TEMPERATURE MEASUREMENT USING A FINE WIRE COMPENSED THERMOMETRY TECHNIQUE IN LEAN PREMIXED FLAME

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An experimental procedure, with post processing in order to measure the temperature fields in premixed turbulent flame, is presented. Temperature profile measurements were performed on lean turbulent premixed flame CH_4-air with an equivalence ratio φ = 0,6. The Fine Wire Compensed Thermometry (FWCT) technique is used. The use of fine wire thermocouples for a temporal resolution of the measurement in high temperature requires specific treatment of these values. These losses are estimated by one of the proposed models, which makes it possible to correct the difference between thermocouple temperature and gas temperature. Morever, the catalytic effect was incorporated to the final balance equation. The flame temperature and its fluctuations are treated and analyzed by digital processing algorithms. Measurements validation made by the FWCT technique, with optical measurement methods (Rayleigh scattering), shows a good agreement.

1. Introduction

The techniques for measuring the flames temperature fall into two categories: intrusive and non-intrusive technique. In our study, the measurement technique by B type thermocouple - FWCT (Fine Wire Compensated Thermocouples) - has been used. This technique is very sensitive to the conditions of temperature and flow velocity. These temperature conditions (velocity and chemical composition of the flow) can affect the physical characteristics of thermocouple materials hence the catalytic effect.

2. Experimental set up and Post Processing

In this study thermocouple type B was used, figure 1 shows this type of thermocouple. The weld heat of these thermocouples is realized between two wires of small-diameter (10 ÷ 500 μ m) to increase the temporal and spatial resolution of the measurement. The wires are fixed to pins more resistant to flow. Each pin is made of the same alloy as the corresponding part of the wire. When the temperature of the environment is high, the radiant loss becomes important, thus the temperature measured by the hot junction is less than the environment temperature. These losses have been estimated and discussed by many authors, (Paranthoën & Lecordier, [1996], Larras [2000], Ikegami & al. [2003], Moss & al., [2007]. Their estimates by one model, can correct the difference between thermocouple temperature and real gas temperature. In addition to that, the temporal resolution of the signal thermocouple is a very important parameter for turbulent flow study. The use of this technique requires an accurate knowledge of heat transfer between the thermocouple and the flow, the physical characteristics of the probe materials, and its geometrical dimensions. That compensation is needed for two reasons: The first relates to the temperature displayed by a thermocouple, which is not necessarily the environment gas temperature, as a result of radiation losses from high temperature thermocouples. For the gas temperature, it is necessary to estimate and correct those losses. The second reason relates to the time response of the thermocouple, which is limited by the inertia of two wires. The digital compensation is then used.

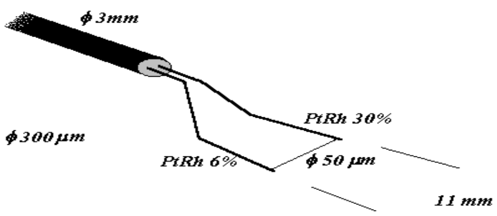

Figure 1. Thermocouple

Knowing the time response characteristic of the thermocouple, ie time constants τ, we can reconstruct the original temperature signal. The method, which takes into account the convective and radiative effects, is directly extracted from the energy balance. It is determined by introducing the gas temperature and the convective time constant.

$$\frac{\partial T_c}{\partial t} = \frac{4Nu\lambda_g}{d^2 \rho c_p}\left(T_g(t) - T_c(t)\right) \quad (1) \qquad \tau_{cv} = \frac{d^2 \rho c_p}{4Nu\lambda_g} \quad (2)$$

$$T_g = T_c + \tau_{cv}\left(\frac{\partial T_c}{\partial t} - \frac{\varepsilon_c \varepsilon_{pa}}{1-(1-\varepsilon_c)\cdot(1-\varepsilon_{pa})}\cdot\frac{4\sigma\left(T_c^4 - T_{pa}^4\right)}{d\rho c_p}\right) \quad (3)$$

The equation can be obtained simultaneously offsetting radiation losses and inertia. This equation is mainly a function of temperature measured by the wire and the Nusselt number. The compensation of inertia thermocouple requires an iterative process. The B type thermocouple (Pt30% Rh-Rh Pt6%) is used in the temperature range from 700 to 2000 K, where it owns good signal amplitude (about 9 μ v / K). A diameter of 50 μ m was chosen to be a good compromise between a low-inertia thermocouple and sufficient mechanical strength. The theoretical values for uncoated thermocouples were calculated from equations proposed in the literature.

3. Results

In unburned gas, fluctuations have low values. On average, they are in the range of 20 °C, ie 1.3% of the temperature of the hot gas. In areas of interaction of unburned gas with the combustion zone, one can notice that fluctuations is the highest, they are between 285 and 410 ° C (Figure 2). The results obtained using compensation were very consistent. In this figure, it is clear that the compensation of a digital signal temperature tends to accentuate the gap 1000°C. It would therefore be interesting to interpret the spatial structure characteristic fluctuations depending on their operating conditions.

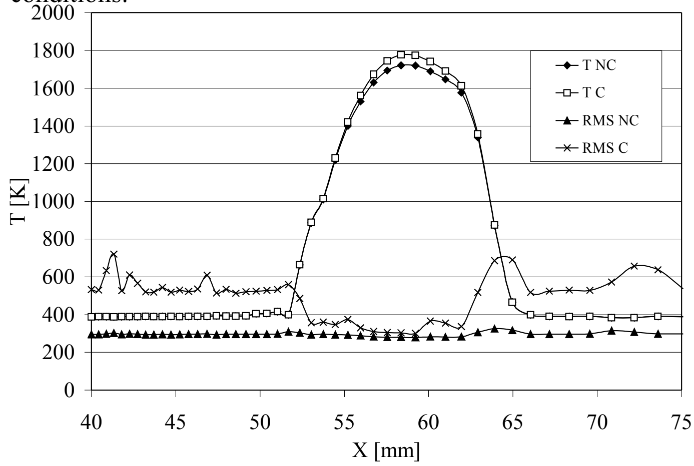

Figure 2. Profile of temperature and RMS (C: Compensed and N.C not compensed).

In figure 3, a validation of measurements made by the technique of FWCT was carried out by making a comparison with the methods of optical measurements (Rayleigh Scattering) was carried out. The results of Rayleigh Scattering are those obtained by Boukhalfa [1988]. This comparison shows a good agreement.

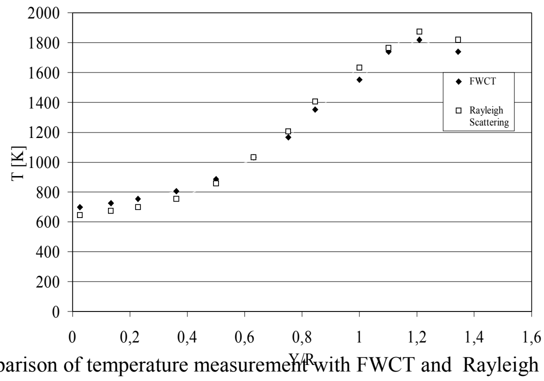

Figure 3. Comparison of temperature measurement with FWCT and Rayleigh Scattering

Conclusion

An experimental procedure with post processing was developed to determine the thermal field in premixed turbulent flames. This procedure was carried out using the Fine Wire Compensed Thermometry (FWCT) technique. The method, which takes into account the convective and radiative effects, is directly extracted from the energy balance. The addition of catalytic effect in the energy balance takes good results. The comparison between FWCT and Rayleigh Scattering results, shows a good agreement.

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