{a}{f \cdot \left(\pi^2 \cdot tg\gamma\right)^{1/2}} \qquad (18)$$

where: a=331+0,59·(t- t_0), [m/s] is the sound speed in air at the temperature t, t_0 = 0, ^{0}C, f [Hz]-generator frequency, γ-the exit cone angle of the channel generator.

The inlet channel diameter d is determined by the continuity equation from the condition:

$$d \geq 2 \cdot \sqrt{\frac{\delta \cdot h}{\pi} \cdot 1{,}6} \qquad (19)$$

The initial data for the sizing calculus of air-jet generator with two resonators are the following: f[kHz]-generator operating frequency, p[MPa]-air gauge pressure, P_{at}[MPa]-enviroment pressure, m [kg/s]- mass flow or volumetric air flow.
The geometrical and operating parameters were determined for the gauge pressure p=0,05 Mpa, air flow Q=10m^3/h, and the considered frequency of f=10,5 кHz [4].
The results are shown in table 1[4]. The value n can have values of 1, 2, 3....but in our calculus n=1. The results in table 1 correspond to the case when in the generator appears the symmetric system of vortex (n=1). In other case of non-symmetrical vortex (n=2) the frequency increased and for the parameters determined in table 1 appears the second frequency of f =21,2 кHz [4].

Table 1. The parameters calculated for experimental sonic generator with two resonators

P,Pa	Q,m^3/h	P_{at}	f,kHz	Sh	δ, mm	D,mm	h,mm	n	L_R,mm	d ,mm
1,6·10^5	10,0	1,1·10^5	10,5	0.3	1,2	8,0	8.06	1	4,08	7,06

The experimental sonic generator construction with two resonators designed by the dimensions calculated is shown in figure 2.

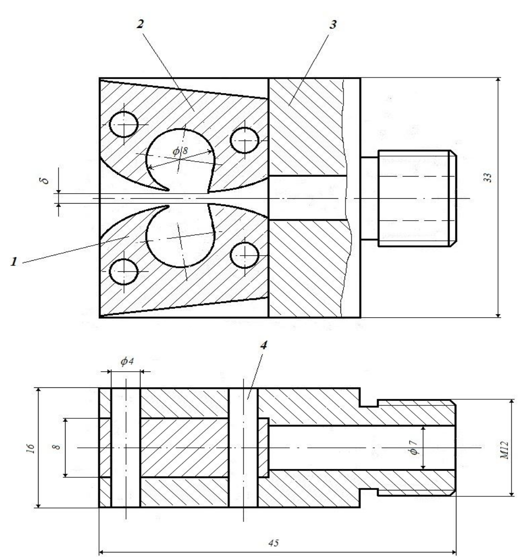

Figure 2. The experimental air-jet sonic generator with two resonators: 1-housing, 2- top resonator, 3- bottom resonator, 4- mounting pin, δ- generator slot

The housing generator 3 has a flat shape with a rectangular chanel which has inside two flat resonators 1 and 2 with thickness of 8 mm. Each resonator has a resonance cyllindric cavity with an interior diameter of 8 mm.
The top resonator 2 has a rounded bottom and a rectangular opening of 4 mm to the symmetry generator axis. The bottom resonator 3 has the top rounded and the rectangular opening upward oriented. Their location with the rounded sides face to face creates a central channel for air passing.
The calculation of air-jet sonic generator with two resonators determined its construction of stainless steel type 20 Cr 120 as shown in figure 3.

Figure 3. The air-jet sonic generator with two resonators

4. Conclusions

The paper contains a new calculus method of the air-jet sonic generator with two resonators.
The sonic generator function is based on a source of compressed air which passes through the two cavities resonators and generates two frequencies, one sonic and the other one ultrasonic.
Following the calculation, it was determined the optimal parameters, namely the supply pressure p=0,05 Mpa, air flow Q=10m^3/h, and the considered frequency of f=10,5 кHz.
The sonic generator type Levavaseur was considered for the water treatment process in the plant systems because it is stable in operation for low working pressure less than 0,05 MPa. This pressure is specific to turbochargers found in the water plants to assure the aeration of raw water.
Thus for the sonic generator operating is required a low supply pressure which implies a small consumption of energy in order to obtain best results in the water treatment process.

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