Delft Piloted Natural Gas Turbulent Nonpremixed Flames

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ABSTRACT

The aim of the document is to provide a full description of data base of Delft piloted natural gas flames, including boundary conditions. LDA, CARS, LIF, Raman/Rayleigh/LIF and Time-resolved PLIF measurements have been performed in these flames. The burner consists of a round fuel tube (diameter 6 mm) and an annulus (inner diameter 15mm., outer diameter 45mm) for air supply. The composition of the Dutch natural gas is (in mole fractions) 81.3 % methane, 2.8 % ethane, 14.3 % nitrogen, 0.9% carbon dioxide and 0.7 % other hydrocarbons. The pilot flames are positioned at the rim between central pipe and annulus. Variations of the natural gas velocity, the primary air velocity and the primary air temperature (295 K and 675 K) resulted in six flames. One of the flames has been examined most thoroughly and will be presented in the data set.

BOUNDARY CONDITIONS

Mean velocities:
U_{fuel} = 21.9 m/s
U_{ann} = 4.4 m/s
U_{cof} = 0.3 m/s (for LDA and LIF measurements)
U_{cof} = 0 m/s (for CARS, Raman/Rayleigh/LIF and Time-resolved PLIF measurements)

All inlet streams at room temperature, 295 K

- Uniform profiles for fuel inlet
- Profiles from developed annulus flow for annulus, calculated using standard k-epsilon model with wall functions
- Uniform profiles for outer coflow

This leads to a set of profiles that are available in the data set.

MEASUREMENT TECHNIQUES

LDA:
A 2D back scatter LDA system was used. Size of the measuring volume: 0.15 x 2.1 mm.
Statistical uncertainties 1 to 1.5 % in averaged velocities, 2.5 % in rms values. The differences between ensemble averaging and residence time weighted averaging were only present (up to 3 %) in the peak maxima of the rms distributions.

LIF:
1D measurements with measuring volume depth of approximately 0.75 mm. Temporal resolution of 6 ns. Calibration has been done in a rich and a lean laminar flame from the McKenna burner. Estimated uncertainty of the averaged OH concentrationos 50 %.

CARS:
Broadband CARS thermometry has been used to measure mean temperatures and temperature PDFs. A folded BOXCARS arrangement was used resulting in an interation length of the

Stokes and pump beams of 0.9 mm. Temporal resolution: 6 ns. The accuracy of CARS temperatures is about 70-120 K in different parts of the turbulent flame. Averaged temperatures compared well with Raman-Rayleigh scattering measurements.

Raman/Rayleigh/LIF:
The measuements have been performed at Sandia National Laboratories in Livermore, USA and provide simultaneous point data on temperature and the concentration of major species (CO_2, O_2, CO, N_2, CH_4, H_2O, H_2), OH and NO and mixture fraction. The application of the Raman technique in the undiluted natural-gas flames proves to be very challenging because of the high fluorescence interference levels. The interference contributions to the recorded Raman signals are identified and subtracted using empirical correlations between the Raman signals and the signals on interference monitor channels. Because of the fluorescence interferences, the acquired Raman/Rayleigh/LIF dataset has certain limitations, the most important of which is the absence of independent CO_2 and O_2 measurements.

Time-resolved PLIF:
Sequential PLIF OH images (up to 8) in Delft piloted turbulent diffusion flames were measured, by using the ultra high repetition rate laser system and fast framing rate camera detector at the Lund Laser Centre (LLC) in Lund, Sweden. Different temporal and spatial scales of the turbulent structures could be tracked by varying the time separations between events in a recorded sequence, ranging from ~100 μs to several ms. Turbulent reactive flow phenomena could be visualised and their development tracked in time in a film like manner.

SUMMARY OF MEASUREMENTS

We have radial profiles at axial positions 50, 100, 150, 200 and 250 mm.

- mean axial velocity
- mean radial velocity
- rms-values of the axial velocity
- rms-value of the radial velocity
- the turbulent kinetic energy
- the Reynolds stress
- mean concentrations of CO_2, O_2, CO, N_2, CH_4, H_2O, H_2, OH and NO
- rms concentrations of CO_2, O_2, CO, N_2, CH_4, H_2O, H_2, OH and NO
- mixture fraction
- mean temperatures
- rms values of temperature
- 2D time sequential images of OH

The LDA measurements have also performed very close to the burner exit at axial positon of 3 mm. Also pdf's of velocities, OH-concentrations and temperature are available.

AVAILABILITY OF DATA

Please contact with Tieying Ding (Email: tieying@ws.tn.tudelft.nl) for more information.

EXISTING MODEL COMPARISONS

At the Thermal and Fluid Sciences Section of TU Delft we have modelled this flame with assumed shape pdf models as well as Monte Carlo pdf models combined with different chemical models. The flame was also calculated by several participants of the ASCE workshop [ERCDFTAC].

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