Stetsyuk, V., Soulopoulos, N., Hardalupas, Y. and Taylor, A.M.K.P.

Thermal dissipation rate measurements in swirl-stabilised flames

Original Citation

Stetsyuk, V., Soulopoulos, N., Hardalupas, Y. and Taylor, A.M.K.P. (2014) Thermal dissipation rate measurements in swirl-stabilised flames. In: Combustion Research and Applications – State of the Art, 24th September 2014, Imperial College London, Engineering Department.

Imperial College London

Combustion Research and Applications – State of the Art

Imperial College London, Engineering Department, 24 September 2014 THE COMBUSTION INSTITUTE (British Section)

Thermal dissipation rate measurements in swirl-stabilised flames

V. Stetsyuk, N. Soulopoulos, Y. Hardalupas and A.M.K.P. Taylor

Department of Mechanical Engineering,Imperial College London, South Kensington Campus, London SW7 2AZ

1. INTRODUCTION

The scalar dissipation rate $\chi \equiv D\nabla z\nabla z$ (z mixture fraction, D is diffusivity) requires modeling in essentially all models for non-premixed combustion. Peters (1983) identified the scalar dissipation rate as a characteristic diffusion time scale, imposed by the mixing field. Direct measurements of scalar dissipation rate in flames are extremely difficult. If the temperature is assumed to be a function of mixture fraction *T=f(z)* and by assuming Le=1, the relationship between the scalar dissipation and the thermal dissipation rate is according to* $\chi_T = \chi(dT/dz)$ where $\chi_T = 2\alpha(\nabla T\cdot\nabla T)$ is thermal dissipation rate.

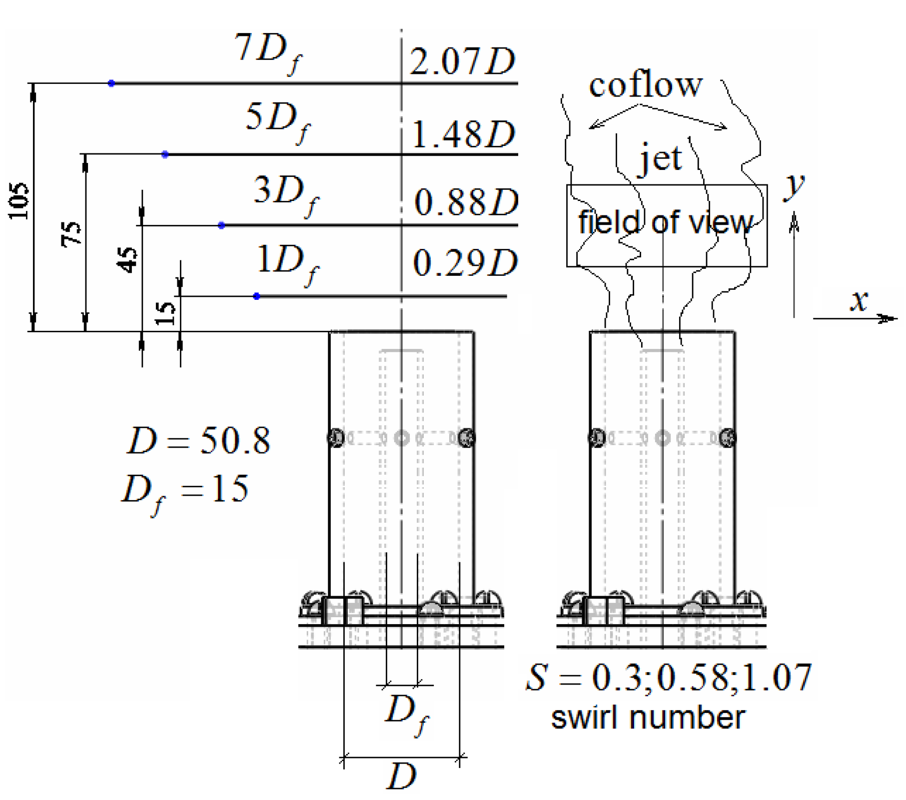
*D.A. Everest, J.F. Driscoll, W.J.A. Dahm, D.A. Feikema. Combustion and Flame 101 (1995) 58-68.

