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INTRODUCTORY INVESTIGATION OF A LIQUID FUEL COMBUSTION NOISE

Summary. In order to determine the combustion noise of atomized liquid fuel, there is derived the formula for the acoustic pressure in a far field. This formula shows the role of the mean droplet diameter of atomized fuel. Theoretical dependence is confirmed qualitatively by means of the experimental results, which are presented on the diagrams.

1. Introduction

With developing technique of liquid fuel combustion more and more attention is paid to the combustion noise. The operations aim at reducing the noise and are worked in order to improve the performance and recently more and more to protect the environment against the excessive noise. The literature on the noise of heterogenous combustion of liquid fuel is not much extensive. There is for instant the consideration [3] of laminar combustion of single droplet as a basic problem. Experimentaly the gas turbine burners [6] were investigated and the influence of quality of used fuel, burner capacity and some other parameters, were taken into account. On the base of experimental results there was analysed [2] the phenomenon of a noise generation at combustion of heavy oil. A lot of problems connected with the noise of liquid fuel combustion is left to explain.

The present paper takes the introductory attempt for the theoretical and experimental determination of an influence of the comminution degree of liquid fuel on the quality of combustion noise emited.

2. Theoretical dependences

The considerations carried out in the present paper are based on the dependence determining the quantity of acoustic pressure p_l in the distance l from the monopol source of sound spreading out sphericaly in the medium of density ϱ_o, [7]

$$p_l = \frac{\varrho_o}{4\pi l}\frac{d^2V}{d\tau^2} \tag{1}$$

The formula (1) shows, that the quantity p_i is dependent on the second order differential of characteristic volume V, which when changing in time, results the generation of sound wave.

This general dependence (1) one can correspondently interpretate also for the case of combustion of an atomized liquid fuel, considered as a collection of droplets for which the diameters D are determined for example by the equation of a Rosin - Rammler distribution, [5]

$$R(D) = \exp - \left(\frac{D}{\bar{D}}\right)^m \tag{2}$$

The quantities $\bar{D}$ and m are the parameters of this distribution and $\bar{D}$ is the mean droplet diameter for which R = 0,368. The quantity R is the gramme ratio of the mass of droplets of a diameter larger than D to the mass of all droplets.

The quantity V is the difference between the volume of the combustion products generated and the volume of an oxygen carrier (e.g. air) taking a part in combustion. The differential in equation (1) one can express, for a single droplet, as follows, [3]

$$\frac{d^2V}{d\tau^2} = \frac{\pi}{6} \alpha k \rho_f \frac{d^2}{d\tau^2} (D^3) \tag{3}$$

where

ρ_f - density of liquid fuel,

α - gramme ratio of amounts of the exygen carrier and the fuel taking part in combustion, $(\alpha \gg 1)$,

and

$$k = \left[\frac{1}{\rho_c} \left(\frac{1}{\alpha} + 1\right) - \frac{1}{\alpha \rho_f} - \frac{1}{\rho}\right] \approx \frac{1}{\rho_c} - \frac{1}{\rho} \tag{4}$$

where

ρ_c, ρ - density of combustion products and oxygen carrier correspondently, $(\rho \ll \rho_f)$.

The acoustic pressure p of sound for a number n of the monopol sound sources of an individual course of $\frac{d^2V}{d\tau^2}$ is the sum of acoustic pressure for particular sources, [1]

$$p = \sum_{i=1}^{n} p_i \qquad i = 1, \dots, n \tag{5}$$

The burning jet of an atomized liquid fuel can be treated as a collection of monopol sound sources and if considered them as all being in far field, one can use (1) and (3) in (5)

$$p = \frac{\varrho_o \varrho_f \alpha k}{24\ l} \sum_{i=1}^{n} \frac{d^2}{d\tau^2} (D_i^3) \tag{6}$$

Assuming for burning droplet the linear change of its square diameter in time, as well as taking into account, by means of a probability function P, the lack of simultaneity of burning of droplet within the jet, one can write, [4]

$$\frac{d(D_i^2)}{d\tau} = P(D_i)\ k_c \tag{7}$$

where

k_c - combustion constant characteristic for a given fuel.

