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ON THE STABILITY OF SOLID FUEL FLAMES: PREDICTION OF THE CHARACTERISTIC FREQUENCY BY MEANS OF LARGE EDDY SIMULATIONS

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Introduction

A solid fuel flame is often characterised by its physical parameters, such as the flame size, shape, brightness, temperature and oscillation.

The dynamic behaviour of a flame can be quantified by its different characteristic frequencies. The flicker frequency, the acoustic spectrum and the temporal turbulent coherent behaviour obtained after the instantaneous variations of the flame parameters, are often used as a reference for flame stability.

Methodology

The flame physical parameters of UKCCSRC Pilot-scale Advanced Capture Technology (PACT) 250 kW combustion test facility located in South Yorkshire, UK. (Fig. 1a) are approximated from performing a Large Eddy Simulation (LES) using the Computational Fluid Dynamics (CFD) code ANSYS FLUENT v17.2 (Fig . 1b).

LES calculations apply a low-pass spatial filter over the instantaneous Navier-Stokes equations in order to separate the larger turbulent structures that can be resolved numerically from the smaller ones, which can be modelled. The greyscale pixel intensity of the temperature contour plot inside the flame zone (Fig. 3a) is calculated at each time step (2×10^{-4} s) and registered through the computed time (Fig . 3b). The direct noise and the temporal turbulent coherent behaviour is calculated after the instantaneous pressure and velocity fluctuations acquired at different points located within the computational domain (Fig . 3a). Power spectral density analysis was performed for the generated transient data in order to obtain the frequency spectrum for all the scalars.

