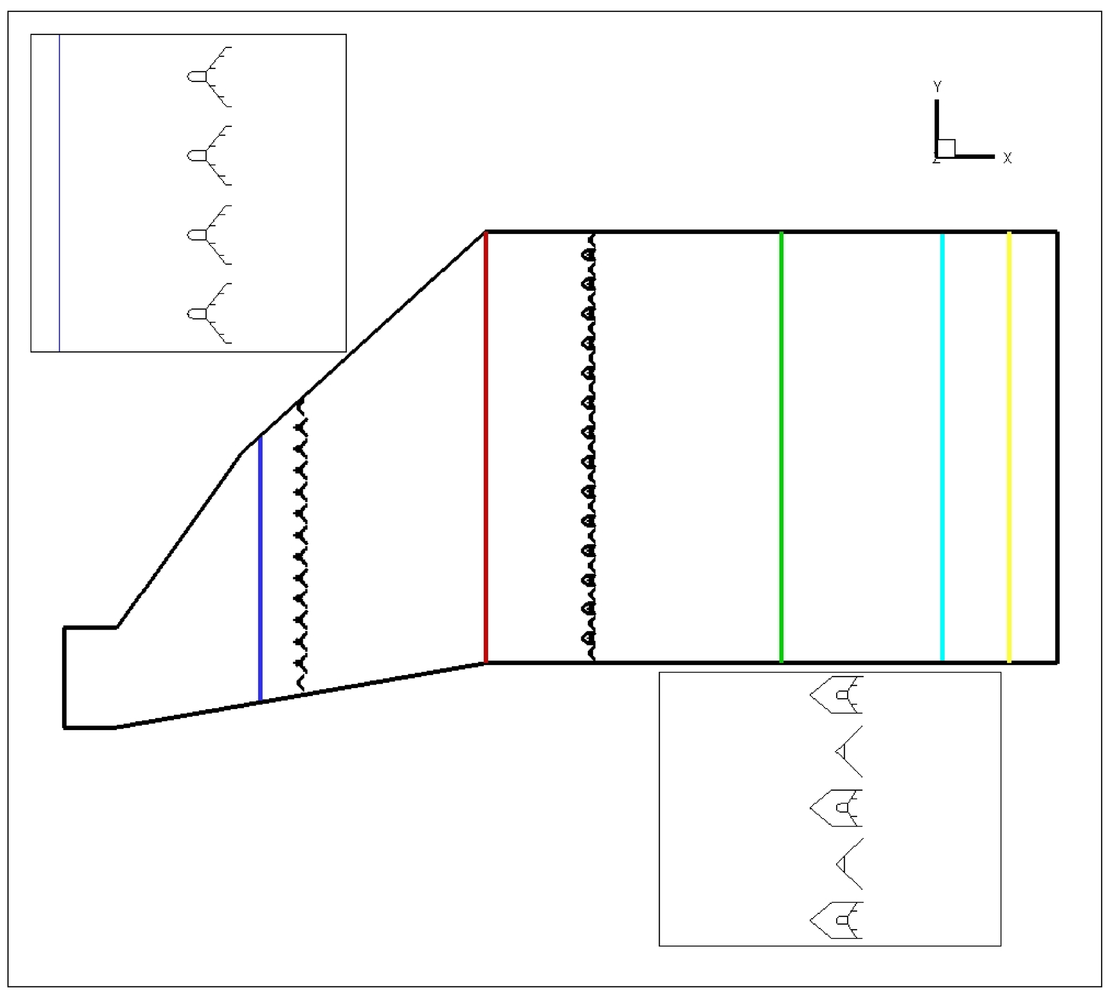
POLITECNICO di MILANO
DIPARTIMENTO di ENERGIA

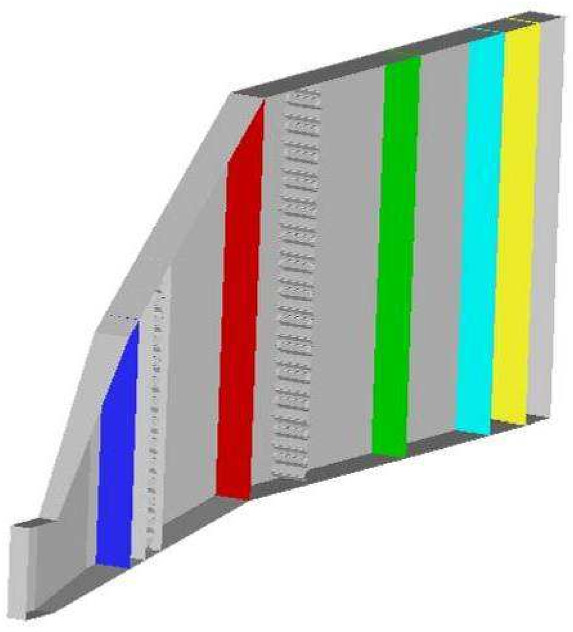
FLOW FIELD AND TEMPERATURE PREDICTION IN A HRSG WITH POST-COMBUSTION

Emanuela Colombo, Fabio Inzoli, Luca Marocco, Riccardo Mereu
Politecnico di Milano, Dipartimento di Energia, Piazza Leonardo da Vinci, 32 - 20133 MILANO