The function P changes in limits of 0,5 and 1. The value 1 corresponds to the droplets of very large or very small diameter D_i.

Using (7) at calculation of the differential which appears in (6) and taking into account the total mass G_f of burning droplets

$$G_f = \frac{\pi}{6} \varrho_f \sum_{i=1}^{n} (D_i^3) \tag{8}$$

and also using the droplet mean volumetric diameter $\bar{D}_V$ resulting from the dependence, [5]

$$n\ \bar{D}_V^3 = \sum_{i=1}^{n} (D_i^3) \tag{9}$$

one can receive from (6) the following formula

$$p = \frac{\alpha k\ \varrho_o\ G_f}{32\ l\ \bar{D}_V^4} P^2\ k_c^2 \tag{10}$$

The formula (10) shows for example, that the quantity of acoustic pressure, deciding about the noise of burning jet of atomized liquid fuel, is inversely proportional to the droplet mean volume diameter in the fourth power.

The connecting of the derived dependence (10) with the equation (2) is possible by using the proper formula taking into account the function gamma Γ, [5]

$$\bar{D}_V = \frac{\bar{D}}{\sqrt[3]{\Gamma(1 - \frac{3}{m})}} \tag{11}$$

The liquid fuel comminution which is described by the equation (2) one can connect with the burning jet noise resulting from the formula (10), in which the diameter $\bar{D}_V$ can be expressed by formula (11).

3. Experimental investigations

The experiments were carried out in the pilot installation presented in the Figure 1, which shows the size (in mm) of the combustion chamber, location of burner and the microphone placed against the inspection hole. The liquid fuel was atomized by means of a compressed air of amount not larger than 1 SCM/(kg of fuel).

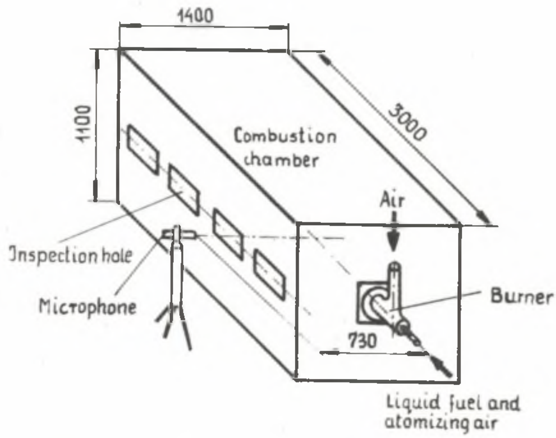

Fig. 1. The investigation stand

The experimental results of the total sound pressure level L are presented in the Figure 2 for the cases of combustion of a heavy oil (line I, II, III) and of a lighter oil (IV). Particular lines correspond to the investigation, at which there was changed only the compressed air pressure p_a. Another parameters during particular investigations were kept constant. The fuel flow rate had the value correspondently 0.68, 0.37, 0.68 and 0.66 kg/s and the excess air ratios were 1,2, 1.5, 1,? and 1.3 correspondently.