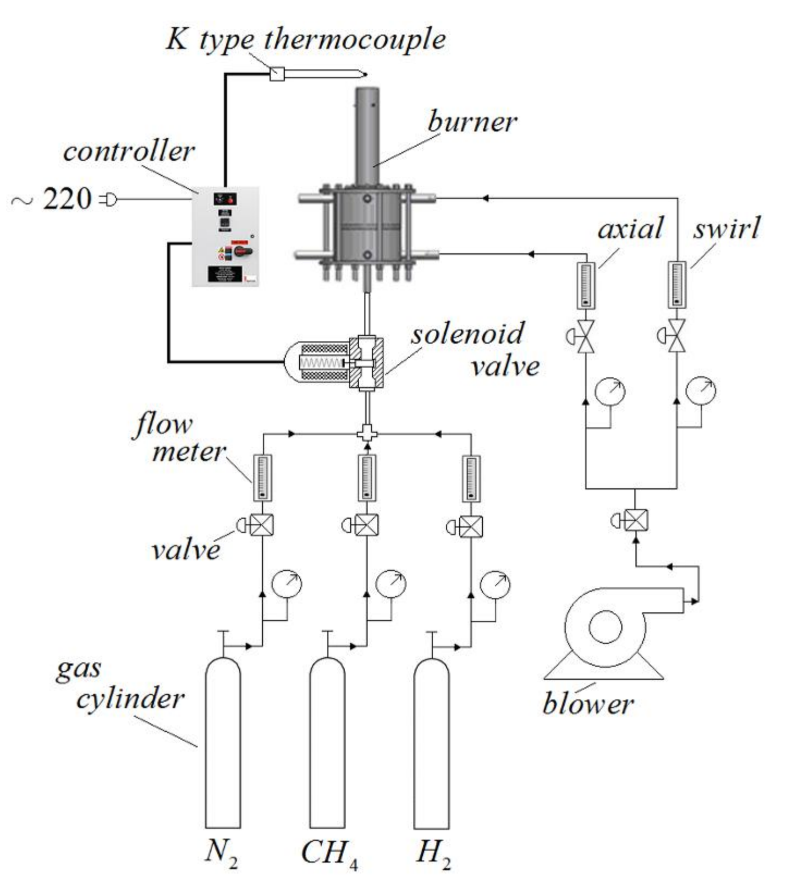
2. AIMS AND OBJECTIVES

- measurements of thermal dissipation rate in turbulent non-premixed, reacting swirling jets

