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THE SONIC WASTE WATER TREATMENT

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ABSTRACT

Sonic technology means the technology where the sonic devices are used and where the intensification of the heat and mass transfer is obtained owing to the pressure or flow capacity oscillations, introduced in the technological flux. This paper consists in the examination of the practical application results of the various technical systems with sonic injectors.

KEYWORDS: water treatment, sonic technology, ultrasound gas-dynamic generator

1. Introduction

A new method of intensifying the technological processes, generally, with low energy consumption, is based on the idea of using the pulsation energy which appears during non-stationary flows of the technological fluids [1]. Technological devices used for this aim can be named Sonics, after the great Romanian scientist George Constantinescu [3], because they do not have mechanical mobile pieces and run normally, in regime of self-oscillations, therefore, in sonic regime.

This paper consists in the examination of the practical application results of the various technical systems with sonic injectors [1].

The main element of a sonic injector represents the sonic generator according to which the sonic injectors are classified. The generator with pressure pulsation or flow capacity without mechanical mobile pieces which normally runs in self-oscillation regime will be called the sonic generator. Depending on the nature of the fluid used for the sonic generators running, the last ones can be hydrodynamic or gas-dynamic.

At the hydrodynamic sonic injectors the generation of the pulsations is produced by the liquid itself (or by the liquid combustible) which is sprayed. Owing to the self-oscillation phenomenon during instable turbionaire flows of the fluids, powerful pressure pulsations are produced.

The flow instability can appear because of the lack of balance between the supply network and generator, or because of the special geometry of the generator which produced the lack of balance between the capacity flow penetrated through the entrance channels and drained through its nozzle.

The gas-dynamic sonic injectors, or another name more famous – acoustic, for liquids combustible spraying (or liquids) use the energy of the high frequency shock waves which appear during non-stationary flows, in supersonic jets of gases, the well known phenomenon – in acoustic – as HARTMANN effect [2].

Sounds and ultrasounds gas-dynamic and hydrodynamic generators can be classified according to the way of producing the sonic field:

-Hartmann generators, which use the non-stationary processes from supersonic gas jets;

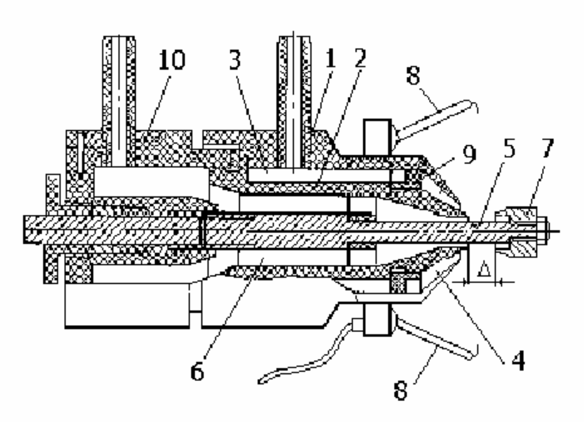
-Helmholtz generators (or acoustic “little whistle”), where the non-stationary processes from subsonic fluids jets are used;

-Generators with tourbillion, which use the instability phenomenon of the turbinate fluids fluxes.

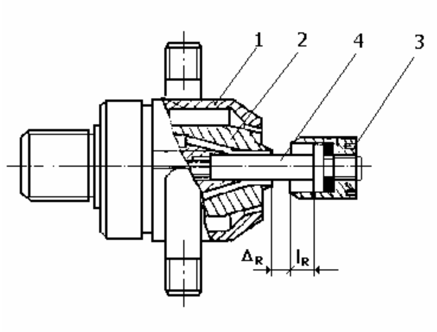
Because the classical generator Hartmann, which represents a “mouthpiece-resonator” mechanical system, is not stable at low variations of supply gas pressure, Hartmann suggested in 1951 [2] the introduction of a central rod in the convergent mouthpiece, in order to fasten the resonator.

The “mouthpiece-rod-resonator” system (Figure 1, at the injectors: RD-1, AFR-2, -3, -4, -5, DRG-1) proved to be stable from an acoustic point of view and obtained large usage in various technological processes and mainly, as injectors for fine spraying of the combustibles and for liquids, in general. This universality takes place because of the phenomenon of the gas which flow “crisis” in mouthpiece, well known in the gases dynamics [2], to which after establishing the critical flowing regime, the flow capacity of gas passed through the generator mouthpiece remains unchanged at variations of state parameters of the medium, where the drain takes place.

