# Pulsating Combustion Effects in the Diffusion Turbulent Flames Structure

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## 1 Summary

Pulsating combustion (P.C.) is an interesting technique to control combustion conditions for several industrial applications. It has received attention in current research due the indications that application in energy generation can offer several advantages, such as: fuel economy, low pollutants emissions, and increase heat transfer by convection, [1], [3], [4], [5], [7]. The acoustic actuation enhances the rate between fuel and air, increasing turbulence in the flame region, and decreasing CO, soot and UHC emissions, which depend on the local mixture [6]. Therefore, it is still necessary to study the complex parameters and phenomena of this process in order to be user in large scale. The present paper shows experimental results for a natural gas circular jet burner [2], [8] operating in pulsating and non-pulsating modes. The presence of an acoustic actuation changes drastically the flame structure.
1) Considerable amplitudes of oscillation could be reached at burner natural frequencies, but a hydrogen pilot flame is necessary to hold the flame close to burner 2) the premixed characteristics are established in some flame regions where the acoustic field is more intense; 3) the increase on oscillation amplitude reduces the flame length; 4) the pulsations change the axial and radial evolutions of hydrocarbon combustion, $O_2$ distribution in the flame region, and $NO_x$ formation mechanism; 5) it promotes changes in the temperature field; 6) by flame tomography technique, it notes the acoustic field promote $C_2$, CH radicals and soot's luminous intensity decrease and change their distribution in the flame. There is a soot's formation decreases drastically in the flame.

## 2 Experimental Set-up

The burner used here was that developed by TUDelft, known as the Delft burner [2], [8]. It consists of a central fuel jet surrounded by a concentric co-flow of air (primary air flow) with twelve small pilot flames, to stabilize the flame on the burner. In this paper, the original burner was increased of the 96 cm to adapt the acoustic system: loudspeaker and decoupling chamber, necessary to acoustically excite the air and to maintain the open-open tube

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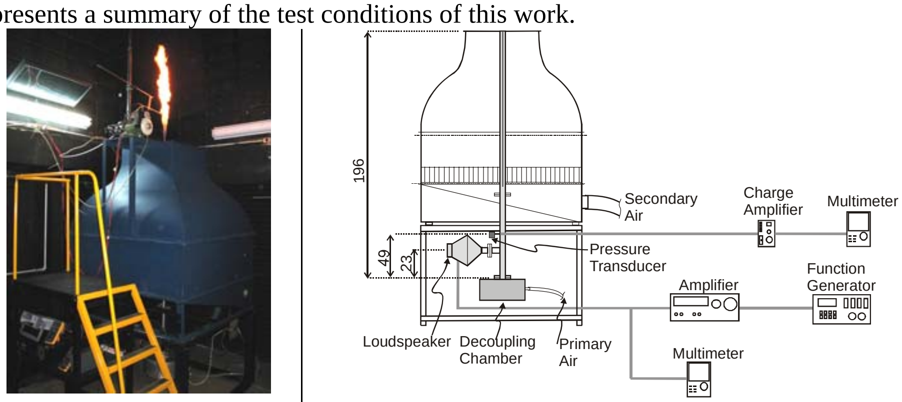
The fuel of the principal flame is the natural gas and an acetylene/hydrogen/air mixtures is used in the pilot flame. Figure 1 shows (a) the experimental set-up, and (b) the experimental set-up scheme with acoustic system. Table 1 presents a summary of the test conditions of this work.




The acoustic actuation was produced by a function generator a charge amplifier and a loudspeaker

**(a)** **(b)**

**Figure 1 –** (a) Delft burner with acoustic system; (b) Experimental set-up with acoustic system (cm dimensions).

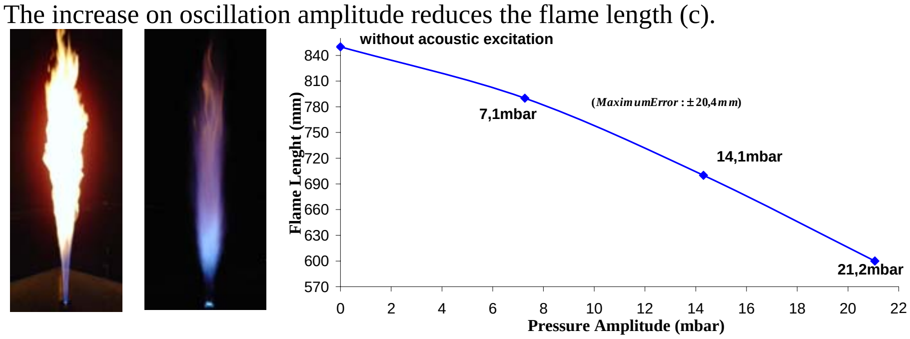
**Table 1**. Test Conditions.

