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LOCAL MEASUREMENTS IN TWO FULL-SCALE SWIRL STABILIZED BIO-DUST BURNERS: A PARAMETRIC STUDY

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Introduction

In the strive for at CO_2-neutral energy profile the exploitation of biomass in central and decentral heat and power plants has continuously increased in recent decades. The further development of these plants are central if they are to live up to the demands for fuel flexibility, stable performance, and high efficiency, making thermal plants the arguably best near-term solution to provide renewable energy suitable for base load operation.

Today the dedicated bio-dust burners can be grouped into two main categories: 1) burners originally developed for pulverized coal combustion and retrofitted to employ biomass fuels and 2) burners purposefully build for pulverized biomass fuel, but based on the experience and data from coal burners.

This work presents $in\text{-}situ$ measurements from two centralized combined heat and power plants employing each of the two generations of wall fired, air-staged low NO_x bio-dust burner: Amager (AP, $350\,MW_{th}$) and Herning Power Plant (HP, $300\,MW_{th}$). Thus, providing insight into how each of these flames react to systematic changes in the operational conditions.

Analytical Methods

The flames are characterized using both non-intrusive high speed optical observations in the visual (VIS) and the infrared (IR) spectrum as well as intrusive probe measurements. As illustrated on Figure 1, flame mappings are made along the center line entering the boiler through the burner. While optical observations are acquired from the view ports installed at the side (A) and back (B) of the boiler. Solely mapping along the center axis ensured fast analysis intervals while still being able to capture key features of the flame.

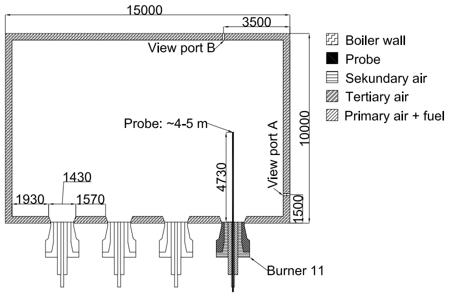

Figure 1: Horizontal cross sectional view of the Amager Power Plant with the probe fully inserted through the center of the burner. View ports used for optical observations are indicated.

The analytical methods applied through the probe include gas phase temperature measurements using both suction pyrometry and optical fourier transform infrared (FTIR) spectroscopy. Gas species concentration measurements of O_2, CO, CO_2, H_2O, and light hydrocarbons have been quantified by temperature controlled extractive gas sampling analyzed by parallel IR and ultraviolet (UV) cells and O_2 paramagnetic analyzer. The optival observations in the VIS are primarily used to characterize flame shape, flame instabilities by e.g. flame lift while the high speed IR imaging can be used to track particle trajectories and particle cloud surface temperatures by two-line pyrometry.

Operational Conditions

Extensive studies were carried out on each power plant compiling a comprehensive database of different operating conditions together with the corresponding flame responses. The changes in operational conditions include:

- Air flows (primary (PA), secondary (SA), tertiary (TA), and combinations herof)

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- Air flow temperatures (PA, carrier air (CA))
- Degree of swirl (SA and TA)
- Fuel load
- Particle size distribution

All changes to the operational conditions have been carried out systematically and with large variations to ensure statistically significant flame responses.

Results

Inherent differences in the flame characteristics have been observed when comparing the results from the two burners employed in this study. As seen from Figure 2, the different mixing patterns of the two burners result in inverted occurrences of the gas species profiles here illustrated by the CO profile. This inverted behavior recur, as well, in gas phase temperatures and relative penetration depth of cold particle clouds.

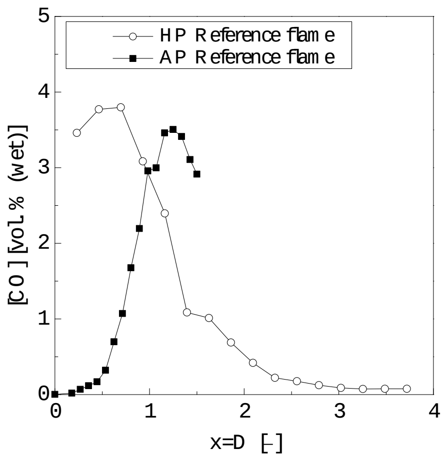

Figure 2: Comparison of the CO profile along the center axis of the two burners in reference configuration. x/D being the axial distance, x, normalized by the burner diameter, D.

Changes in the burner air flow were found to influence to the greatest extend on the flame properties, i.e. changes to the degree of swirl, air-split settings, etc. In general, flow changes impacting directly on the internal recirculation zone (IRZ) seem to have high impact on the observed characteristics. Decreasing the swirl number by approximately $20\,\%$ reduces ($> 50\,\%$) or in some cases even eliminates the presence of pyrolysis gases in the near burner field from maximum quantities of 2–3 vol. % CO and 0.2–0.3 vol. % methane and acetylene. Destabilizing the IRZ also lowers the flame temperature in the near burner field with as much as 200 K.

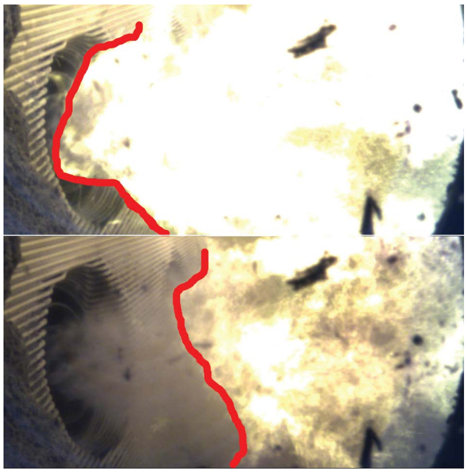

Figure 3: Significant visual differences are observed between well attached (upper) and detached (lower) flames.

Flame instabilities could easily be observed by visual means, as seen in Figure 3. Destabilizing the IRZ caused frequent and significant flame lifts and general changes to the flame shape. Such flame instabilities where not immediately obvious from the temperature or chemical species profiels but could be correlated to the penetration depth of cold particles visualized by imaging in the IR spectrum.

Conclusions

The inherently different mixing patterns in the two flames facilitate direct comparison of different burners. The coarse flame mapping has proven to be a successful method for making quantitative evaluation of flame responses to changes in the operating conditions. Thus, providing a full set of *in-situ* data that can be used for large-scale burner evaluation.

Acknowledgements

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