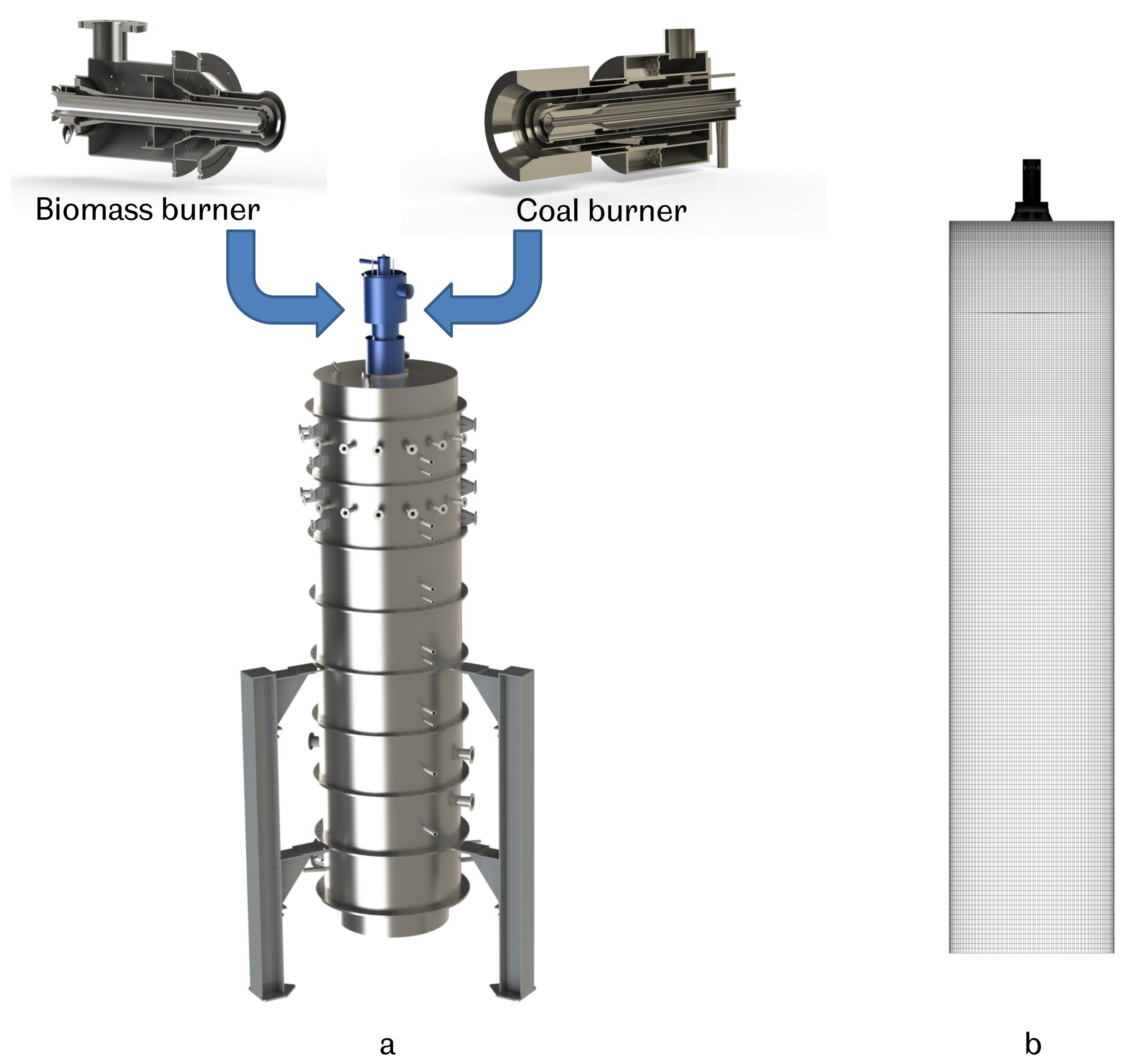


Figure 1. a) Computer representation of the UKCCSRC Pilot-scale Advanced Capture Technology (PACT) 250 kW combustion test rig. b) Computational domain used for LES computations consisting in 6.75 million hexahedral cells.

Results

The temperature distribution plot obtained after the LES computation of an air-fired coal combustion case is showed in Figure 2. The transient data for the greyscale pixel intensity and pressure fluctuations are showed in Figure 3. The frequency components for the normalized flicker spectrum are presented in Figure 4, the referred flicker frequency corresponds to the weighted sum of all frequencies using the normalized power density value. Figure 5 shows the frequency spectrum for the direct noise prediction in terms of the sound pressure level.

