Large eddy simulation of a coal flame: estimation of the flicker frequency under air and oxy-fuel conditions

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Abstract for oral presentation:

Fossil fuel combustion, such as coal combustion, currently meets the majority of the global energy demand; however, the process also produces a significant proportion of the worldwide CO_2 greenhouse gas emissions. Further improvement in the efficiency and control of the combustion process is needed, as well as the implementation of novel technologies such as carbon capture and storage (CCS). Oxy-fuel combustion is a very promising CCS technology, where the air in the combustion process is replaced with a mixture of recycled flue gas and oxygen producing a high CO_2 outflow that can effectively be processed or stored. The adjustment of the combustion environment within the boiler resulting from the high CO_2 concentration will modify the flame characteristics. It is therefore important to evaluate properly the changes of the flame that occur with different flue gas recycle schemes.

A coal flame is often characterised by its physical parameters, such as the flame size, shape, brightness and temperature, and it can be considered as a stable flame by the presence of ignition and the propagation of the flame. The oscillatory behaviour of a flame can be quantified by the flicker frequency obtained after the instantaneous variations of the flame parameters, and is used as a reference for flame stability.

Computational Fluid Dynamics (CFD) is widely used to model coal combustion. This work compares the estimated flicker frequency taken from CFD calculations against measurements undertaken at the experimental facilities of the UKCCSRC Pilot-scale Advanced Capture Technology (PACT) located in South Yorkshire, UK. The 250 kW combustion test facility consists of a down-fired, refractory lined cylindrical furnace, which is 4 m in height with a 0.9 m internal diameter. The furnace is fitted with a scaled version of a commercially available Doosan Babcock low-NOx burner.

The flame physical parameters are approximated from performing a Large Eddy Simulation (LES) using the CFD code ANSYS FLUENT v15. The flicker frequency obtained from the CFD approach is compared against the experimentally measured value from a 2D flame imaging system. A series of oxy-fuel cases are then examined in the same fashion in order to assess their flame stability and the boiler operational limit. The flicker frequency trend obtained from the computations and measurements helps to determine the dynamic response of the flame for different combustion environments, and the results will be applicable in determining the optimal recycle ratio applied in future oxy-fuel systems.

Keywords: LES, flame, flicker frequency, oxy-fuel, coal combustion, CFD, digital imaging.

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