# Numerical modelling of gas phase wood combustion in a travelling grate furnace

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**The experimental and numerical modeling results of the influence of air flow distribution on the CO emissions within a medium power wood chips fired boiler are presented. The numerical study concerns only the gas phase combustion of wood volatiles. Both experimental and numerical results show a CO emission reduction as the air flow configuration changes. The current work allows a better understanding of operating conditions of medium-scale wood fired boilers.**

## Introduction

This study is focused on the numerical modeling of gas phase wood volatiles combustion within a medium power traveling grate wood chips fired boiler and it is a part of a project that aims to a complete simulation of the boiler for industry application. Thus experimental and numerical modeling investigations have been carried out, first on the influence of the secondary airflow distribution on the CO emissions.

## Experimental

The experiments were carried out on a 400 $kW_{th}$ wood chips fired boiler (Fig. 1). The wood is fed into the furnace by a feed screw at top of the grate. The primary air enters into the fuel bed from beneath the grate. The wood chips advance along the grate as they suffer the thermal decomposition. The resulting ash is collected into the ash pit at the end of the grate. The volatiles released from the bed flow upward, mix with the secondary air from side walls of the furnace to continue the combustion process. Tertiary air is added to ensure a complete combustion of these gases. The secondary air is provided by 16 inlets on each sidewall. The hot gases enter then in the heat exchanger tubes, where they are cooled down, then evacuated to the fly ash removal system and finally to the stack. The global measurements are the air temperature and velocities, the wood mass flow rate and flue gas composition. The local measurements concern the temperature field inside the furnace measured by the mean of four refractory steel sheaths, each one containing three N type thermocouples, and that were introduced into the combustion chamber by the access holes on the side wall, bellow the secondary air inlets.

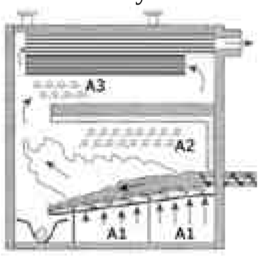


**Figure 1 -** Schematic of the 400 $kW_{th}$ wood fired boiler. A1 – primary air, A2 – secondary air, A3 – tertiary air

Two different secondary airflow rate configurations were studied. The first one (C1) presents an asymmetrical distribution with 16 opened inlets whereas the second configuration (C2) is symmetrical with 18 opened inlets. For both cases the tertiary air mass flow rate was kept null.

## Numerical

The present calculations were performed using the CFD finite-volume code Fluent. The turbulence is modeled using the k-e Realizable model [1]. The chemical kinetics was predicted using the Eddy Dissipation Concept (EDC) [2] model. The combusting wood volatiles are considered to be composed by methane, ethane, acetylene, carbon monoxide and hydrogen. A global two-step reaction mechanism with six reactions is used for each species as follows:

R1 $CH_4 + 1.5O_2 \rightarrow CO + 2H_2O$

R2 $C_2H_4 + 2O_2 \rightarrow 2CO + 2H_2O$

R3 $C_2H_2 + 1.5O_2 \rightarrow 2CO + H_2O$

R4 $CO + 0.5O_2 \rightarrow CO_2$

R5 $CO_2 \rightarrow CO + 0.5O_2$

R6 $H_2 + 0.5O_2 \rightarrow H_2O$

The P-1 model is employed to predict the thermal radiation heat transfer.

The computational grid was generated using a hexahedral mesh with 535 200 cells.

The wood bed surface was supposed to have a 150 mm height at feed screw level and approximately 5 mm at the end of the grate. The temperature and volatile species mass fractions profiles along the bed surface are based on the results obtained by Huttunen *et al*. [3] and adapted to the mass fluxes corresponding to the present study.

## Results

The temperature field inside the furnace is illustrated in Figure 2 for both studied configurations. The region with higher temperature, thus so the reaction zone, shifts downward to the surface bed, when the secondary air distribution changes.

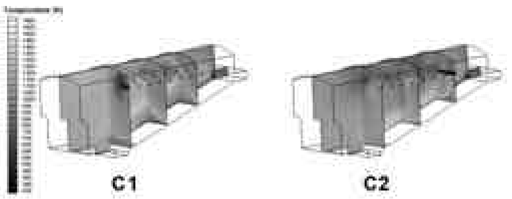


**Figure 2 -** Computed temperature field

The measurements show a temperature decrease for all thermocouples in the second case (C2) which confirms the temperature shift, the computed values being in the same range as the measurements.

The flue gas experimental analysis was determined at a point situated after the fly ash removal system while the calculated concentrations were reported at the computational domain outlet. The predicted and measured mean values for $O_2$, $CO_2$ and CO concentrations in the flue gases are presented in Table 1. The experimental results show a CO concentration reduction by a factor of three after the secondary air configuration is changed.

**Table 1 -** Flue gas concentrations

| Values | | $O_2$ (%) | $CO_2$ (%) | CO* ($mg/Nm^3$) |
|---|---|---|---|---|
| Computed | C1 | 6.4 | 9.8 | 8722 |
| | C2 | 7.8 | 9.3 | 3990 |
| Measured | C1 | 11.2 | 8.9 | 540 |
| | C2 | 11.3 | 8.1 | 163 |

* Expressed at 11 % $O_2$

However there is an important difference between the measured and the predicted CO concentrations. This is due to the global chemistry mechanism. Nevertheless, the numerical model presents approximately the same reduction factor. The $CO_2$ concentrations show a slightly decrease because the air-to-fuel ratio is higher in the second case, which is confirmed by the predicted oxygen concentration increase. The computed oxygen value is smaller than the measured one and is explained by the air infiltration in the furnace that was discovered later and hence not accounted for the numerical simulation.

## Conclusions

The airflow distribution inside the furnace has a strong influence over the wood volatiles combustion. The CO emission is reduced by a factor of three when the asymmetrical secondary airflow distribution is changed into a symmetrical one. The measurements show a shift of the temperature inside the furnace. The numerical simulation reproduces this temperature shift, the predicted values having the same order of magnitude as the measured ones. The mathematical modeling reports an over predicted value for the CO concentration; this is due to the global kinetic mechanism. However, the numerical model is capable to reproduce, from a qualitative point of view, the CO emission reduction. A mathematical submodel for the solid phase must be considered in order to achieve a more accurate prediction of temperature and species concentration profiles at the fuel bed surface.

## References

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[3] M. Huttunen; L. Kjäldman; J. Saastamoinen; Analysis of grate firing of wood with numerical flow simulation; IFRF Combustion Journal; article n° 200401; 2004.