CHARACTERIZATION OF PARTICLE EMISSIONS AND TEMPERATURE PROFILES IN A DOMESTIC WOOD PELLET-FUELLED BOILER: INFLUENCE ON THE RADIATIVE HEAT FLUX AT THE COMBUSTION CHAMBER WALL

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Biomass represents approximately 14% of the worldwide energy consumption. Unfortunately, its combustion generates a number of air pollutants, including hydrocarbons, nitrogen oxides, carbon monoxide and particle emissions containing both large fly ashes (>1 μm) and fine soot particles (<1 μm). These particles are also involved in the mechanism of heat transfer at the combustion chamber wall. This study aims to investigate a typical wood pellet-fired boiler dedicated to domestic heating, considering the particle emission and the thermal exchange at the combustion chamber wall, in particular the radiative heat transfer.

In-situ and ex-situ techniques are investigated to this aim and measurements are performed during the slumber and the steady-state mode for different working conditions of the boiler. For in-situ measurements, a chimney with three optical accesses is implemented to the exhaust gas pipeline. Soot volume fraction is measured using the two-color LII technique (2C-LII): LII signal excited at 1064 nm is detected at 530 and 700 nm. The detection efficiency of the laser system has been determined by using a calibrated integrating sphere, leading to an instantaneous measurement of the absolute soot volume fraction. In parallel, extinction technique is applied to calculate the volume fraction of the nano and micro sized absorbing particles (soot and ashes). Measurements are performed with a Continous Wave laser (165 mW at 1064 nm). The incident and transmitted beams are recorded simultaneously with the LII decay time of soot excited with the pulsed Nd-YAG laser. The comparison between both techniques allows the determination of soot concentration (with 2C-LII) and the total particle concentration (ash and soot) with extinction. LII signals are also recorded simultaneously with temperature fields through six thermocouples type S with 200 μm bead diameter implemented at different heights in the boiler. Finally, the size distribution of particles is measured using a SMPS (scanning mobility particle sizer) in the combustion chamber (brazier) and in the exhaust gas.

The particle emissions have an important influence on the radiative heat flux at the combustion chamber, then on the performances of the boiler. The wall radiative heat flux is evaluated from the Radiative Transfer Equation (RTE) solved with a discrete ordinate method, with the Hypothesis of Thermodynamic Equilibrium. The wall is supposed fouled by soot particles with an emissivity of 0.9. The radiative properties of the medium in the combustion chamber are modelled with a correlated-K model described in the literature. This model is applied with the measured values of soot volume fraction and temperatures as input data, and from the estimated quantities of H_2O and CO_2 in the combustion chamber evaluated with the combustion equation of wood pellet.

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