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STUDY ON THE INFLUENCE OF SONIC GENERATOR GEOMETRY ON ACOUSTIC PARAMETERS

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ABSTRACT

The acoustical parameters, dimensional determination and construction of sonic generator is described in the paper. The generator's dimensional determination and construction show that the nozzle slot, the axial resonator slot and the distance between the nozzle and the resonator have adjustable dimensions and determine the results for the acoustical parameters of the sonic generator. Thus, due to this adjustment, the sonic generator can be set for certain geometrical parameters that determine the acoustical parameters required.

KEYWORDS: Generator, Sonic, Acoustic, Resonator, Nozzle.

1. Introduction

The sonic generator induces into the environment both an air jet and sound waves at a certain design dimensions that determine also the acoustical parameters: acoustic intensity, oscillations amplitude and frequency. The air jet and the sound waves being emitted simultaneously by the generator due to his high frequency and gas flow rate.

Thereby the paper presents the analysis of the sound intensity and the gas mass flow, as well as the geometry, the acoustical parameters and the effective construction of the sonic generator.

2. The geometrical parameters of the sonic generator

The main generator's geometrical parameters (fig.1) that determine its acoustic characteristics are:

- the nozzle diameter D_a;
- the nozzle slot δ;
- the bar diameter d_t;
- the resonator internal diameter D_R;
- the resonator depth l_R;
- the resonator slot δ_R;
- the resonator adjusting distance Δ_R.

In order to determine these parameters, it is necessary first to calculate a gas-dynamic characteristic of the sonic generator, namely the non-isobaric coefficient *n,* using the equation below [1]:

$$n = \frac{P_0}{P_{ex}} \cdot \pi(M_a) = \frac{p + P_{ex}}{P_{ex}} \cdot \pi(M_a), \qquad (2.1)$$

where: P_0 is the total nozzle pressure;
P_{ex}=0,1012 MPa, is the exterior pressure;
p- the measured pressure;
$\pi(M_a)$=0,5263 is the gas dynamic function π from the gas dynamic tables corresponding to Mach number in the exit section area of the nozzle M_a=1,0.

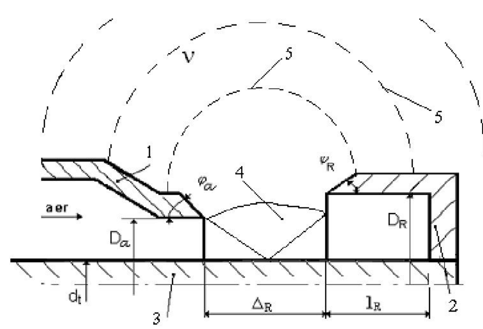

Figure 1. The constructive scheme of the sonic generator: 1 – nozzle; 2 – resonator; 3 – bar; d_t – bar diameter; D_R - resonator internal diameter; D_a - axial nozzle diameter; Δ_R- resonator adjusting distance; l_R –resonator depth.

Then you can determine the dimensionless geometrical parameters [2] of the resonator

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namely the resonator adjusting distance, the resonator depth and the resonator internal diameter:

$$\overline{\Delta}_R = 0{,}74 \cdot n + 0{,}20 \ , \tag{2.2}$$

$$\overline{l}_R = 1{,}1 \cdot \overline{\Delta}_R \ , \tag{2.3}$$

$$\overline{D}_R = 0.34 \cdot n + 0.56 \ , \tag{2.4}$$

Further, using the values of $\overline{\Delta}_R$, $\overline{l}_R$, $\overline{D}_R$, n and the work frequency (chosen from the frequency area ν =20÷30 kHz), it is obtained the nozzle slot [2]:

$$\delta = 0{,}075 \frac{a_0 \cdot n^{\frac{1}{3}}}{\nu \cdot \overline{l}_R^{\frac{1}{4}} \cdot \overline{\Delta}_R^{\frac{1}{6}} \cdot \overline{D}_R^{\frac{2}{3}}} \ , \ [\text{mm}] \ , \tag{2.5}$$

where:

$$a_0 = 331 + 0{,}59 \cdot (T - T_r), \ [\text{m/s}] \tag{2.6}$$

is the sound velocity in air standby generator at an ambient temperature T, towards the reference temperature $T_r = 0^0$C; ν[kHz] being the working frequency of the generator.
The determination of the nozzle slot allows us to calculate the dimensional values of the resonator slot, the resonator adjusting distance and depth [2]:

$$\delta_R = \overline{D}_R \cdot \delta, \ [\text{mm}], \tag{2.7}$$

$$\Delta_R = \overline{\Delta}_R \cdot 2\delta, \ [\text{mm}], \tag{2.8}$$

$$l = \overline{l}_R \cdot 2\delta, \ [\text{mm}]. \tag{2.9}$$

More, we need to calculate another gas-dynamic characteristic of the sonic generator, namely the mass flow [2], together with the sectional area of the nozzle exhaust exit:

$$\dot{m}_a = \frac{P_0 \cdot F_a}{\sqrt{T}} \left(\frac{k+1}{2}\right)^{\frac{k+1}{2(k-1)}} \left(\frac{k}{R}\right)^{\frac{1}{2}} [\text{kg/s}] \tag{2.10}$$

and:

