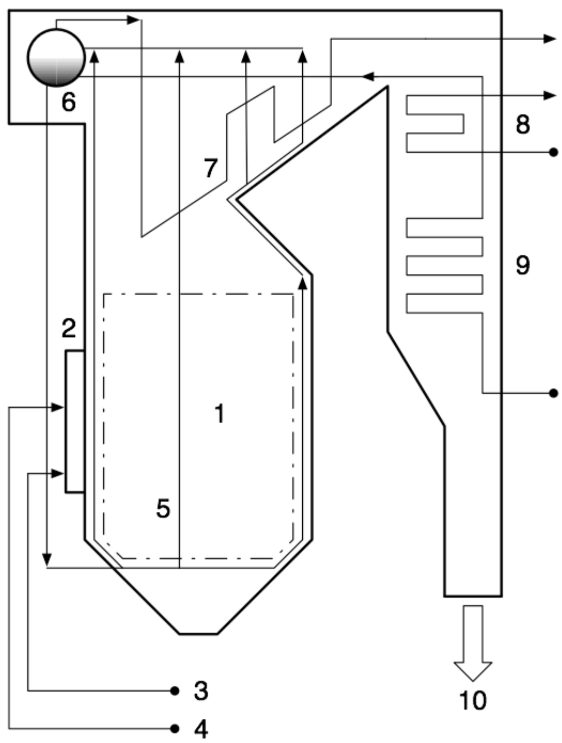
Coupled simulation between 3D CFD and Flownex applied to coal-fired boiler

Introduction

This case study demonstrates the capability of Flownex to do simulations where Flownex and a 3D CFD code are coupled.

System Description

The illustration in Figure 1 shows the boiler configuration considered in this example. Inlet massflow and pressure for the air, fuel and water inlets are known and the combustion is modelled with CFD.



1 Boiler combustion chamber	6 Steam drum
2 Boiler burners	7 Boiler platen superheater
3 Secondary air	8 Boiler reheater
4 Primary air	9 Boiler economiser
5 Riser tubes	10 Outlet to precipitators and chimney

Figure 1: *Thermal circuit of boiler*

Objective of Simulation

The objective of this study is to model the boiling process in the riser tubes with Flownex and calculate the heat fluxes through the side walls, as needed for accurate CFD models of the combustion process.

Flownex Model

The combined CFD and Flownex models of the system are shown in Figure 2 and Figure 3. The riser tubes are modelled in Flownex using pipe elements with external heat sources and boundary flow conditions on inlet and outlet nodes. Two pipe sections represent front and back riser tubes that combine before entering the boiler superheater (modelled using the heat exchanger element). The gas flow from the boiler outlet is linked to the inlet conditions of the primary side of the superheater.

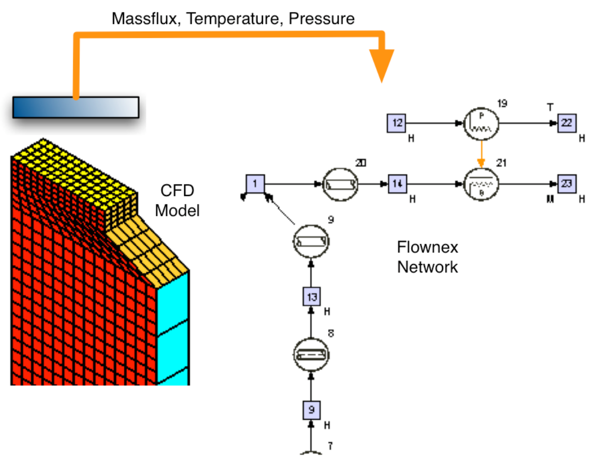


Figure 2: *Transfer outlet conditions from boiler to heat exchanger*

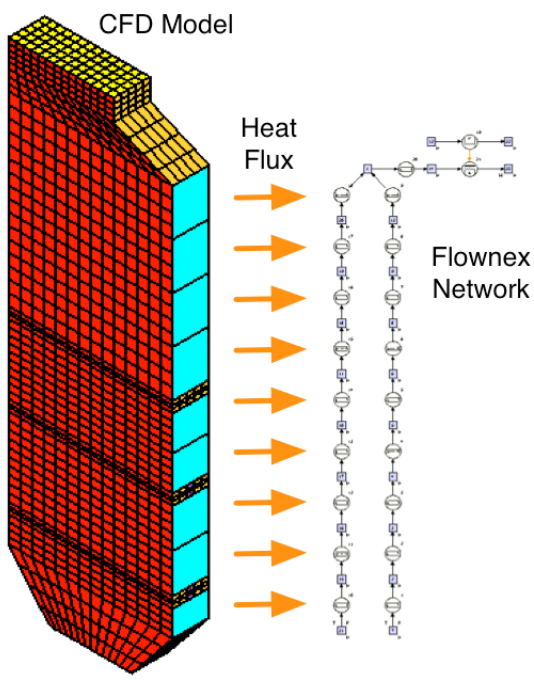


Figure 3: *Transfer heat flux from boiler to riser tubes*

Description of Simulation

The fixed inlet temperature and pressure are specified on the riser tubes and the required steam mass flow is specified at the outlet of the heat exchanger.