Research Framework

The optimization of combustion systems in term of efficiency and reduction of pollutants is considered the main aim of combustor research projects and for an accurate design heat and mass transfer phenomena need to be taken into account.
The goals of this research is the prediction of the temperature distribution in a Heat Recovery Steam Generator (HRSG) design for a plant operating in Qatar with the goal of driving the choice of the material for the liner inside the HRSG.
The original approach in this research is the model strategy to simulate the injection the fuel gas from the burner nozzles. It is injected as particles streams in geometrical location close to the original nozzles with the mass flow rate and velocity related to the specific power load.





Global view, with coloured surfaces: blue for the grid, red for SH, green for EVA, light blue for ECO and yellow for SCR.

The case study is an HRSG with two ranks of burners: the first one (Duct Burner #1) is formed by 12 burners and 2 baffles (upper and lower elements) while the second one (Duct Burner #2) is formed by 29 elements (14 burners alternated with 15 baffles); burners of second rank present secondary air inlet nozzles. Each burner has 49 fuel nozzles.
Two critical operating condition have been investigated.

Case A:
Flow rate: 104.16 kg/s ; Temperature 603 K.

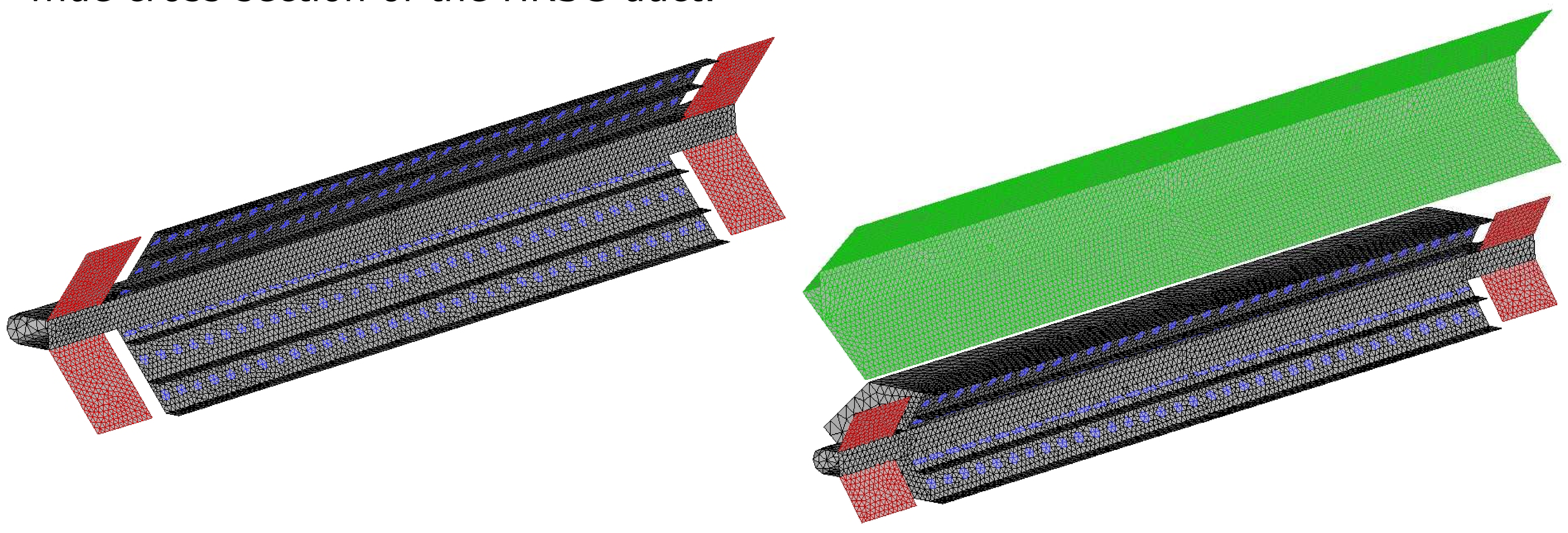
- Power load Burner#1: 30.74 MW.
- Power load Burner#2: 68.05 MW.

Case B:
Flow rate: 122.8 kg/s; Temperature 699 K

- Power load Burner#1: 67.48 MW
- Power load Burner#2: 81.81 MW

Numerical model

The mesh generation process is based on an hybrid approach in order to gain the best compromise between the required accuracy and the CPU time. The model is made up with more than 11 million hybrid cells and a second order scheme has been used for the spatial accuracy. One of the most critical aspect in this case is the presence of a high range of dimensions spreading from the small gaps of the second air inlet placed on the burners and the holes of the burners wings to the wide cross section of the HRSG duct.