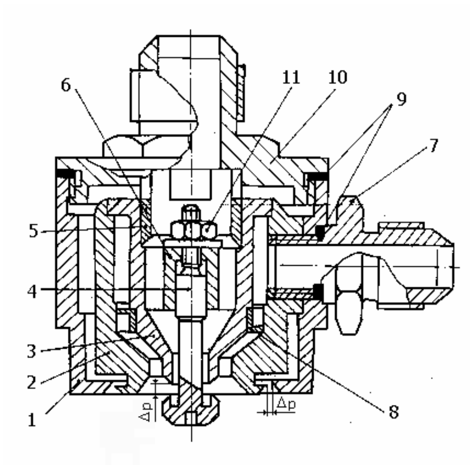
In Table I, the technical characteristics, usage domains and several constructions (Figure 1) of the performant sonic injectors made by the authors [1, 2] are presented. The technological advantage of the gas-dynamic injectors represents the independence from the nature of the technological medium (liquids or gases) and the conditions in exterior medium (vacuum and overpressure) where they have to run [1].



AFR-4



RD-1



DRG–1

Fig. 1. *Sonic injectors.*

Table 1. *The technical specification of the spraying sonic devices*

Type	RD-1	AFR-4	DRG-1
Capacity flow, g·s^{-1}	150	20	100
Working air consumption, g·s^{-1}	25	4	10
Working pressure, MPa	0.2-0.3	0.3	0.3
Liquid supply pressure, MPa	<0.3	<0.2	0.3
Working frequency, kHz	8.0	16	20
Sauter medium diameter (for water), µm	15-25	15-25	5-10
Angle of the dispersed jet	30-120	30-140	50-70
Dimensions, mm	40×60	30×100	50×70
Usage domains	Thermal engine, boiler, burning equipment	Thermo-isolating building materials, engineering zootechny	Metallurgy burning equipment, alimentary industry

2. Experimental hydro-pneumatic plant

In the research activity, the sonic treatment process requires certain technical requirements to ensure the directing and control of the technologic process, which are described in the experimental scheme of the technological water treatment (Fig. 2).

The plant allows the sonic generator supply to use, as working medium, the filtered air with filter 5 or the oxygen from the cylinder 4. The agency work (air or O_2) passes through generator 7, which is located inside the tank 10 and produces ultrasonic waves and bubbling, at the same time, thereby ensuring the sonic treatment of the technological fluid from the tank.

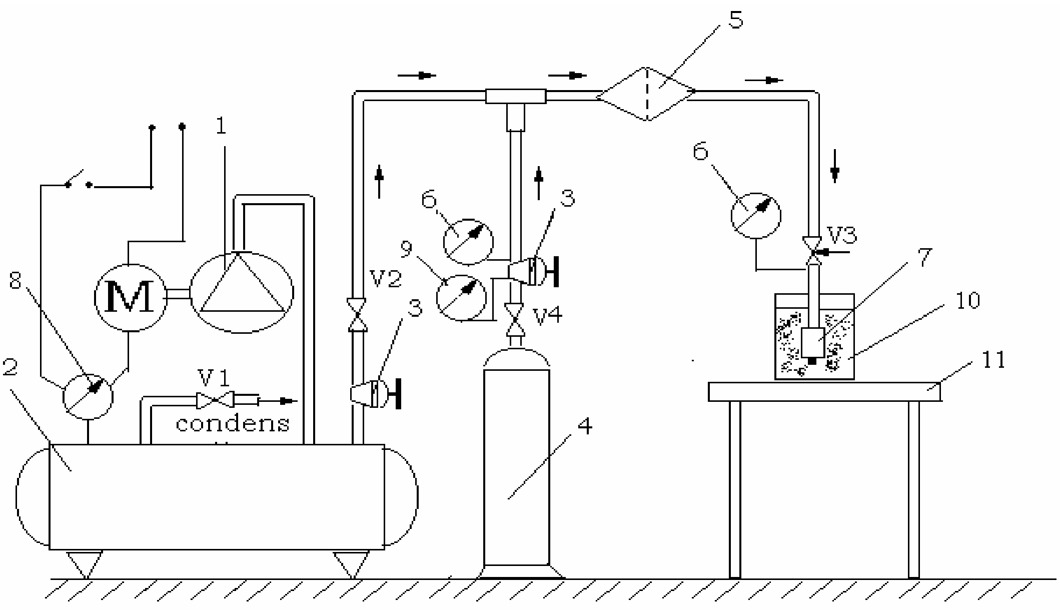


Fig. 2. *Experimental scheme for technological water treatment: 1. compressor, 2-tank battery, V_1-pressure control valve, M-electric motor, 3-pneumatic gearbox, V_2-way valve, 4-cylinder oxygen, 5-air filter 6-gauge, 7- ultrasounds gas-dynamic generator, 8-manometer, 9-gauge manometer, 10-tank work, H-depth work, V_3-control valves V_4-gas cylinder valve.*

