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Coal-firing and biomass-firing in a 150kW swirl-stabilized burner flow reactor

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Introduction

The worldwide concern with global warming and low availability of fossil fuels has spurred interest in using biomass for energy production. Co-firing biomass with coal in existing large-scale power plants offers an attractive option.

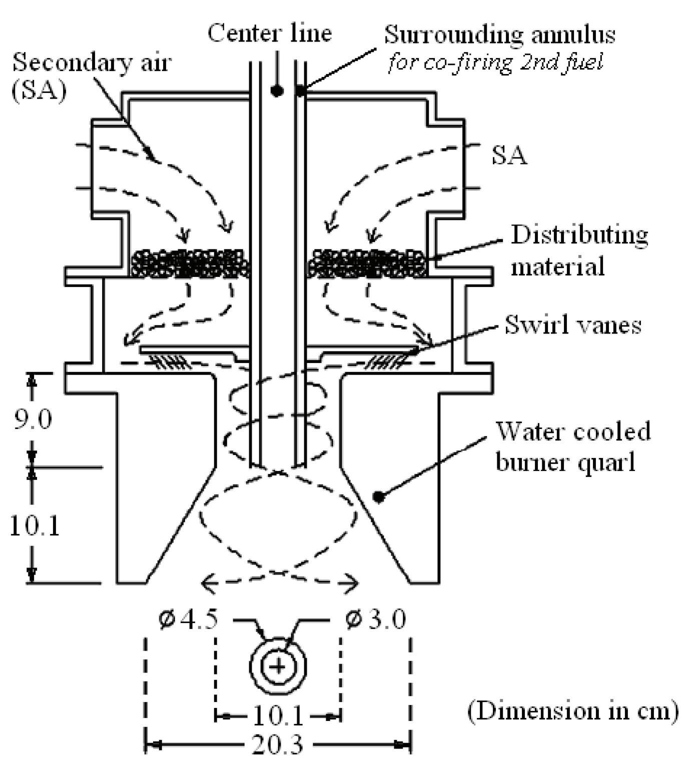
Co-firing biomass in a wall-fired boiler could be far more challenging, because burner aerodynamics and fuel properties have a much greater impact on combustion and emission characteristics in a suspension-fired boiler than other boilers. The body of useful work available in literature for the fundamental characteristics of biomass/coal co-firing flames is still severely limited, in particular, the comparison of firing pure biomass and firing pure coal under similar conditions.

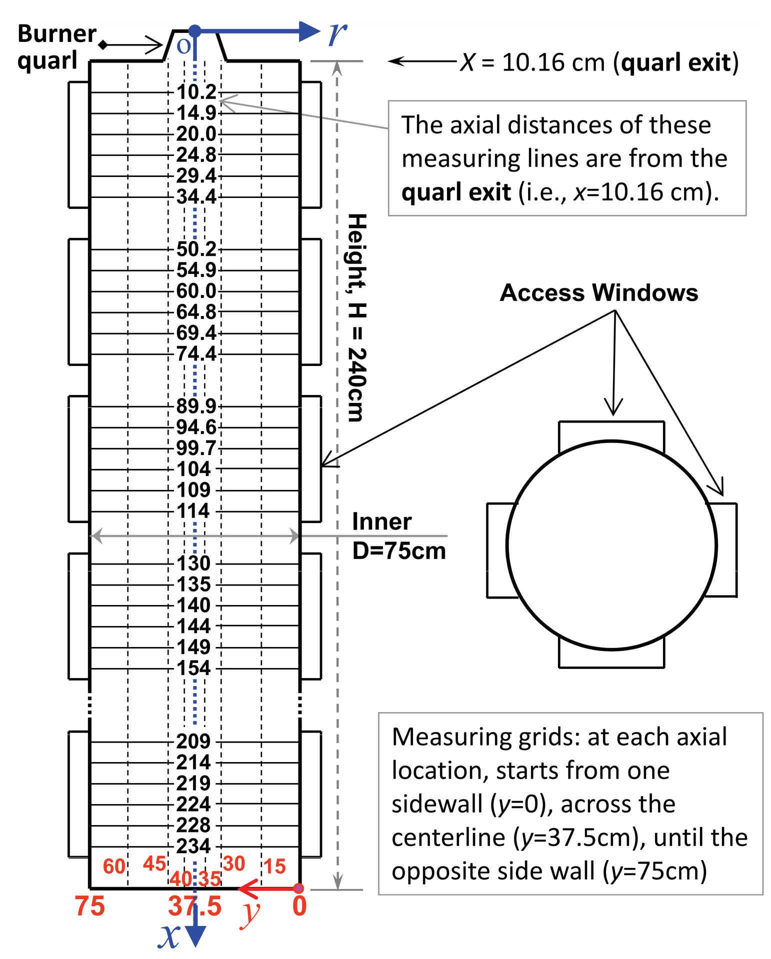
This paper studies the combustion characteristics of firing pure coal and firing pure wheat straw in a 150kW swirl-stabilized burner flow reactor **under nearly same conditions.** The results indicate very different combustion characteristics between the coal flame and straw flame and provide some clues in design of biomass (co-)firing.