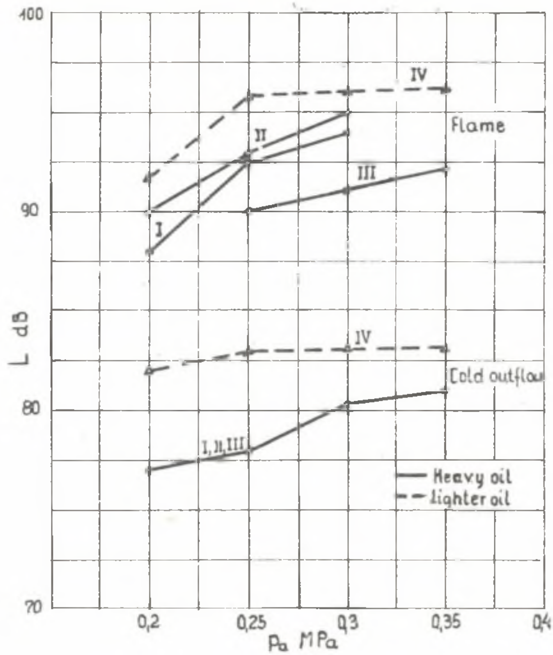

Fig. 2. The total sound pressure level versus an atomizing air pressure

There also were carried out some measurements of the sound pressure level L_f depending on a frequency f. For example, the noise spectra are presented for the cold substrates outflow and for burning jet, which were performed during investigation III at the compressed air pressure of 0,3 and 0,2 MPa (Fig. 3) and during investigation IV at the compressed air pressure of 0,35 and 0,2 MPa (Fig. 4).

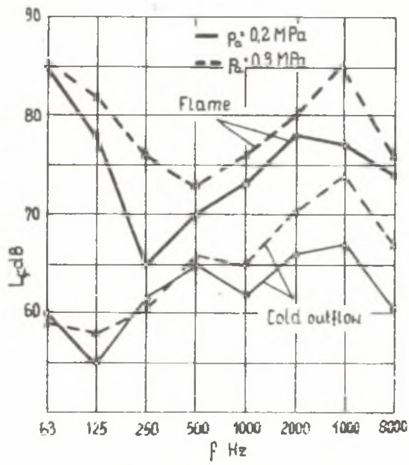

Fig. 3. The noise spectrum for atomization of heavy oil

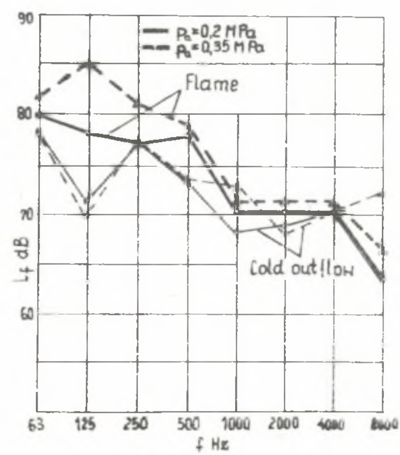

Fig. 4. The noise spectrum for atomization of lighter oil

4. Conclusions

It results from the Figure 2 that the increase of atomizing air pressure causes an increase of the sound pressure level of the flame and at the cold substrates outflow. In general, the increase of a sound pressure level caused by the increase of an atomizing air pressure is considerably larger than the increase of a sound pressure level of a cold substrates outflow.

The formula (10) as well as the experiments show that the more comminuted fuel, (it means the smaller $\bar{D}_v$ which relates to the larger p_a), the larger sound pressure level.

The analysis of the noise spectra allows to state (e.g. Fig. 3 and 4), that the larger increment of sound pressure level caused by the increase of the atomizing air pressure appears for the high frequencies for the cold substrates outflow and for the low frequencies for a flame.

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WSTĘPNE BADANIA HAŁASU SPALANIA PALIW CIEKŁYCH

S t r e s z c z e n i e

Celem określenia hałasu spalania rozpylonego paliwa ciekłego wyprowadzono wzór na wartość ciśnienia akustycznego w dalekim polu. Ze wzoru tego wynika znaczenie średniej średnicy kropel rozpylonego paliwa. Zależność teoretyczną potwierdzono jakościowo za pomocą doświadczeń,których wyniki przedstawiono na wykresach.

ПРЕДВАРИТЕЛЬНЫЕ ИССЛЕДОВАНИЯ ШУМА ГОРЕНИЯ ЖИДКИХ ТОПЛИВ

Р е з ю м е

Целью определения шума горения разпылённого жидкого топлива представленный вывод формулы значения звукового давления в дальной области. Формула эта представляет влияние среднего диаметра капли разпылённого топлива. Теоретическая зависимость качественно квитированая экспериментами, которых результаты представлены на диаграмах.