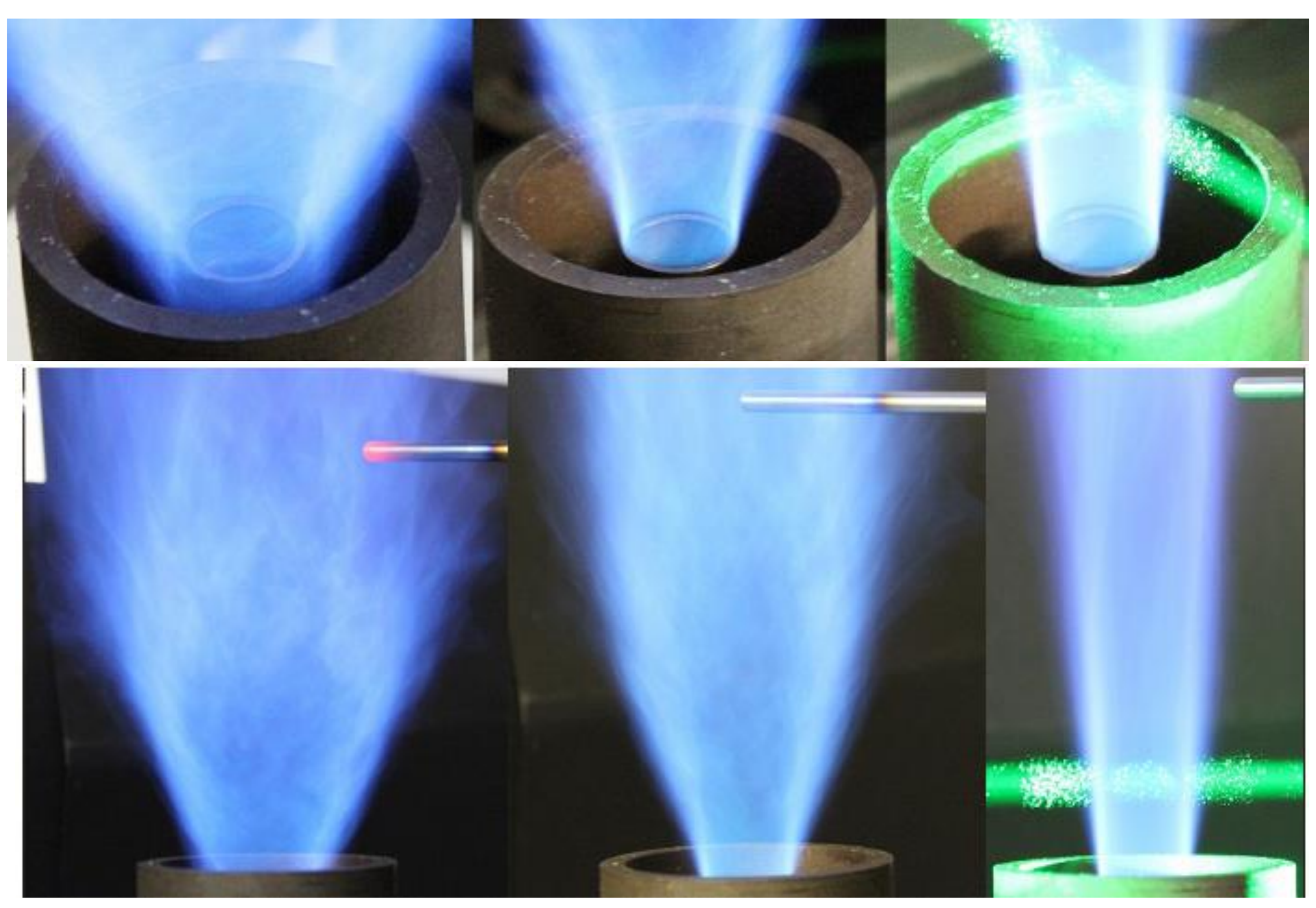
3. EXPERIMENTAL SETUP

A central fuel nozzle is surrounded by a concentric swirling air flow. The "fuel" used was a mixture with volumetric composition of 22.1%CH_4, 33.2%H_2, 44.7%N_2 (stoichiometric mixture fraction is 0.167). The combination of this fuel and the air yields a Rayleigh scattering cross section, which is constant within ±3% across the flame. Scale factor was 0.025 (mm/pixel), while the actual spatial resolution, quantified by the modulation transfer function (MTF), was 0.3(mm) at 50% MTF. The Kolmogorov scale was circa 0.15 mm. The swirl number of swirling co-flow was in the range of 0.3-1.07. The Reynolds number of swirling and jet fuel flow are 28662 and 3770 respectively. Rayleigh scattering optical diagnostic technique was used to measure temperature distribution, which then was converted into thermal dissipation rate after appropriate denosing.