Method

- Model development & numerical simulations: 62600 quadrilateral cells for steady 2D axisymmetric swirl simulation; custom vs. default DPM laws; Realizable k-ε; DO radiation; Jones and Lindstedt (JL) 4-step mechanism vs. Westbrook and Dryer (WD) 2-step mechanism. Simulations validated with the measured species map (done by project partner, BYU at Utah, USA).
- Use the validated simulation as a tool to look into more details.

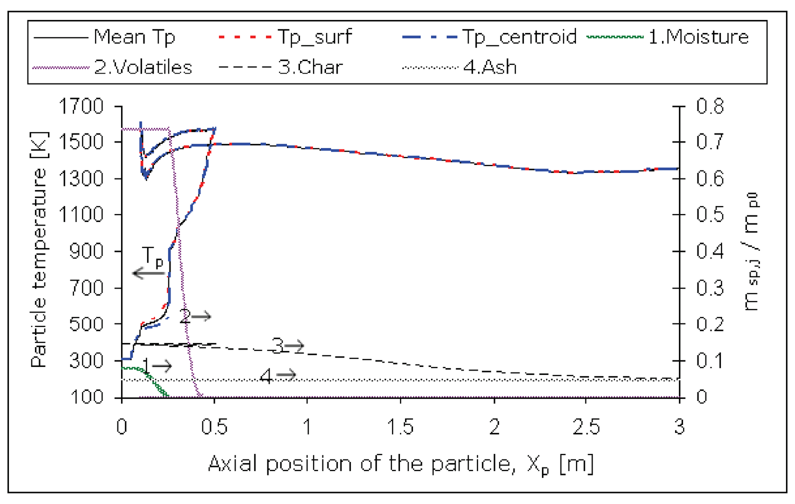
Experimental