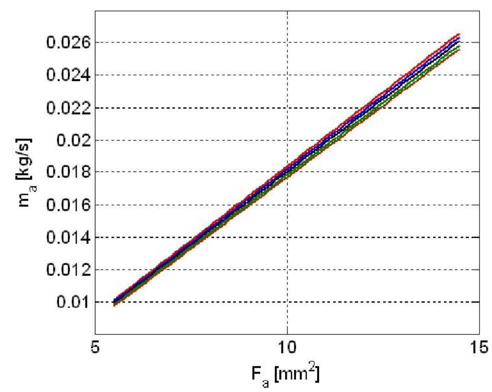
$$F_a = \frac{\pi \left(D_a^2 - d_t^2\right)}{4} \ [\text{mm}^2], \tag{2.11}$$

where: T-the input gas temperature;
D_a- the nozzle diameter;
d_t- bar diameter;
R=R/μ, R=8314[J/kmol·K] is the universal ideal gas constant; μ- molar gas weight (μ=29 kmol, for air), k=1,41 being the adiabatic exponent.
On the basis of the data obtained above, we can calculate the nozzle diameter [2] and the internal resonator diameter:

$$D_a = \frac{F_a}{\pi \cdot \delta}, \ [\text{mm}] \tag{2.12}$$

$$D_R = D_a - 2 \cdot \Delta_R, \ [\text{mm}] \tag{2.13}$$

After the calculus of the geometrical parameters of the generator it was examined the evolution of gas mass flow [4] according to the sectional area of the nozzle exit at different values of input gas temperature.



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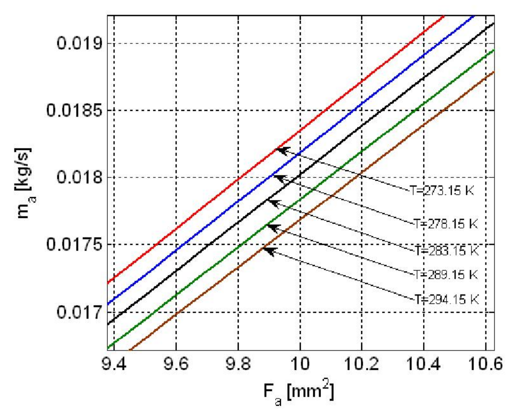

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Figure 2. The evolution of gas mass flow according to the cross sectional area of the nozzle exit at temperature variation:a- general view ;b - view in detail

A significant linear increase of the gas mass flow is observed (fig.2), regardless of gas temperature considered, with the growth of the section area of the nozzle exit. The graphic shows that the gas mass flow rate will grow

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with the increase of F_a up to 100%. Thus, the increasing gas mass flow is achieved by adjusting the nozzle exit section.

3. The acoustic parameters of the sonic generator

The parameter that incorporates the characteristics of amplitude and frequency noise of a sonic generator is the sound intensity [2] produced by a point source, given by:

$$I = \frac{\rho_0 \cdot a_0^3 \cdot n^{0,7} \left(0,7a \cdot n + 0,20\right)^2}{\bar{l}_R^{0,46} \cdot \bar{D}_R^{1,38} \cdot \bar{\Delta}_R^{0,34}} \cdot K_I , \qquad (3.1)$$

where:
I, [W/m^2] is the sound intensity;
ρ_0,[kg/m^3] – density of gas supply;
a_0- sound velocity in air standby generator at ambient temperature;
a – sound propagation velocity in environment;
K_I– calculation constant:

$$K_I = 0,04\pi^2 \cdot K_A \qquad (3.2)$$

and K_A– scale factor:

$$K_A = 4,6 \cdot 10^{-5} \qquad (3.3)$$

In terms of the geometrical parameters influence on the acoustic characteristics, it was determined that the increase of the internal resonator diameter D_R, from the value equal to the nozzle diameter $D_R = D_a$, rises the sound intensity I higher.
Also, with the increasing depth l_R at D_R = const., Δ_R=const. and n=const., the resonator's volume grows and that leads to increased oscillation amplitude and lower frequency. Once the oscillation amplitude grows, the sound intensity is lower.
The same way, the initial increase in the distance Δ_R by moving the bar 3 (fig.1), at l_R =const., D_R = const., n = const. leads to increased oscillation amplitude [3], which means again the sound intensity decrease.
Further, we analyzed the evolution of the acoustic intensity (fig.3) depending on the resonator internal diameter D_R at different values of sound propagation velocity in the environment 'a'.
Thus, the evolution of the acoustic intensity [4] has a character of a curve that becomes more obvious with the increase of the sound propagation velocity in the environment.
Also, acoustic intensity, in all cases considered, increases with decreasing of the resonator internal diameter, which means that the maximum acoustic intensity was obtained for the lowest value of D_R.