| *Jet* | *Natural Gas (g/h)* | *Primary Air (kg/h)* | *Acetylene (g/h)* | *Hydrogen (g/h)* | *Pilot Air (g/h)* |
|---|---|---|---|---|---|
| I | 756 | 15,3 | 1,63 | 4,49 | 73,85 |
| II | 1044 | 18,2 | 2,25 | 6,19 | 101,84 |

The study of the influence of the acoustic field in the flame, was conducted by point measurements in the radial position, to study the CO, $CO_2$, $O_2$ and $NO_x$ concentrations, the temperature and the distribution of the $C_2$, CH radicals and soot in 50, 150 and 250mm axial positions at the flame. The gases were captured from flame by cooled probe and then led to analyzers. The temperature was measured by a thin wire thermocouple across the flame. Radicals and soot were studied by Tomography Reconstruction [9].

# 3 Results and discussion

Harmonic frequencies corresponding to the three first harmonics of gas injector were calculated theoretically and determined experimentally: 97 Hz, 181 Hz, and 282 Hz. The airflow and the equipment inside the burner did not change its natural frequencies. The acoustic actuation changes drastically the flame structure, as shown in Figure 2. The increase on oscillation amplitude changes the color of a typically non-premixed flame to (a) a blue color, showing the transformation (typical of a natural gas piloted jet burner) in a premixed flame, by the acoustic field. The increase on oscillation amplitude reduces the flame length (c).




The point where the CO concentration reached the gas analyzer sensibility (0,05%) was assumed the flame end.

**(a).** **(b)** **(c)**

**Figure 2** – Flame (a) without acoustic actuation; (b) with acoustic actuation; (c) length with acoustic excitation.

Figure 3 presents the (a) CO (b) $CO_2$, (c) $O_2$ and (d) NOx concentrations ([ ]) and (e) temperature in the radial and axial positions Jet I, for 181Hz and 21mbar with and without the acoustic field.

