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Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

In-Flame Characterization of a 30 MW_{th} Bio-Dust Flame

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<u>Oral presentation at the symposium is preferred</u>

1. Summary and Purpose

This work presents a comprehensive flame characterization campaign on an operating full-scale Danish power plant. Amagerværket Unit 1 (AMV1, 350 MW_{th}, 12 identical burners on 3 burner levels) is 100 % fuelled with wood dust burned in suspension and stabilized by swirling flows in a triple concentric low-NOx configuration. The measurements focus on a single 30 MW_{th} flame and include: Quantification of the gas temperature, the gas phase composition: O_2, CO, CO_2, H_2O, and light hydrocarbons by intrusive probe measurements. It also includes both seeded and unseeded 2D laser doppler anemometry (LDA) velocity measurements, flame shape observations by video imaging, and particle entrainment by high speed infrared (IR) imaging. The flame is characterized along the geometrical centreline as well as in the horizontal and vertical plane of the flame. The results shed light on the flame anatomy of a full-scale burner and provide a comprehensive data set that quantifies key parameters: Gas phase temperature, composition, and flow field required in order to evaluate the performance of CFD simulations of complex combustion systems.

2. Approach and Methods, Scientific Innovation, Relevance, and Results

Full-scale flame characterization studies are scarce in the literature, however, of high value in the development of burner technologies. They supplement complex CFD simulations which have become increasingly popular with the increase in readily available computational power, raising the reliability of the simulations by providing evaluation data. In-flame probe measurements together with both infrared (IR) and visual spectrum (VIS) high speed video recording make up the back bone of the flame characterization. The probes were inserted into the flame through the centre of the burner (replacing the oil lance) for measurements along the geometrical centreline as well as perpendicular to the flow direction through a view port on the side of the boiler. Entry through the side of the boiler allowed for mapping in both the horizontal and vertical plane of the flame at multiple axial distances. Experimental orientation and outline of the flame is enclosed in supplementary material. Special water cooled probes, developed in-house, made it possible to penetrate 4.5 meters into the flame through the centre of the burner. In the perpendicular direction the probe reached beyond the geometrical centre of the flame. Probe measurements included temperature measurements using both suction pyrometry and optical fourier transform infrared (FTIR) spectroscopy. Gas species concentrations of O_2, CO, CO_2, H_2O, and light hydrocarbons have been quantified by extraction of gas samples analysed by parallel infrared (IR) and ultraviolet (UV) cells and O_2 paramagnetic analyser. The flow field was characterized by 2D LDA velocimetry. 2D velocity measurements have to our knowledge not been carried out on a full-scale biodust burner, however, often requested by CFD groups. The relatively low number density of particles in a bio-dust flame makes it potentially difficult to carry out LDA measurements. This work includes the comparison between unseeded and seeded (both with ash and laboratory grade glass beads). Flame shapes and particle cloud behavior have been observed using high speed imaging in both the visual and IR region, enabling for analysis of particle cloud trajectories, and particle cloud surface temperature estimates by two-line pyrometry.

Stable operating conditions were maintained throughout the three days campaign. Double determination experiments confirmed comparable flame characteristics. The flame assumes a classic flame type-1, following the IFRF flame classification system. The flame characteristics were distinctly represented in all measurements providing a rational and complementary data set. A distinct cold centre of the flame, stretching up to 1 quarl diameter into the flame, was accompanied by almost ambient oxygen concentrations and entrainment of cold particle clouds. Well defined differences in the axial velocity measurements suggested a poor radial mixing especially profound in the near burner field. The cold centre was surrounded by a high temperature reaction zone in which oxygen levels reached close to depletion.

3. Conclusions

A fully operational biodust flame has successfully been characterized using complementary analytical methods, providing a comprehensive data set suitable for evaluation of CFD simulations. It provides much needed quantification of the flow field of full-scale flames. The results of the applied analytical methods complement each other in a logical manner and distinctly describe a type-1 flame.

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