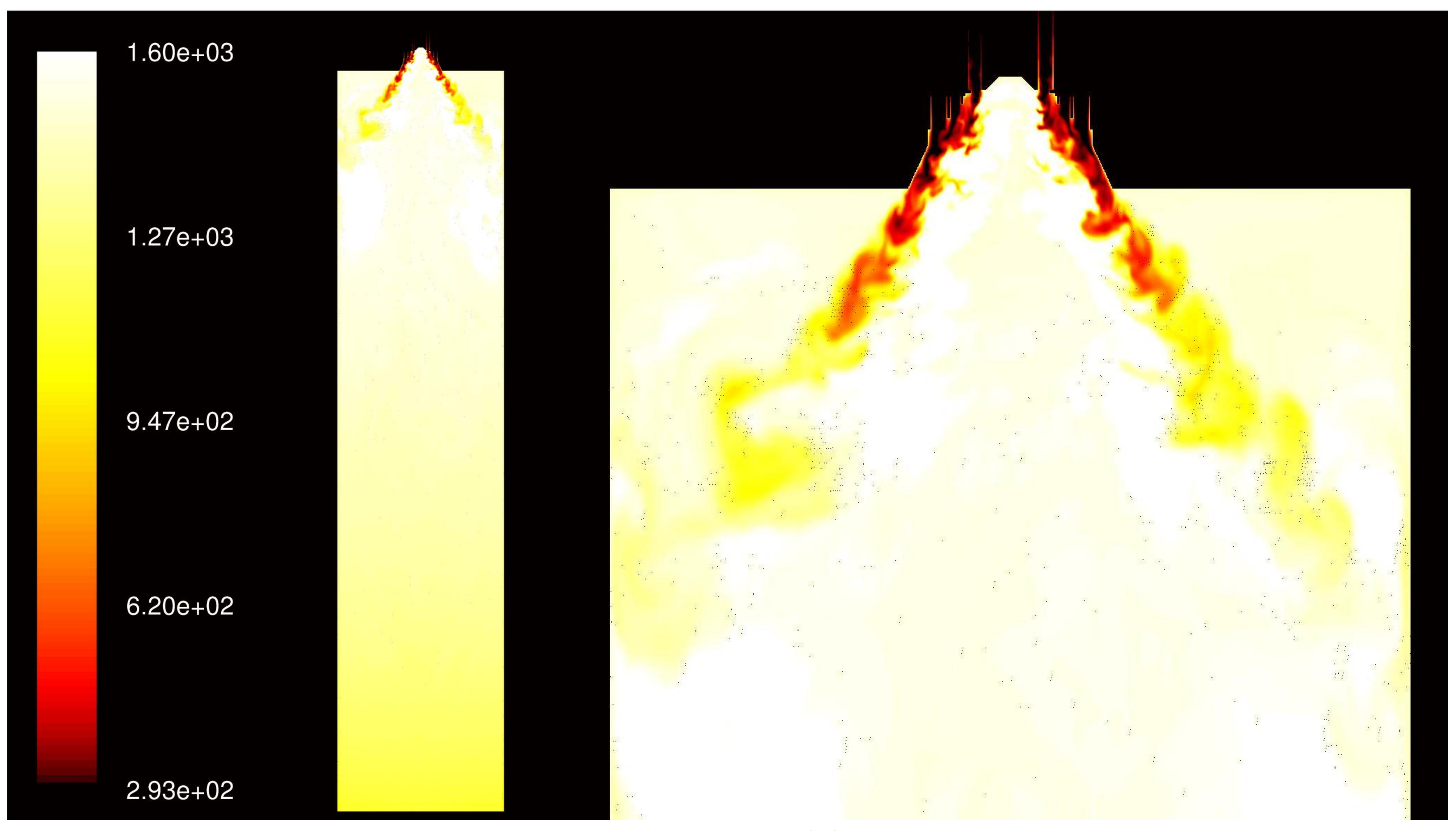


Figure 2. Instantaneous temperature distribution (K) of an air fired coal combustion case at t=0.35s.