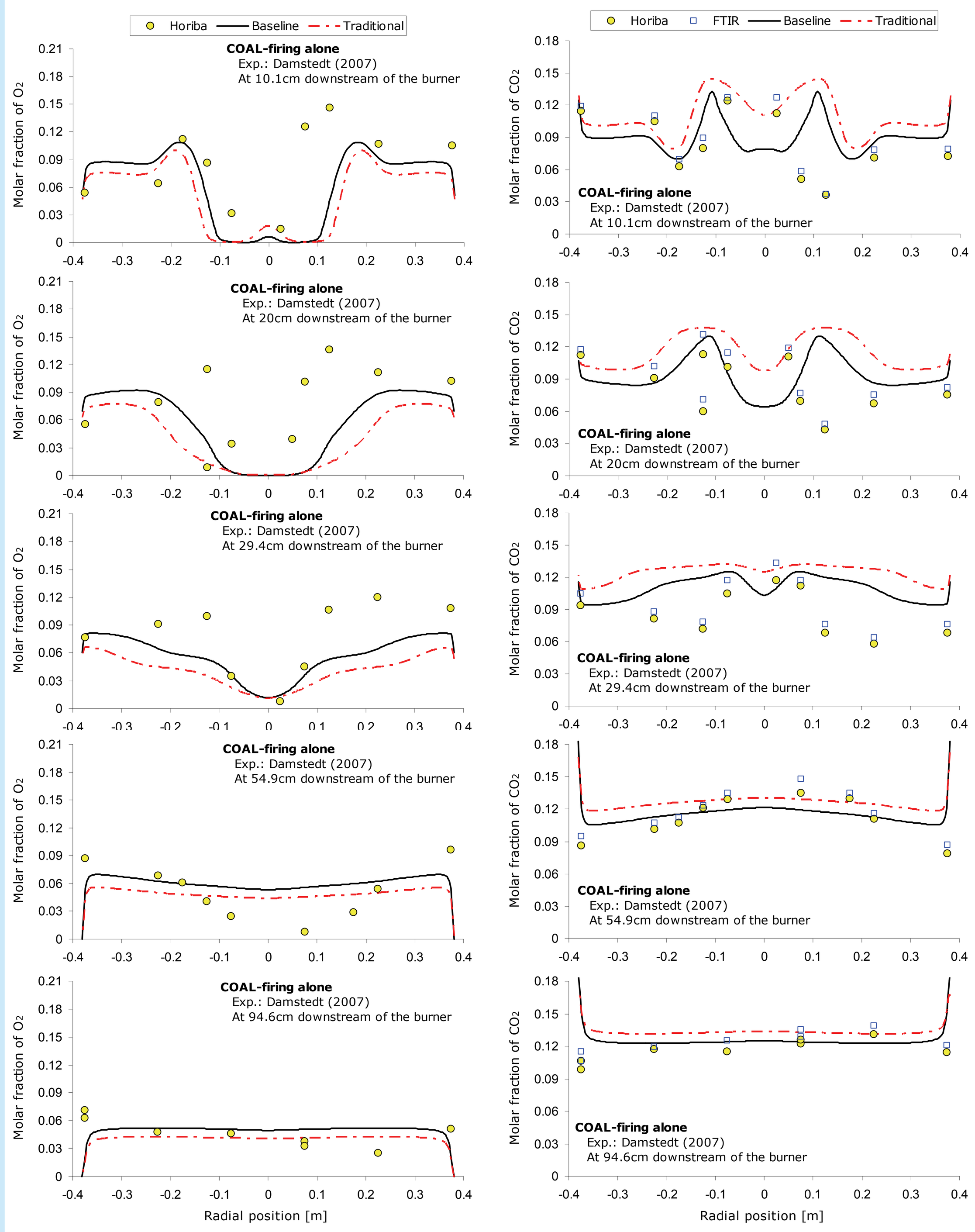
Result

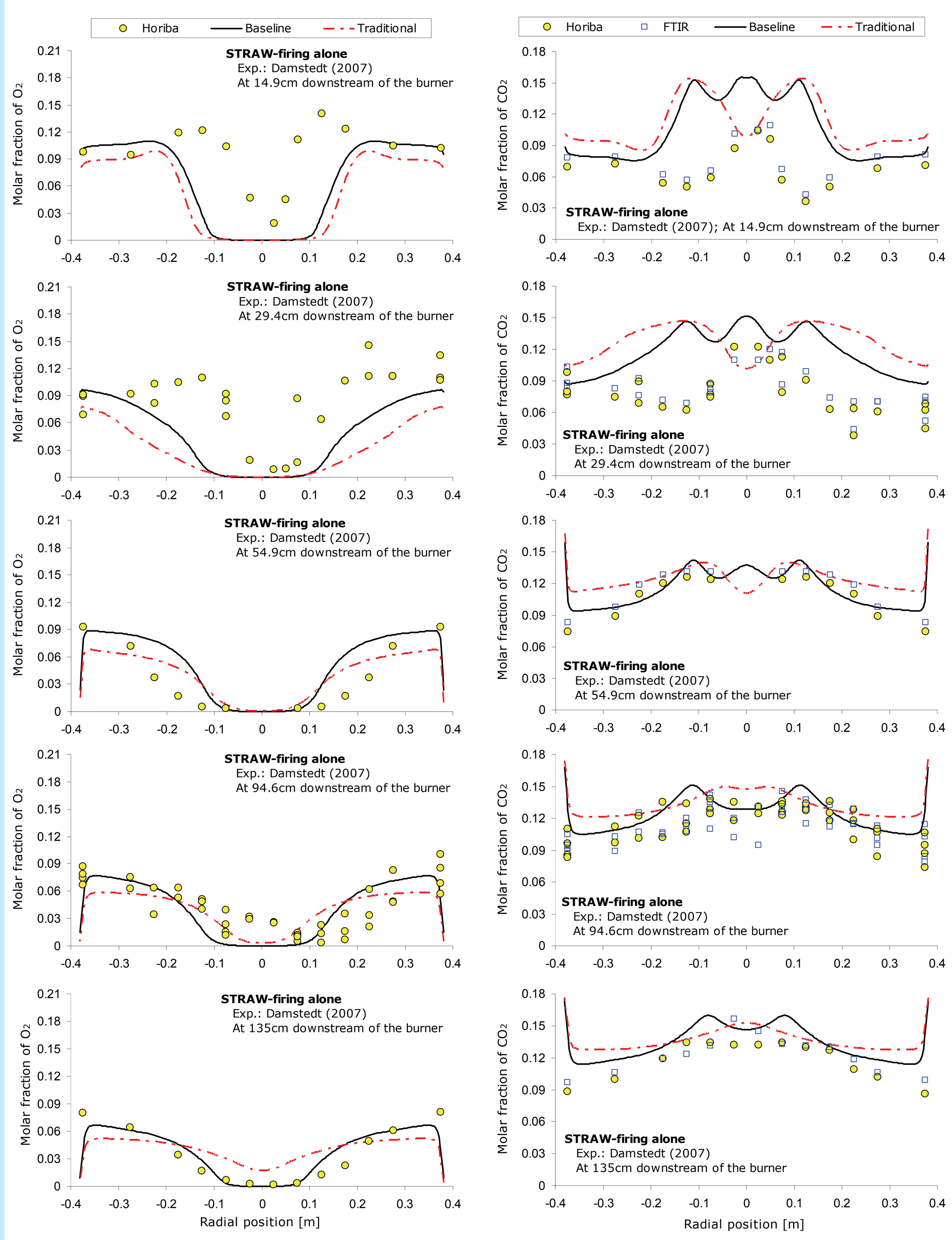
- For pulverized biomass particles of a few hundred microns in diameters, the intra-particle heat and mass transfer is a secondary issue at most in their conversion.