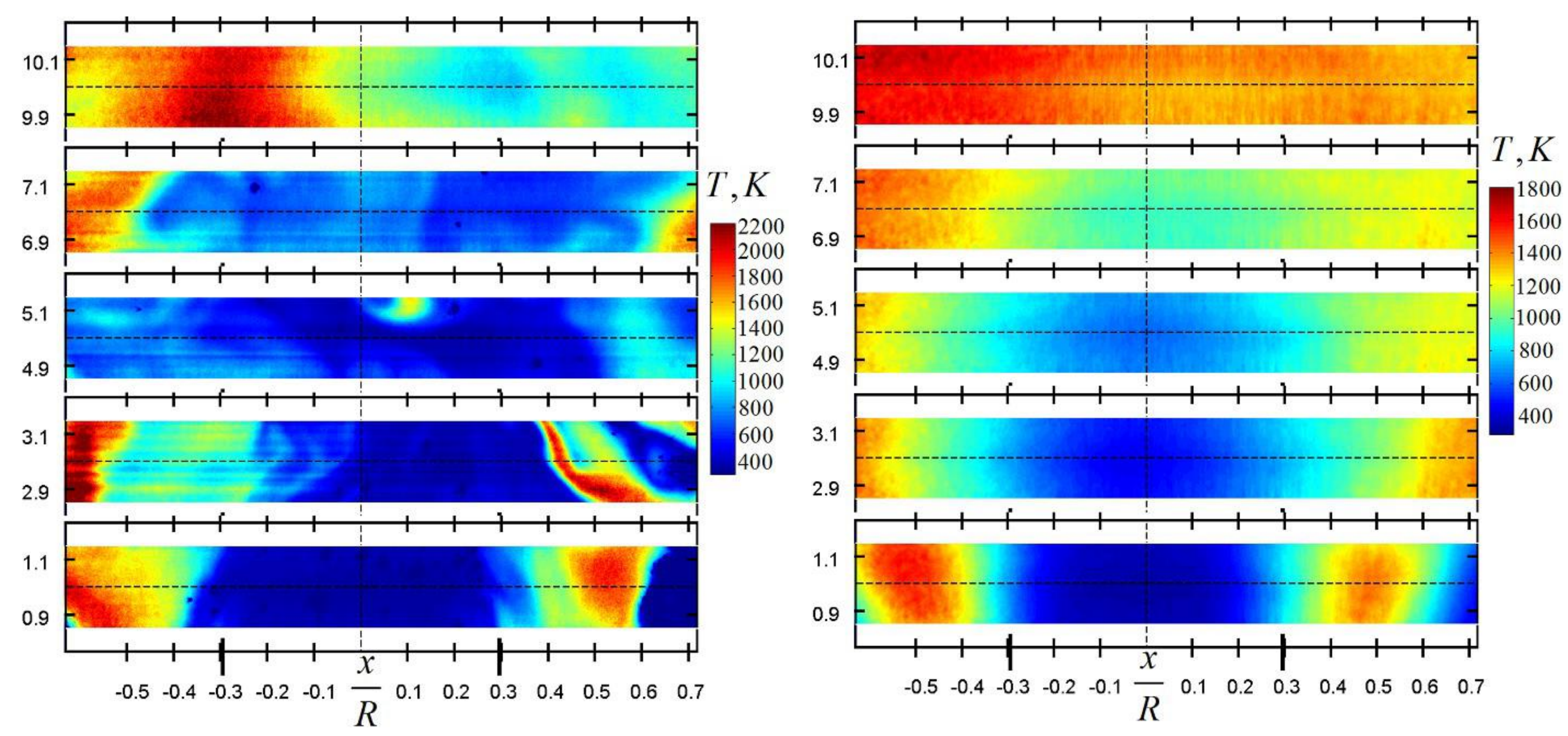




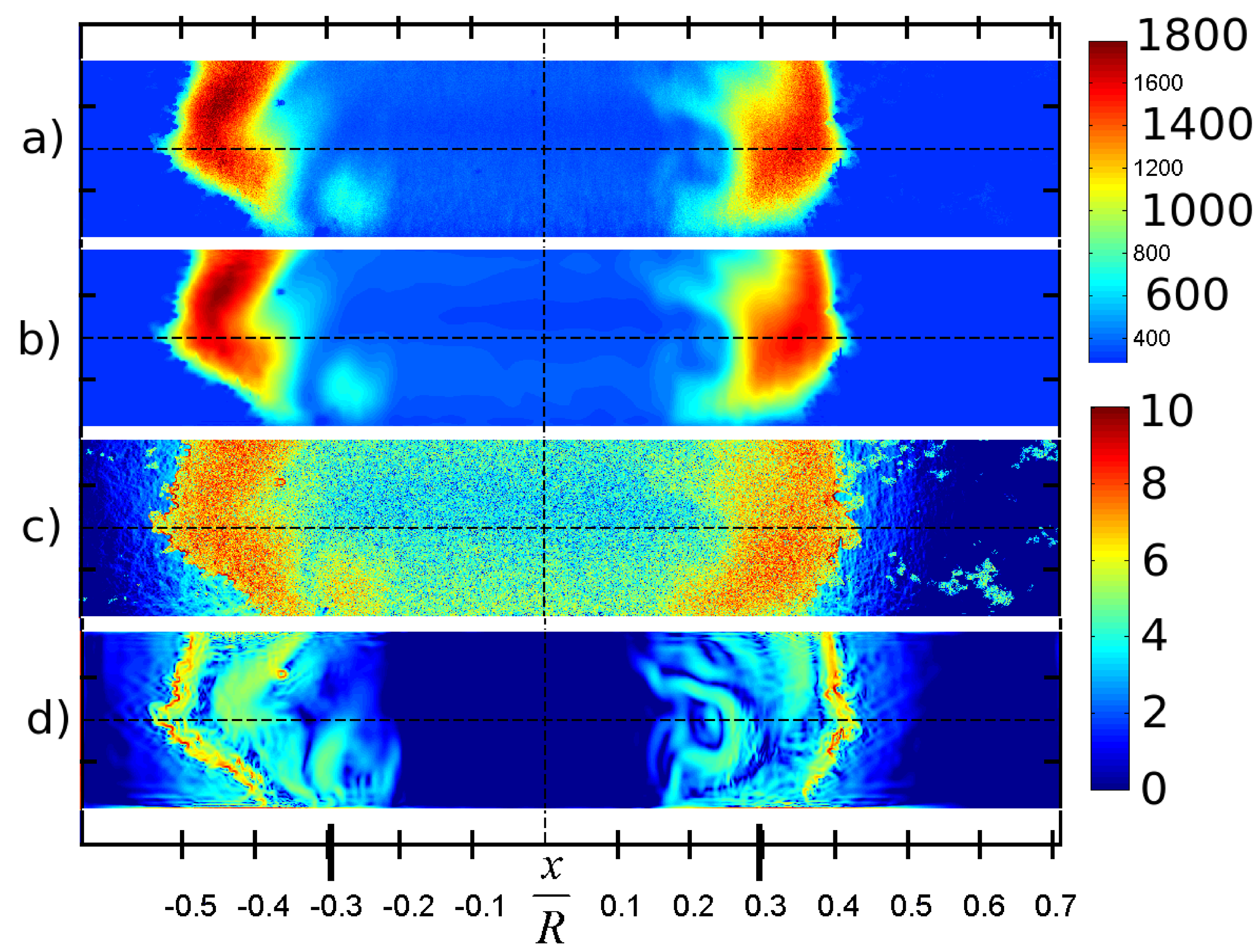
3. RESULTS



A photograph of the flame as a function of swirl number. From left to right S=1.07, 0.58 and 0.3.



Instantaneous (left) and mean (right) temperature distribution for S=0.58 at y/Df=10, 7, 5, 3, 1 (from top to bottom).



a) Raw temperature obtained from the measurements;
b) Denoised temperature
c) Logarithm of base 10 of raw thermal dissipation (without filtering)
d) Logarithm of base 10 of denoised thermal dissipation rate

5. CONCLUSIONS

- The flame was stably attached to the fuel nozzle for all S.
- Higher downstream mean temperatures for higher S.
- P.d.f. of temperature fluctuations is dependent on S.
- Lower temperature fluctuations for higher downstream distances