The combustion process and gas flow through the boiler is simulated with CFD. Heat flux through the side walls are linked to Flownex which calculates the steam quality in the riser tubes. The pipe temperatures are linked back to the CFD model as boundary conditions.

The process of transferring data is repeated until convergence is reached for both the Flownex network model and the detail CFD model.

Results

The temperature distribution in the boiler is shown in Figure 4. Results from the Flownex model for the element temperatures and heat fluxes are shown in Figure 5 and the steam quality for the different nodes is shown in Figure 6. The steam quality is seen to increase due to the higher temperatures at the top of the boiler and results in superheated steam in the topmost riser tubes.

Conclusion

The results illustrate the advantages of using the combined approach to model coupled problems in situations where previous (uncoupled) assumptions in simulations proved to be rather inaccurate. In this instance, the ability to model the liquid phase change in the pipes enabled the calculation of more realistic, non-uniform wall heat fluxes for the CFD model.

By linking the two different methods, improved boundary values and system behaviour could thus be obtained for both the CFD model and fluid network model.

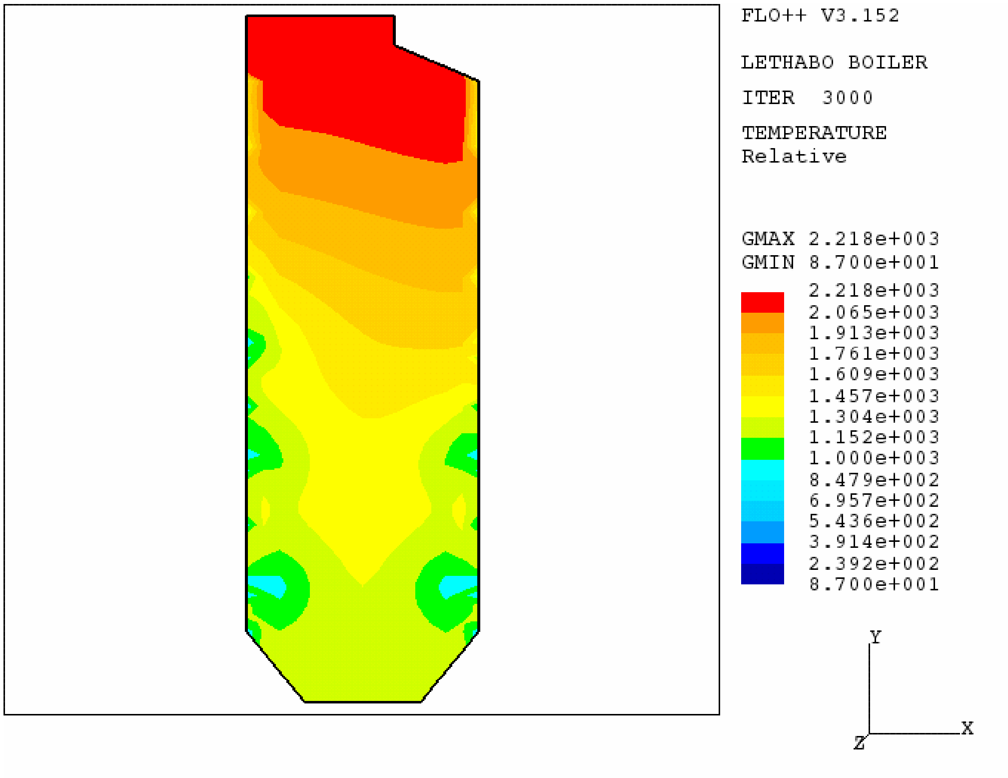


Figure 4: *Temperature distribution on burner centreline*

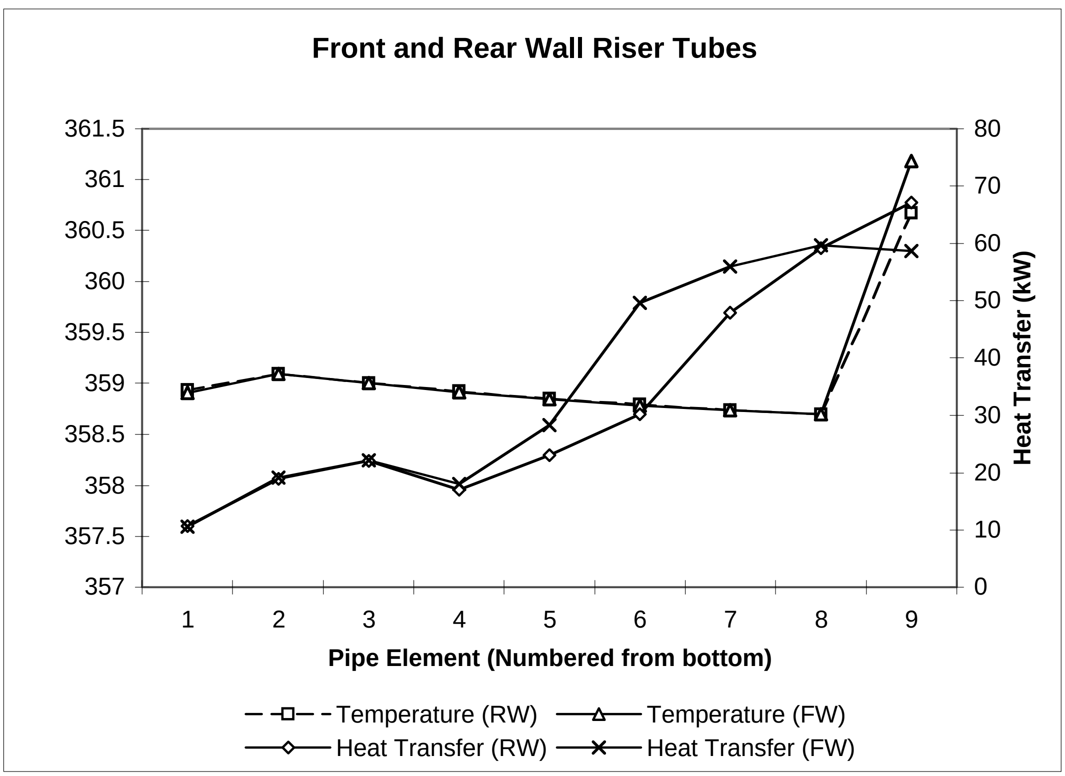


Figure 5: *Temperature and heat flux distribution in pipe elements*

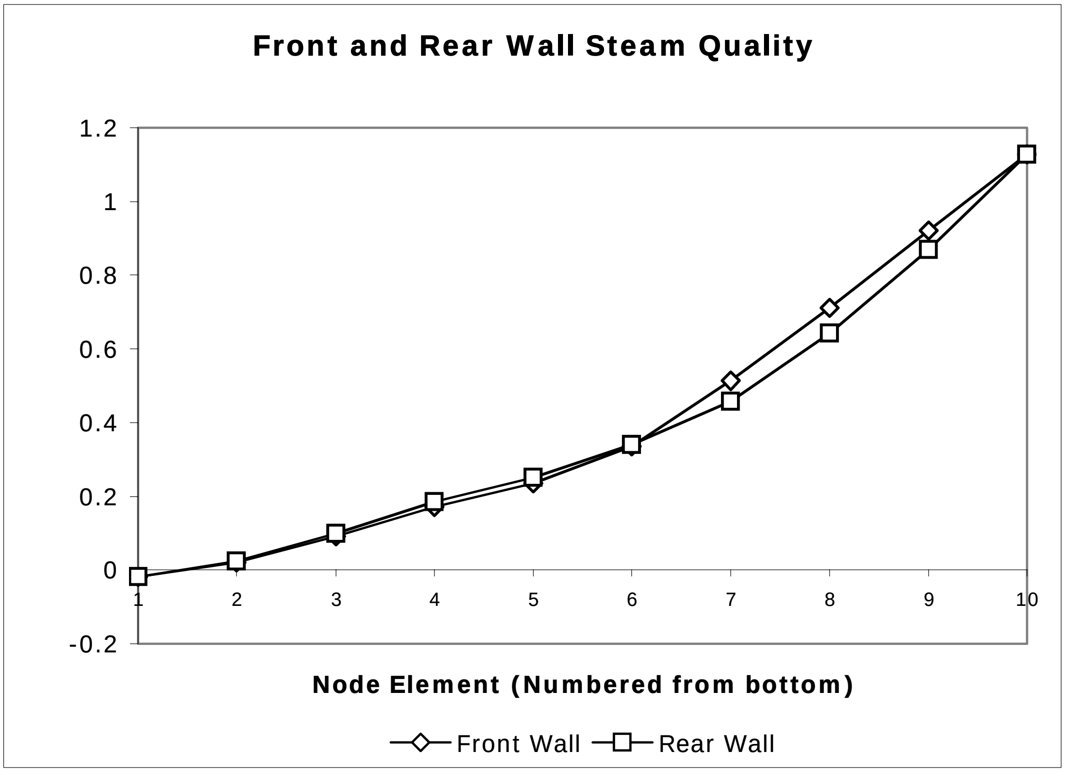


Figure 6: *Steam quality in node elements*