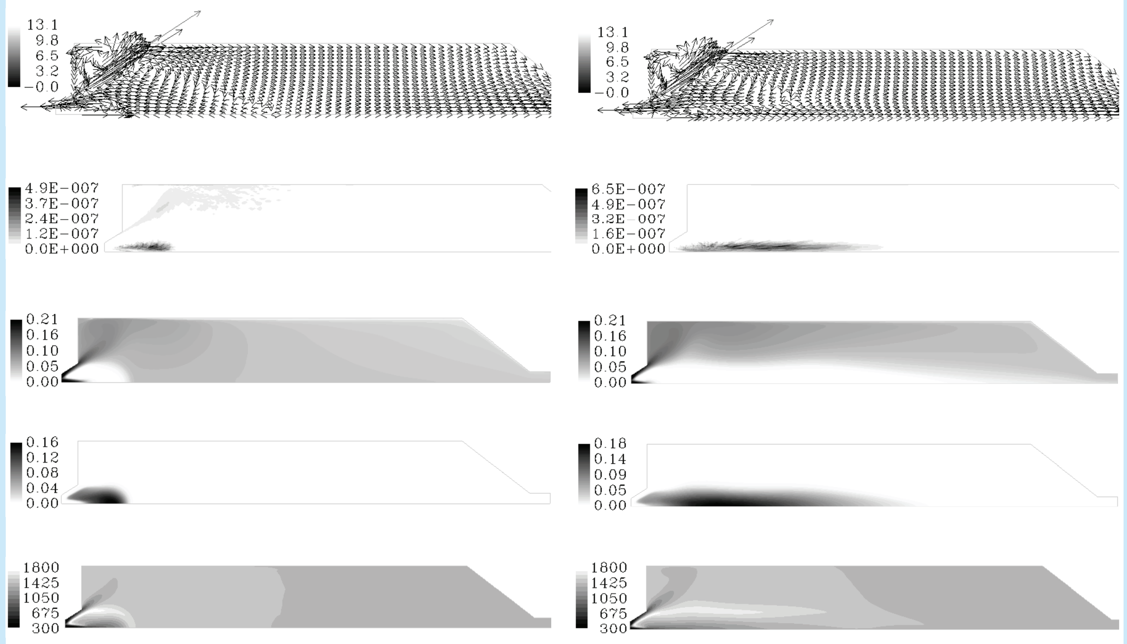


Temperature & conversion history of a straw particle as it travels in the reactor.

- Very different combustion aerodynamics and characteristics between the coal flame and the straw flame.

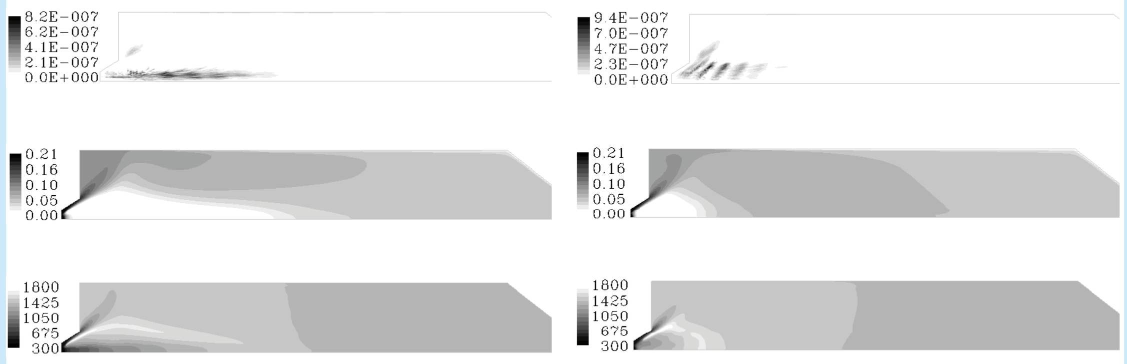






Vector grayed by swirl velocity [m/s], DPM mass source [kg/s], O_2 molar fraction, CO molar fraction and gas temperature [K] (from top to bottom), for the coal flame (left column) and the straw flame (right column), in both of which the fuel is fed through the center tube into the reactor..

- Simple switch of fuel feeding may easily break the balance between the fuel/air jet and the internal recirculation zone, change the combustion aerodynamics and compromise the burner and downstream processes.



DPM mass source [kg/s], O_2 molar fraction and gas temperature [K] (from top to bottom), for the straw flame, in which the fuel is fed into the reactor through the surrounding annulus (left column) and with the outer SA jet (right column).

	Average residence time [s]	Char burnout [%]
The coal-flame	7.623	89.89
The straw-flame	4.748	71.14
Straw from annulus	5.040	68.62
Straw with SA	5.104	66.51

Conclusions

For pulverized biomass particles of a few hundred microns in diameters, the intra-particle heat and mass transfer is a secondary issue at most in their conversion. JL 4-step mechanism can better predict the gas phase combustion.

There exist different combustion aerodynamics and characteristics between the coal flame and the straw flame. In order to better implement biomass/coal co-firing in a swirl burner, comprehensive consideration on fuel feeding, air supply and combustion aerodynamics must be made.

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