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Two-dimensional precision measurement of Methane-Air premixed flame using CT-TDLAS

M. G. Jeon[1], J. W. Hong[2], Y. Deguchi[3] and D. H. Doh[1*]

[1]Division of Mechanical Eng., Korea Maritime & Ocean University, Busan, Republic of Korea
[2]Division of Refrigeration & Air-conditioning Eng., Graduate School of Korea Maritime & Ocean University, Busan, Republic of Korea
[3]Division of Advanced Technology and Science, Graduate School of Tokushima University, Tokushima, Japan

[*]Corresponding author: doh@kmou.ac.kr

1. Introduction

Recently, the control environment of the manufacturing process is a very important factor in the real industry. It can improve the quality of the product by adjusting various gases in the manufacturing process. To solve this problem, the temperature and concentration of gases can be measured simultaneously by TDLAS (tunable diode laser absorption spectroscopy) [1]. Among the more advanced technologies, CT-TDLAS (computed tomography-tunable diode laser absorption spectroscopy) is the most important technique for measuring the distributions of temperature and concentration across the 2-dimensional planes [2-3]. However, supplying gases or real flame are not uniform. In this study, suggest a 2-dimensional measurement of irregular flow or exhaust gases.

In this study, CT-TDLAS has been adopted for the measurement of temperature distribution at a cross-section of Methane-Air premixed flame. Used the SMART (simultaneous multiplicative algebraic reconstruction technique) algorithm among the CT algorithms. The absorption spectra of H_2O vapor near the wavelength 1388nm were used for signal reconstructions. In the CT process, it is important to adopt the initial values for the temperatures at all grids. Therefore, CSLOS (corrective summation of line of sight) method has been adopted. The temperatures obtained by using CT-TDLAS technique were compared with those obtained by thermocouples.

2. Theory and methods

When irradiated with laser light to the measurement target gas, state changes the gas molecules absorb light of certain wavelengths. TDLAS used such kind of properties. It is based on Lambert Beer's law. This method utilizes the intensity ratio of incident light and transmitted light for the laser, such as can be measured the temperature and concentration of target gas. This relationship can be explained as shown in Eq. (1).

$$I_\lambda / I_{\lambda 0} = exp\{-A_\lambda\} = exp\left\{-\sum_i \left(n_i L \sum_j S_{i,j}(T) G_{Vi,j} \right)\right\} \tag{1}$$

Here, $I_{\lambda 0}$ is the incident light intensity, I_λ is the transmitted light intensity, A_λ is the absorbance, n_i is the number density of species i, L is the path length, $S_{i,j}$ is the temperature dependent absorption line strength of the absorption line j, and $G_{vi,j}$ is the line broadening function.

Several types CT algorithms to reconstruct data form of the tomography system. In this study used the SMART algorithm for 2-dimensional calculate. It can be shown following Eq. (2). It has been used for accelerating the convergence speed for the calculation of a large amount of data.

$$\alpha_{\lambda,i}(x,y,z)^{k+1} = \alpha_{\lambda,i}(x,y,z)^k \cdot exp\left(\sum_{j=1}^{J} \frac{L_{ij}}{\sum_{i=1}^{I} L_{ij}} \cdot log \frac{A_{\lambda,j}(x,y,z)}{\sum_{i=1}^{I} \alpha_{\lambda,i}(x,y,z) \cdot L_{ij}} \right) \tag{2}$$

Here, α is the absorption coefficients.

Performing the iterative calculation which was used for minimizing the differences between the real flame absorbance and the CT reconstruct absorbance using the MSE (Mean Squared Error) equation as shown in Eq. (3).

$$Error = \sum \left\{ (A_{\lambda,j})_{theory} - (A_{\lambda,j})_{experimental} \right\}^2 \tag{3}$$

3. Experimental setup

Fig. 1 shows the experimental setup. The absorption spectra of H_2O in a flame burner have been measured. The burner has a double-tube structure composed of a sintered bronze filter and external piping. Methane (CH_4) gas has been used as fuel and it has been mixed with air supplied through a sintered bronze filter. The 16 path CT-TDLAS measurement cells as shown in Fig. 2 have been set at the position 95mm above the burner. The experimental parameters are summarized in Table 1.