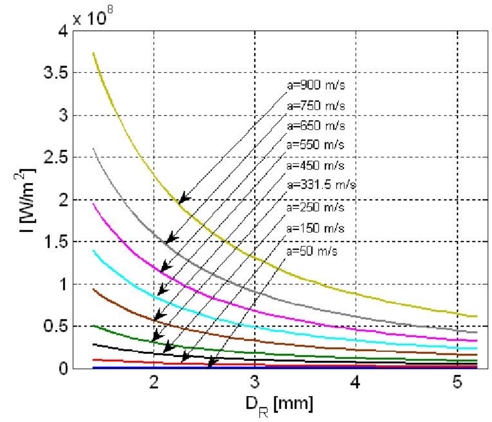

Figure 3. The evolution of acoustic intensity according to the resonator internal diameter for sound propagation velocity in environment variation

In addition, you also notice that up to the value of sound propagation velocity equal to the sound velocity (a=331,5 m/s), the acoustic intensity has lower values (up to 0,5x10^8 W/m^2), and after exceeding that it has a significant increase.

4. The construction of the sonic generator

Based on the determination of the geometrical parameters the sonic generator (fig.4) designed for working gas insertion was achieved.
Thus resulted the main parameters of the constructed generator [4]: D_a=4,0 mm; d_t=3,0 mm; D_R=4,5 mm; l_R= 2,0 mm; Δ_R=1,2±0,5 mm; $\delta=\delta_R$=0,5 mm.
The sonic generator (fig.4) was made of stainless steel of the type 20 Cr 120.


Figure 4. The sonic generator

The working gas used for the generator's function (fig.5) is either the air from a compressor or the gas (oxygen, carbon dioxide) from a gas tank included in the installation which was introduced in the generator.

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Thus the air evacuates the generator via the nozzle slot, encounters the resonator and enters into the resonator slot, then leaves the resonator slot and returns, encountering the nozzle.
The compressed air passed through the nozzle 1 reaches the resonator 5 fixed on the rod 4, which is inside and can be rotated and you can move the resonator.
A part of the air that encounters the nozzle is dispersed into the environment and the other part encounters again the resonator slot. Encountering the metallic part of the nozzle or of the resonator, the working air or gas generates vibrations.

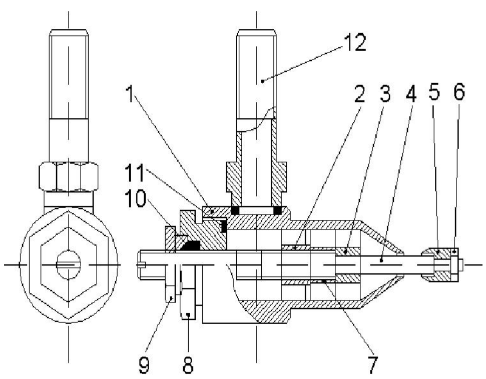

Figure 5. The sonic generator scheme: 1-air nozzle; 2,3-cross support; 4-rod; 5-resonator; 6-screw-nut M2,5; 7-sleeve; 8-cover; 9-locking nut; 10-gasket; 11- ring; 12-fitting.

This route of the gas influences the frequency of the sonic jet projected from the generator to depend on the nozzle slot dimension, as well as the resonator adjusting distance and the resonator slot dimension.
Hence the sonic generator produces both the air jet and the sound waves and is designed for experimental use and functions in the range of gas pressure: p=0,15÷05 MPa.

5. Conclusions

The calculus method of the sonic generator was elaborated.
The acoustic research of the sonic generator shows that the acoustic intensity depends on the resonator internal diameter. The acoustic intensity decreases with increasing inner diameter of the resonator, so the highest intensity is obtained for the lowest value of D_R regardless of the sound propagation velocity into environment. Also, the increase of the internal resonator diameter D_R, from the value equal to the nozzle diameter $D_R = D_a$, increases the sound intensity I.
On the other hand, increasing the depth l_R at D_R =const., Δ_R=const. and n=const., the sound intensity falls lower.
The geometry calculus showed the dependence of the gas mass flow on the sectional area of the nozzle exit. The gas mass flow rate increases with the sectional area of the nozzle exit by 100% regardless of the gas temperature.
The sonic generator function is based on a source of compressed air or another gas. Thus, the supersonic jet of air from the nozzle, after interaction with the cavity resonator loses stability and delivers high-frequency shock waves.

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