Burning Velocities of Alternative Gaseous Fuels at Elevated Temperature and Pressure

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A new range of alternative fuels are being considered for use in industrial gas turbines. Such fuels can be divided into two groups: those containing CH4 diluted with CO2 in bio-derived fuels, and those containing CH4 enriched with H2. The study has been undertaken to investigate turbulent burning velocities of gaseous fuel mixtures at elevated temperature and pressure using the Bunsen burner method. The tests have been carried out in a Gas Turbine Research Centre (GTRC) of Cardiff University as part of a EU progamme.

Fuels tested:
100% methane
85% methane - 15% carbon dioxide
70% methane - 30% carbon dioxide
85% methane - 15% hydrogen
70% methane - 30% hydrogen

Pressure:
3 bara, 7 bara

Temperature:
473 K, 673 K

Figure 1. Gas Turbine Research Centre

METHOD

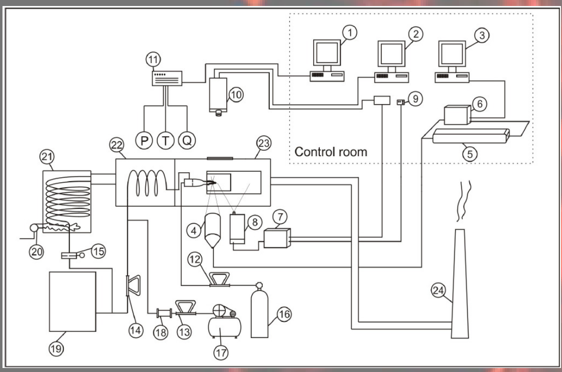

Figure 2. Experimental setup

Two different laser techniques:

- ***Laser Doppler Anemometry*** **(LDA)**
  to determine velocity and turbulence characteristics
- ***Planar laser tomography*** **(PLT)**
  to define the flame front

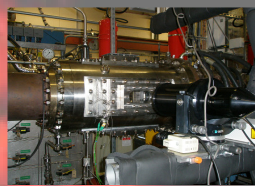

Figure 4. LDA setup

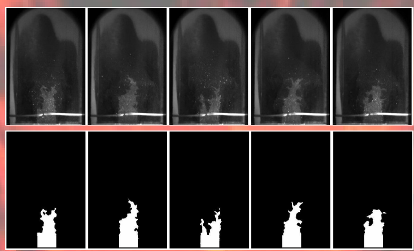

Figure 3. Raw and binary flame images

Flame surface area

$$A = \sum_{i=1}^{k} (\pi n_i w h)$$

A = 3.14 x number of pixels x pixel width x pixel height

Turbulent burning velocity

$$S_T = \frac{\dot{m}_R}{\rho_R \cdot A}$$

S_T = mass flow rate / (density x flame surface area)

Two methods for calculating the flame front area:

- ***Average Flame Shape*** - *raw images are averaged, the flame front is found and then the flame area is calculated*
- ***Average Flame Area*** - *the flame front of every single image is found, the flame area is defined and the mean flame area is calculated*

RESULTS

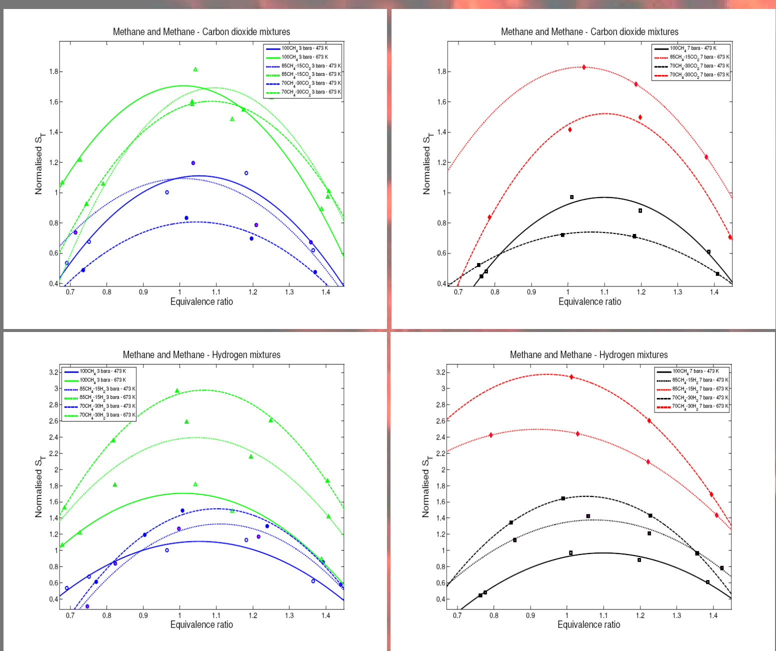

Figure 5. Normalised burning velocities of gas mixtures

CONCLUSIONS

- An alternative analysis method for turbulent flame image processing and turbulent burning velocity calculation has been proposed and applied.
- CH_4 and CH_4-CO_2 mixtures turbulent burning velocity results have been compared with Peters' and Zimont's et al. correlations and recent data of Filatyev at al. The results show reasonable agreement with Peters' predictions and Filatyev's et al. experiments.
- Increase in initial ambient gas temperature significantly increases turbulent burning velocity, while increase in ambient pressure induces a reduction. CH_4 and CH_4-CO_2 mixtures demonstrate similar trends with respect to the influence of ambient conditions.
- Even small H_2 addition increases turbulent burning velocity considerably. For lean CH_4-H_2 mixtures, an increase in temperature or pressure augments burning velocity, whereas the influence of ambient pressure is minimal for rich mixtures.