A DFB (distributed feedback) diode laser (NTT Electronics Co., NLK1E5GAAA) of which working wavelength is 1388 nm with a scanning range of 0.6 nm was used to get H_2O gas absorption spectra. In order to measure simultaneous 2-dimensional absorption spectra a 16-path cell as shown in Fig. 2 has been used.

Table 1 Table caption must be centered

	CH_4 (L/min)	Dry air (L/min)	Surrounding Air (L/min)	Equivalent ratio
Methane-Air premixed flame	0.74	3.4	96.6	2.08

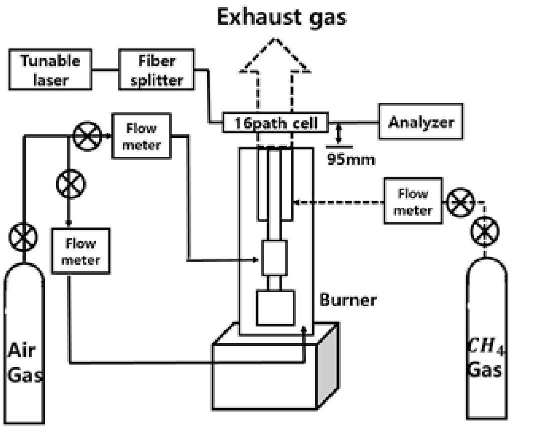

Fig.1 Experimental apparatus for 2D temperature measurement in flame burner using CT-TDLAS

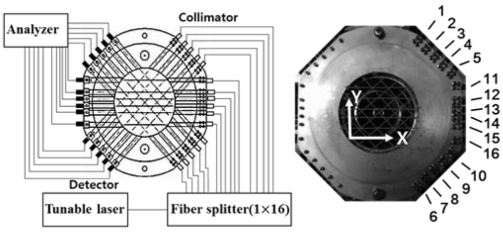

Fig.2 16-paths CT-TDLAS measurement cell

4. Results and discussion

Fig. 3 show the result obtained by the CT-TDLAS, in which the SMART algorithm has been adopted. It can be seen that the temperature distribution is similar to the distribution measured by the thermocouple as shown in Fig. 4. Therefore, revealing that the temperature calculated by the current approach of CT-TDLAS is validated.

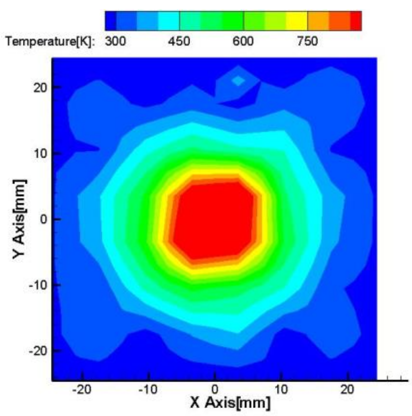

Fig.3 Temperature distribution reconstructed by SMART algorithm

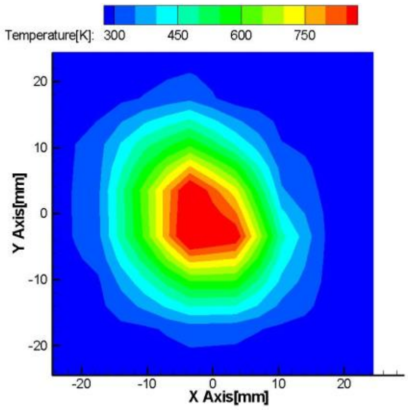

Fig.4 Temperature distribution measured by thermocouple

5. Conclusion

Measurements for temperature distribution have been performed by a thermocouple. The temperature distribution has been reconstructed by the SMART algorithm and the results have been compared with those by the thermocouple. It was confirmed that there was no significant difference in the measured temperature values from the two methods. As results, CT-TDLAS technique will serve as a suitable measurement method for temperature measurement of irregular flow or exhaust gases.

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