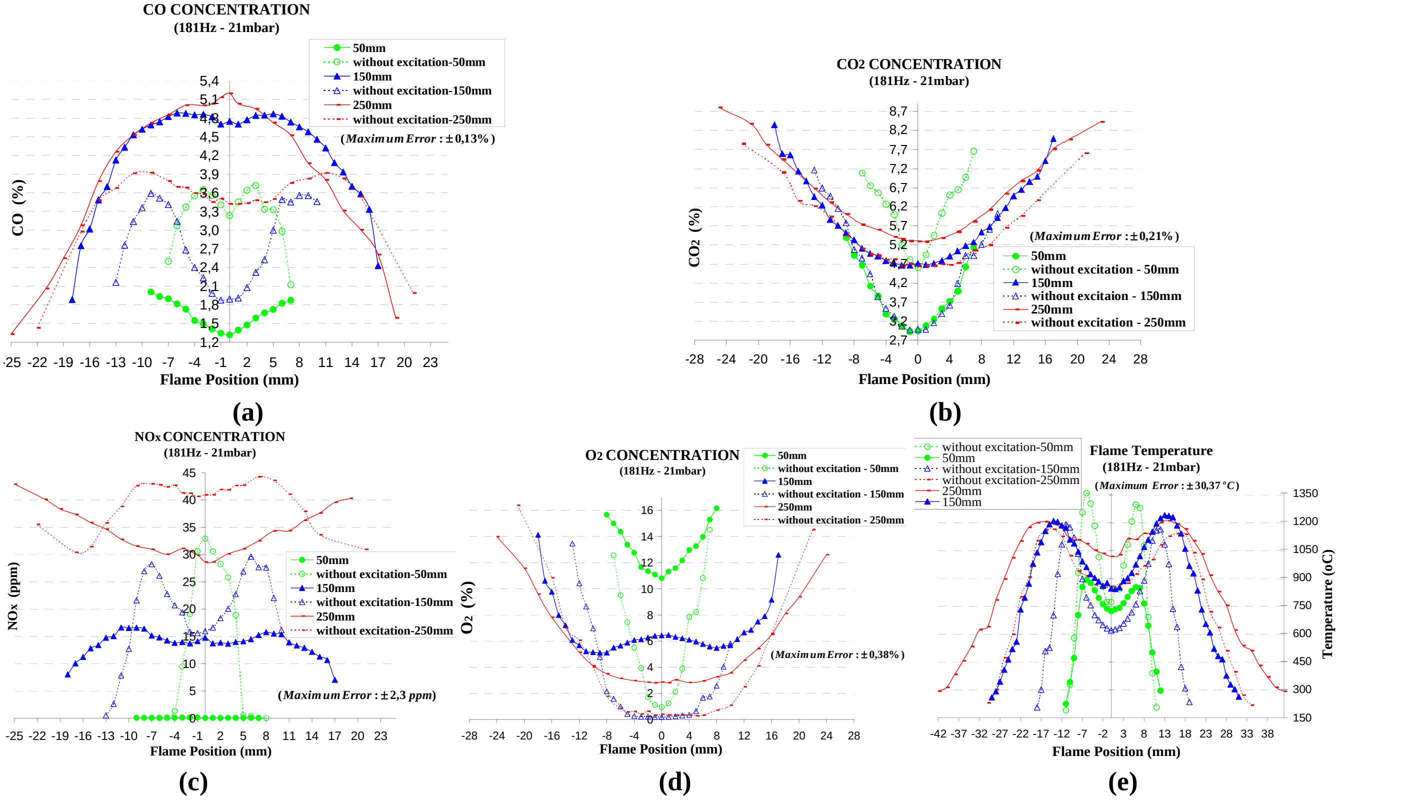



**Figure 3** – CO, $CO_2$, $NO_x$ and $O_2$ radial distribution in volumetric percentage (corrected measurements to $O_2$ 3%) and temperature in Jet I.

There was [$O_2$] increase (d), and then it was necessary to correct the combustion gas concentration to $O_2$ 3%. In 150 and 250mm there is a [CO] increase (a) with P.C., but up to the axial position of 250 mm, there was not conversion to $CO_2$, with or without P.C. Measurements made to obtain the flame length shows this tendency. There is [$CO_2$] increase (b) with P.C, but in 50mm [$CO_2$] decrease with P.C. because residence time to convert CO in $CO_2$. There is [$NO_x$] decrease (c) with P.C in 50mm. It happened because in this position the temperature decreases (e) and then the thermal $NO_x$ is reduced. There is in this region $O_2$ increase (d) due acoustic field near. But the temperature increases in 150 and 250mm with P.C., because the local combustion reactions are more efficient with the acoustic field.

By using interference filter of 800 nm in Jet I, Figure 4 presents soot projected images and its tomography reconstruction (T. R.) in 250mm for case: without the acoustic field (a), (b) and with the acoustic field for 181Hz/21mbar (c, (d), respectively.

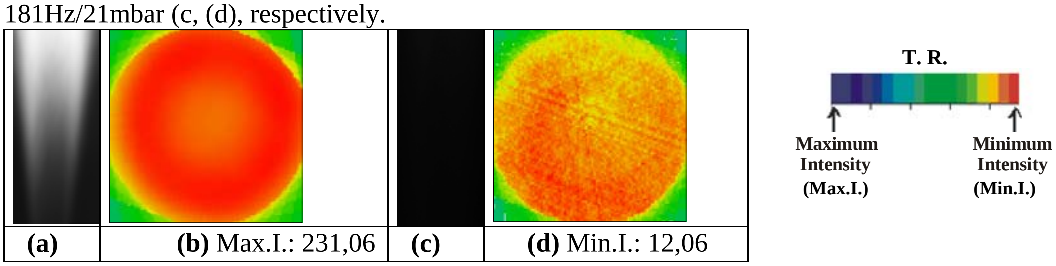



**Figure 4 -** Soot projected images and its T.R. without P.C. (a), (b) and with P.C. in 181Hz/21mbar

Acoustic field encourages luminous intensity decrease. There is a probability that it promotes a better mixture between the fuel and oxidant.

## 4 Conclusion

This paper describes an experimental research about the influence of the acoustic fields on the combustion process of a natural gas turbulent jet diffusion flame. The results show drastic changes in the premixed regions of the flame structure, reduction of flame length, flame's bluish color, alterations of the $NO_x$ formation. There are changes in the $C_2$, CH radicals and soot space distributions and in their luminous intensity.

## 5 References

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