Modelling the air-fuel mixture in an atmospheric burner

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ABSTRACT

Nitrogen oxides (NOx) from combustion devices are responsible for the formation of acid rain and photochemical smog. This led to a growing environmental concern resulting in the creation of rigorous legislation for harmful emissions. Water heating for domestic applications is a major component in energy usage. Amongst the various technical alternatives, instant water heating represents one of the main alternatives available. In the US, as of 2009, this amounts to 350,000 units/year [1]. In this, no storage is present and hot water is produced on demand. In addition to an automatic ignition system (usually driven by a pressure differential resulting from the water flow), the boiler includes a heat exchanger (usually finned tubes) and a burner. Their power band is within the range of 19 through 30 kW and it can provide a temperature differential of up to 50 ºC. Appliances for domestic hot water production, particularly water heaters, there are already some solutions in the market able to achieve low pollutant emissions. However, the complexity of the solutions makes the price tag significantly higher, hampering its mass adoption. It is therefore essential to design and develop simpler and low cost solutions that meet the limits imposed by legislation. This work reports the analysis and validation of the air-gas fuel mixture in a water heater low NOx gas burner element. This is based on a pre-mixed flame made of two separate fuel systems, also known as the thick and thin fuel combustion [2]. One is a lean mixture that provides the bulk of the heat load. The other is a rich pilot flame, used to stabilize the flame. For that, a computational model was developed and applied, which, upon initial settings, allows for the prediction of the amount of primary air drafted by the fuel jet. It is a two fluid model that describes the air and gas fuel inside the burner. It enables the calculation of the local air/fuel concentration and assess flow maldistributions inside the burner. To validate the theoretical results, experimental tests were performed using a Laser Doppler Anemometer to evaluate the influence of the throat length in the amount of entrained air, as well as, the air induced in the burner element under study. Furthermore, a parametric analysis was performed which evaluated the influence of some variables (geometry, physical properties of fluids, etc.) in the amount of entrained air. The numerical results for the air-fuel equivalence ratio of a conventional burner element (between 0.645 and 0.794) proved to be reasonably close to the value announced by the manufacturer (0.7). Numerical analysis of the burner element with pilot stabilization resulted in values that verify the difference between the richness of the two mixtures. By adjusting the throat-diffuser geometry one may tune the air-fuel ratio of each mixture.

REFERENCES

[1] Ryan, D. et al., 2010. Water Heater Market Profile. ENERGY STAR - U.S. Department of Energy, p.34.3.07.053, (2013).

[2] Bhattacharjee, S.; West, J. and Dockter, S. 1997 A simplified theory for de ris flame over thick and thin fuel beds, Combustion and Flame, 104, pp. 66–80