

Clean Coal Combustion: Burning Issues of Syngas Burning

Overview of the Project
Y Zhang and X Jiang

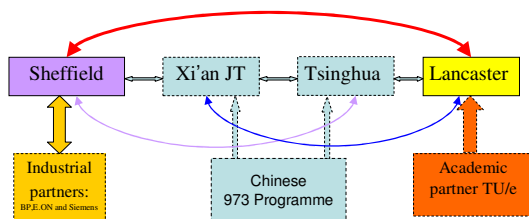
The Linkage to CCS

- To understand combustion problems associated with the development of CCS technology.
- In a wide sense combustion problems linked to fuel variability, which is in an ever increasing trend.

Research Objectives

- To investigate the **potentially damaging combustion phenomena of hydrogen enriched fuels** such as flashback and combustion instability which are caused particularly by the existence of hydrogen.
- To study the flame characteristics of hydrogen enriched fuels by further developing **innovative combustion diagnostic tools**.
- To develop **numerical methodologies** which are able to **predict the behaviours of hydrogen enriched fuels** at both the fundamental level and practical application level.
- To study flame and wall interactions of hydrogen enriched fuels and further **develop near-wall flow, heat transfer and combustion models** for unsteady reacting flows.

The Interactions Between Different Partners



Terahertz investigation of Sooty flame at high pressure: probing flame where conventional diagnostic tools would fail

Stereo Imaging and reconstruction of flame dynamics and structure

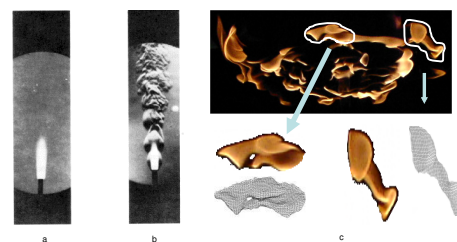
3D reconstruction

Flame/acoustic wave interactions

Industrial gas turbine combustor test rig: High speed stereo imaging of thermoacoustic instability

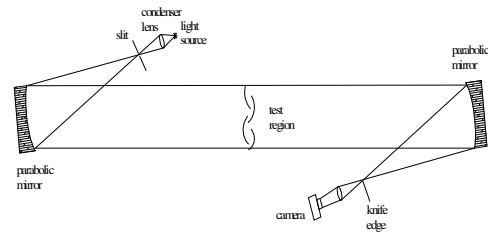
Labels in the test rig diagram: Pilot Burner, Main Burner, Double Skin Impingement Cooled Combustor, PreChamber, Radial Swirler.

High Speed Schlieren Stereo Imaging and reconstruction



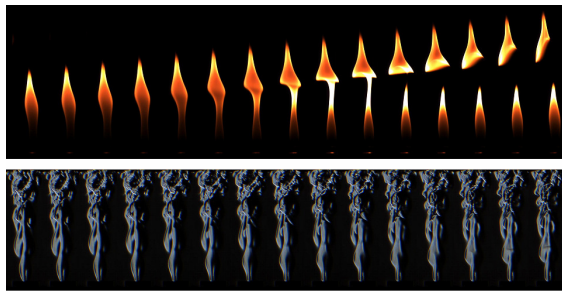
Why Schlieren

- It's a technique to make the invisible density variation visible
- Hydrogen flame is difficult to visualise by eye or camera directly
- The mixing of the hot combustion products with ambient air can be visualised
- It's convenient to compare with DNS simulation
- It's a technique worth revitalisation.

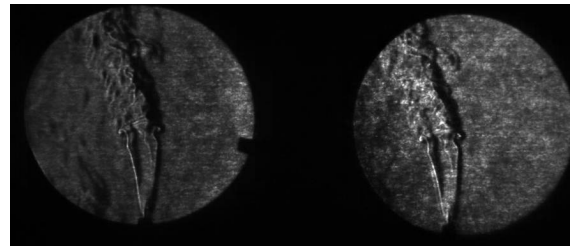


Z-type Schlieren system setup

Propane at $V=0.2$ m/s



First pair stereo of a candle flame



(Prof Xi Jiang: Overview of the Syngas Project)

Background

Advanced CFD

DNS can obtain results that are *not possible* using any other means. LES is being adopted by industry.

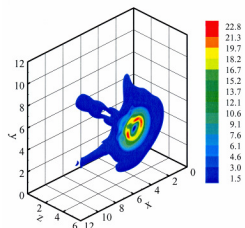
Computational Codes

DNS:

6th-order Padé scheme for spatial differentiation; 4th-order Runge-Kutta scheme for time advancement

LES:

Complex geometry; SGS combustion modelling



Develop near-wall flow and heat transfer models using a DNS database for turbulent impinging flames

Jiang, X. et al., *ASME Journal of Heat Transfer*, 2007

(Prof Xi Jiang: Overview of the Syngas Project)

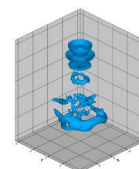


Why not commercial packages?

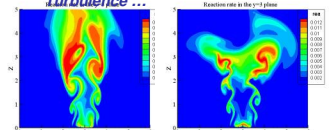
We do what commercial packages are *not* capable of – advanced ...

Why Advanced Computational Combustion (DNS/LES) ?

Experimental work?



Sample DNS/LES results (Jiang et al.): Swirl, Vortices, Details of Mixing & Turbulence ...



Planned Computational Activities

● Syngas (hydrogen-enriched fuel) combustion

Fundamental understanding: flashback; combustion instability;
flame-wall interaction

Flame unsteadiness; chemistry; buoyancy; diffusivity

● DNS & LES approach

> DNS - Flamelet Generated Manifolds (FGM) approach

Realistic representation of flame chemistry at affordable costs
Still too costly: laboratory flame only (at its very best!)

> LES: Collaboration with TU/e

Complex geometry; SGS combustion modelling