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CFD-simulation of a baled biomass-fired furnace: Combustion modelling and design optimisation for the reduction of emissions

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INTRODUCTION

Computational fluid dynamics (CFD) is a powerful tool for the design and optimisation of combustion chambers. The purpose of the present work is to apply appropriate CFD methods for the development of a new 2 $MW_{thermal}$ baled biomass combustor and to compare the results with experimental pilot plant data. An overview of the considered combustion chamber geometry is given in figure 1.

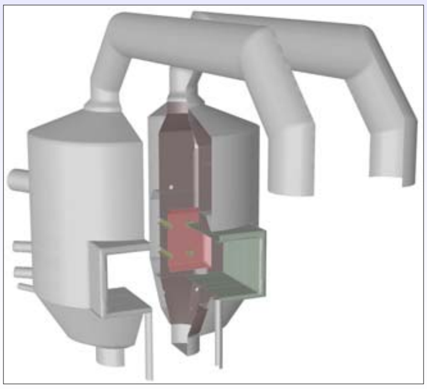

Figure 1: Overview of the combustion chamber

MODEL IMPLEMENTATION

For the development of a CFD model - considering turbulence, heterogeneous combustion, conduction, radiation and gas/solid flow - a stepwise refinement has been chosen:

- Cold gas simulation and experiments for tests and selection of turbulence models (SST-k-ω, see [1], [2], [3]). Results are shown in figure 2.
- Hot gas simulation (using volume heat source) for implementation and tests of temperature-dependent physical properties (taken from [4], [5]).
- Simplified biomass combustion modelling using a CH_4/CO/H_2O-mixture to achieve realistic flue gas temperatures and composition ("mixed is burned" model).
- Implementation of a radiation model (DTRM) to account for radiative heat transfer. Estimation of wall temperatures and inlet temperatures of combustion air (Results are shown in figure 3).

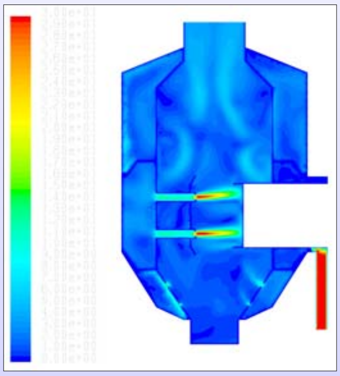

Figure 2: Contours of velocity magnitude on a cross-section of the furnace in m/s

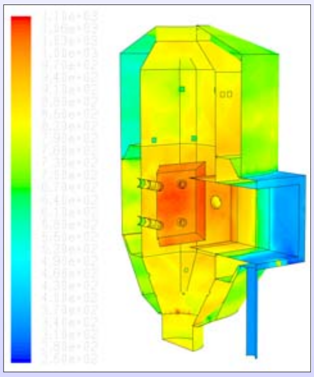

Figure 3: Combustion chamber wall temperatures in K

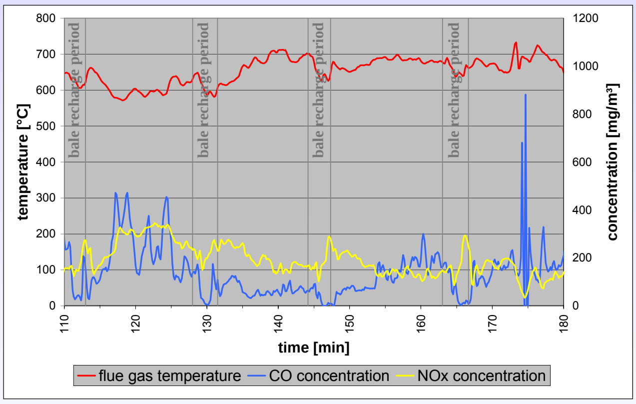

Figure 4: Flue gas temperature and CO/NO_x-emissions of a typical combustion experiment

COMBUSTION EXPERIMENTS

For the validation of the computational models several combustion experiments have been accomplished. Some results of these experiments are shown in table 1 and figure 4.

	unit	experiment	calculation
wall temperature (postcombustion zone)	°C	585	579
wall temperature (afterburning zone)	°C	618	596
flue gas temperature	°C	654	696
flue gas volume flow	Nm³/h	5733	5741
flue gas oxygen concentration	%v	8,10	6,03
flue gas CO_2 concentration	%v	12,66	14,01
flue gas CO concentration	ppm	170	0,009

Table 1: Experimental and calculated values of some relevant combustion parameters (Average experimental values, steady state CFD values)

FUTURE WORK

Further CFD simulations will focus on the prediction of emissions and the implementation of solid biomass combustion. The next steps will involve:

- Implementation of appropriate gas phase reaction kinetics.
- Implementation of a model for solid biomass fuel combustion considering the process steps proposed in figure 5, adapted from [6].
- Simulation of several partial and full load scenarios
- Optimisation of the geometry and operation characteristics to increase volume specific thermal output and to reduce emissions.
- Scale-up studies.

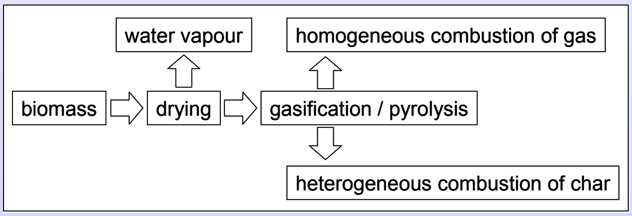

Figure 5: Combustion process of solid biomass

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