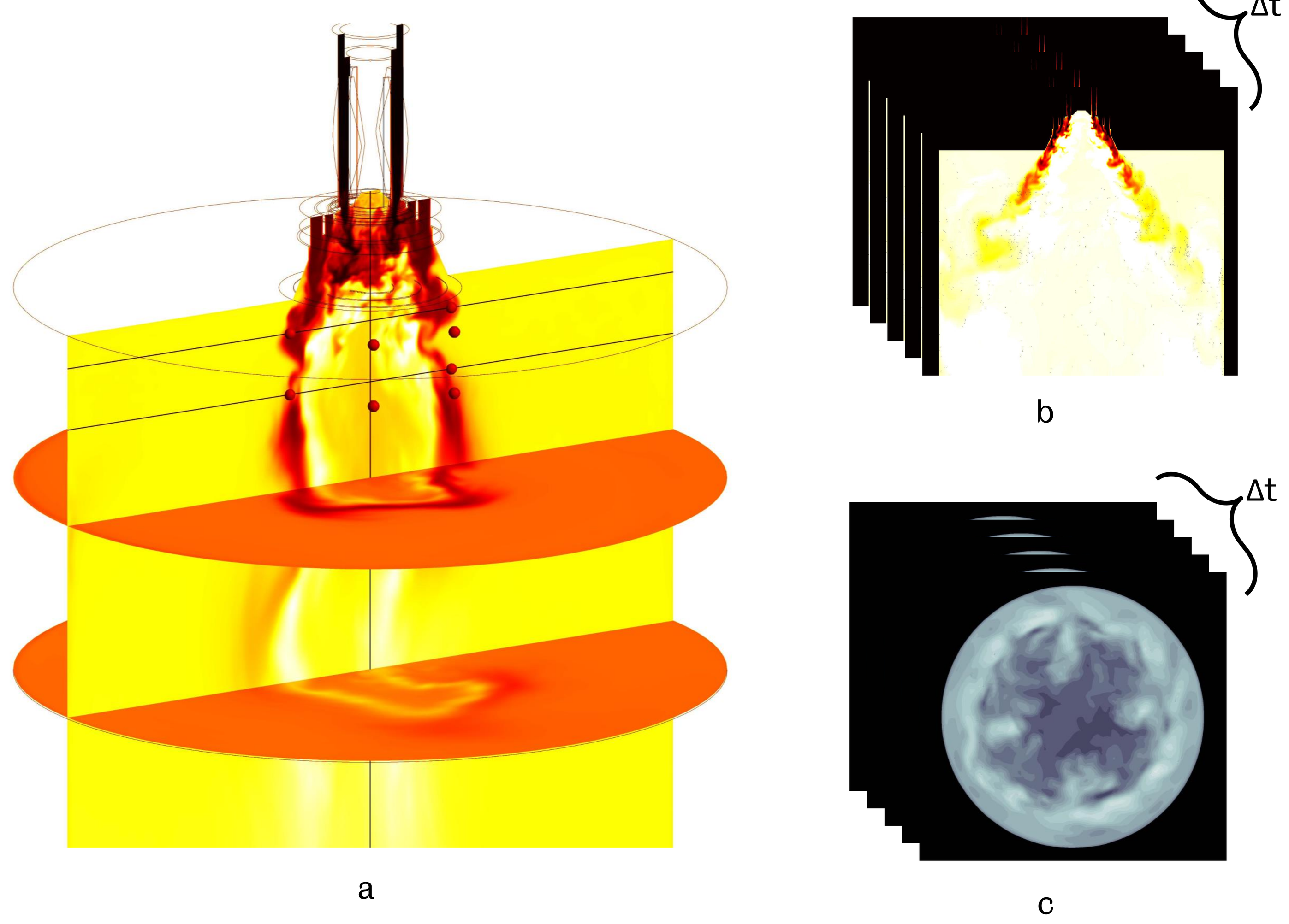
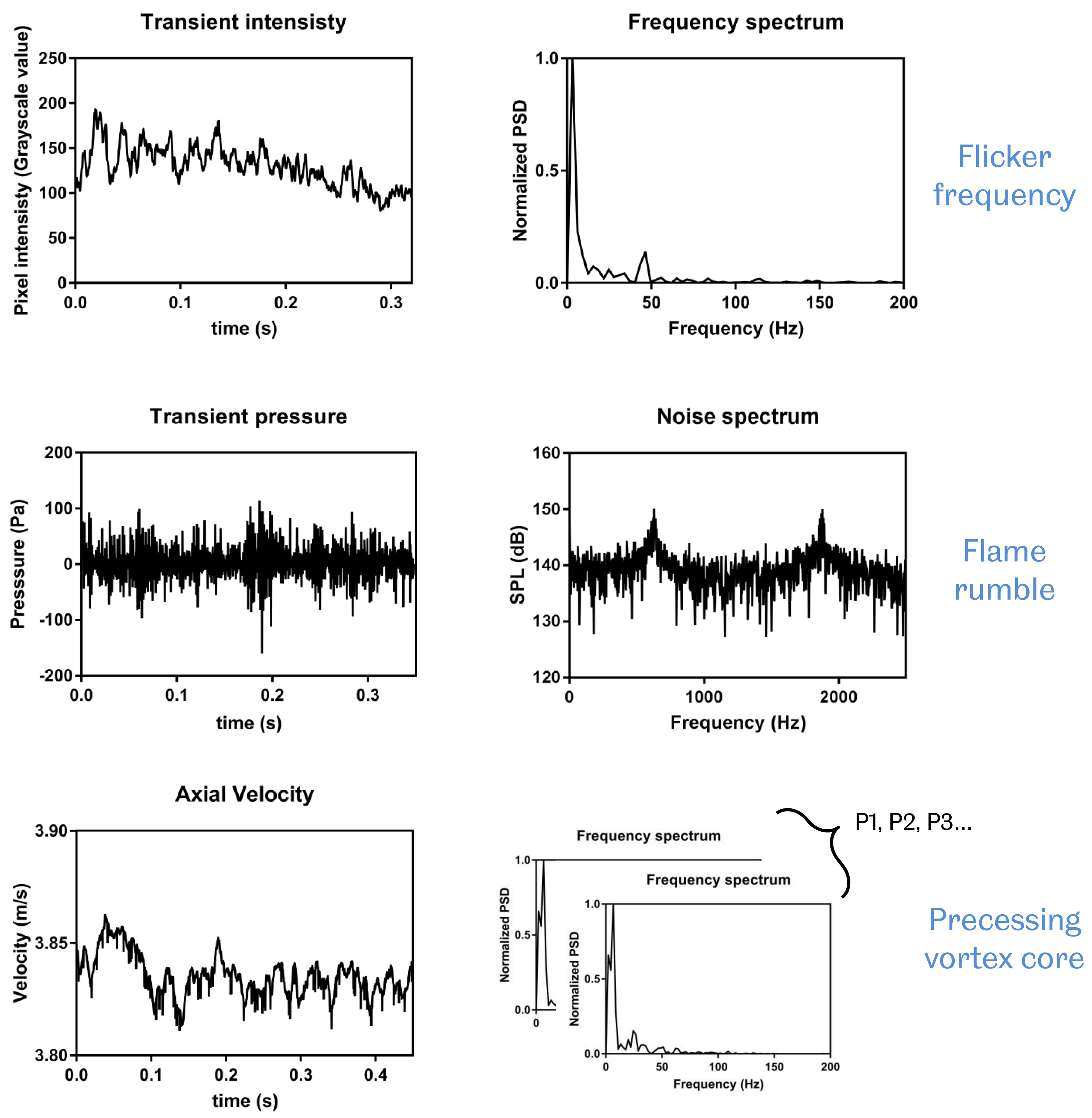


Figure 3. a) Cross sectional planes used for flicker frequency estimation and monitoring points (red) for direct noise and temporal turbulent coherence estimation. b) Transient temperature distribution. c) Transient axial velocity distribution.



Conclusions and further work

The range of frequencies obtained after a series of large eddy computations can be used as a reference of the dynamic behaviour of the flame and therefore, as an estimation of its stability. This methodology will be applied to a different fuels and combustion scenarios such as biomass and oxy-fuel conditions and the results will be applicable in determining each operational limit.

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