3. Parametric study of the experimental gas-dynamic generator

Initial data required for calculation are the following:

ν - operating frequency, [kHz];

$\dot{m}_a$ - mass flow of working gas (air), [kg/s];

W_a - acoustic power, [W];

p = (0,1÷0,4) - working pressure gauge generator, [MPa],

The non-isobar parameter of the gas flow generator is determined as follows:

$$n = \frac{P_0}{P_{ex}} \cdot \pi(M_a) = \frac{p + P_{ex}}{P_{ex}} \cdot \pi(M_a), \qquad (1)$$

where: P_0 – total pressure nozzle;

P_{ex}– outside or atmospheric pressure (P_{ex}=0.1012 MPa);

p – value of the pressure gauge for compressed air supply;

$\pi(M_a)$ = 0.5263– gas-dynamic function π, from the gas–dynamic tables, corresponding to the Mach number M_a=1.0 in the nozzle exit section.

Depending on the parameter value of the jet n non-isobar jet, is determined the optimum dimensionless geometric parameters of the resonator (Fig.2), from which the maximum acoustic intensity power is obtained:

$$\overline{\Delta}_R = \frac{\Delta_R}{2\delta} = 0{,}74 \cdot n + 0{,}20 \qquad (2)$$

$$\overline{l}_R = 1.1 \cdot \overline{\Delta}_R \qquad (3)$$

$$\overline{D}_R = \frac{\delta_R}{\delta} = 0.34 \cdot n + 0.56 \qquad (4)$$

where:

δ is slot nozzle, $\delta = \frac{D_a - d_t}{2}$;

δ_R -is the slot resonator, $\delta_R = \frac{D_R - d_t}{2}$;

D_a, d_t – - nozzle diameter, respectively, the rod;

Δ_R, D_R, l_R - distance control, diameter and depth of the resonator (Fig. 3).

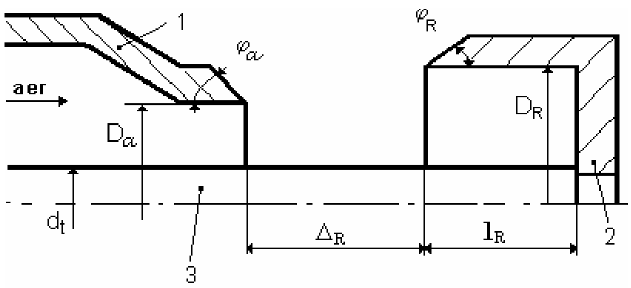


Fig. 3. *Design scheme for the dimensional calculation of the gas-dynamic generator with shaft: 1. nozzle 2. resonator, 3- rod; D_a – resonator diameter; dt–rod diameter, Δ_R – resonator control distance, D_R resonator diameter, l_R resonator depth.*

The optimal values of parameters $\overline{\Delta}_R$, $\bar{l}_R$, $\overline{D}_R$, the value of n and the frequency of the generator are used to determine the size of the slot nozzle, (ν =27 kHz):

$$\delta = 0{,}075\frac{a \cdot n^{\frac{1}{3}}}{\nu \cdot \bar{l}_R^{\frac{1}{4}} \cdot \overline{\Delta}_R^{\frac{1}{6}} \cdot \overline{D}_R^{\frac{2}{3}}} \qquad (5)$$

where: a – sound speed in the nozzle exit section,

$$a = a_0 \cdot \left(\frac{2}{k+1}\right)^{\frac{1}{2}}, \text{ m/s}$$

a_0 - sound speed in air at rest at ambient temperature t.

Air mass flow is determined from the relationship:

$$\dot{m}_a = \frac{P_0 \cdot F_a}{\sqrt{T}}\left(\frac{k+1}{2}\right)^{\frac{k-1}{2(k-1)}}\left(\frac{k}{R}\right)^{\frac{1}{2}} \qquad (6)$$

where: F_a is section area of the generator nozzle exit,

$$F_a = \frac{\pi\left(D_a^2 - d_t^2\right)}{4} \qquad (7)$$

P_0 - total pressure,

T - supply gas temperature,

k - the adiabatic exponent, k = 1.41.

Using the parameter values D_a, d_t, D_R, l_R, Δ_R is determined the non-isobarity n:

$$n = \frac{(D_a - d_t)^3 \cdot \nu^3}{a^3 \cdot (0{,}15)^3} \cdot l_R^{\frac{3}{4}} \cdot D_R^2 \cdot \sqrt{\Delta_R} \qquad (8)$$

Acoustic power generator is obtained from the relationship:

$$W_a = \frac{\rho_0 \cdot a_0^3 \cdot n^{2\frac{1}{3}} \cdot F_a}{\bar{l}_R^{-2\frac{1}{4}} \cdot \overline{D}_R^{-2\frac{2}{3}} \cdot \overline{\Delta}_R^{-\frac{1}{6}}} \cdot K_W, \text{ [W]} \qquad (9)$$

where: ρ_0 is the density of the compressed air supply, $\rho_0 = \frac{P_0}{a_0^2} \cdot k$.

Thus, by the method of calculation, the gas-dynamic sonic generator is designed and constructed with the following experimental dimensions:

D_a=4.0 mm, d_t=3.0 mm, D_R=4.0 mm, l_R =2.5 mm, Δ_R=1.42 mm. It results that the slot nozzle and the slot resonator have the same size: $\delta=\delta_R$=0.5 mm.

4. Construction of the gas-dynamic experimental sonic generator

The axial gas-dynamic sonic generator, used in the experimental wastewater treatment plant is illustrated in Figure 3:

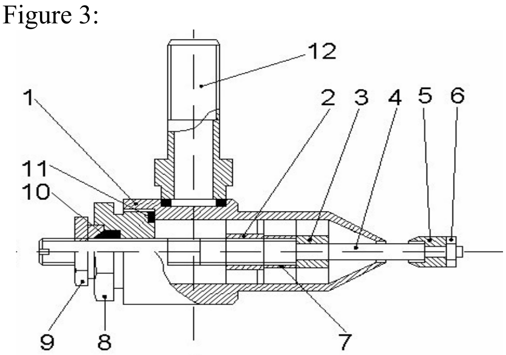


Fig. 3. *Axial gas-dynamic sonic generator: 1 - nozzle, 2,3 - cross support; 4 - rod, 5 - resonator, 6 - nut, 7 - bush, 8 - cover, 9 - nut, 10 - gasket; 11,13 - ring; 12 – socket.*

Compressed gas passes through nozzle 1 and resonator reaches 5. Supersonic gas jet from the nozzle, after interaction with the resonator cavity, loses its stability and emits high-frequency shock waves. The construction of the axial generator allows the adjustment of the dimensional parameters, which determine acoustics and gas-dynamics parameters change.

5. Conclusions

Recent research projects have underlined the potential of ultrasound as a chemical free treatment in water-related applications.

This article reviews the use of ultrasound technology, with a focus on wastewater, irrigation and aquaculture applications.

To reach this goal, the sonic systems use a 'blend' of very specific ultrasound frequencies of certain power which are emitted into the water by specific transducers.

To obtain the successful treatment of water, one should first know that no water body is the same -- every water body is unique and should be treated uniquely. Wastewater is any water that has undergone changes quality because of human intervention. Often, wastewater is being treated for re-use as drinking water or for other purposes. As high levels of nutrition are available in these waters, algae may grow rapidly as well as other micro-organisms such as bacteria. Algae can compete for nutrients against the bacteria in charge of sludge reduction and can also clog complete systems. The sonic technologies use the newest ultrasound techniques to remove the threat of algae from wastewater treatment plants and reclaimed water reservoirs.

Briefly, some of the results achieved in wastewater applications using the sonic technologies systems are:

• Reduction of biofilm formation;

• Reduction of TSS, turbidity, BOD, COD levels etc.;

• Reduction of free bacterial counts (E. coli, Enteroccoci, etc.);

•Ultrasound vibrations make it more efficient for bacteria present in the sludge to obtain nutrients, and speed up the utilizations of nutrients, accelerating the degradation of organic waste and the consumption of nitrates and phosphates.

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