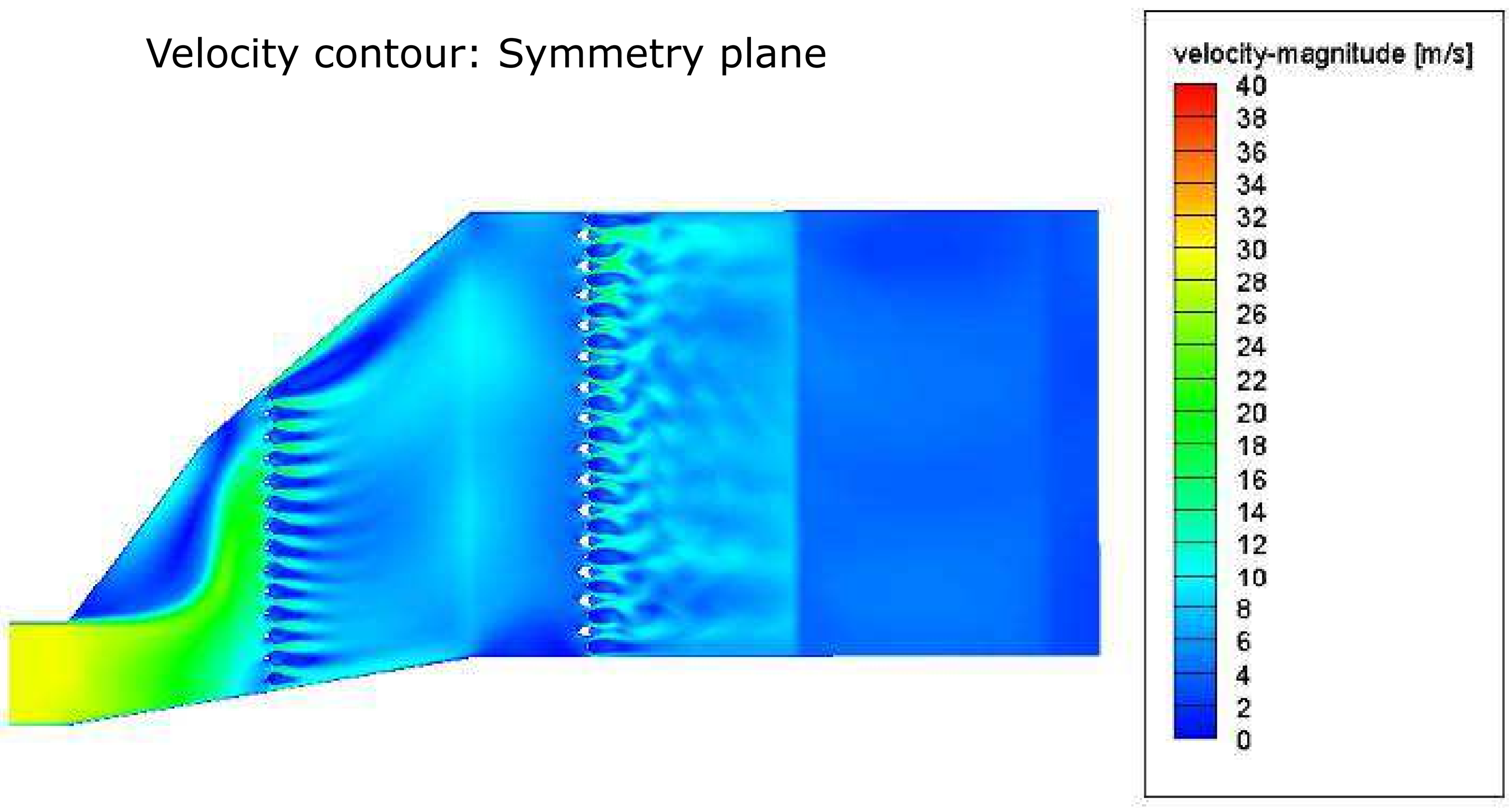
Surface mesh on the Burner #1 (left) and Burner #2 (right) and baffle (green surfaces). The red surfaces represent the lateral grid baffle while the blue ones refer to holes for supplying air

The k-ε realisable turbulence model is used. Species transports are considered and the combustion occurring in the two ensemble of burners were model as equivalent combustions of methane (with the same heating value as the operating fuels) and the activating mechanism was imposed to be driven by mixing rather then by kinetic mechanism as it is acceptable with high Reynolds flow field.
Flue gas coming from the turbogas are considered as a mixture composed by CO_2, H_2O, O_2, N_2 with thermodynamics properties defined as a piece wise polynomial function of temperature.
The P-1 model is used as radiation model.
The segregated solver is used for approaching this problem: a second order scheme is used for the spatial accuracy and the SIMPLE algorithm is applied to the pressure velocity coupling.

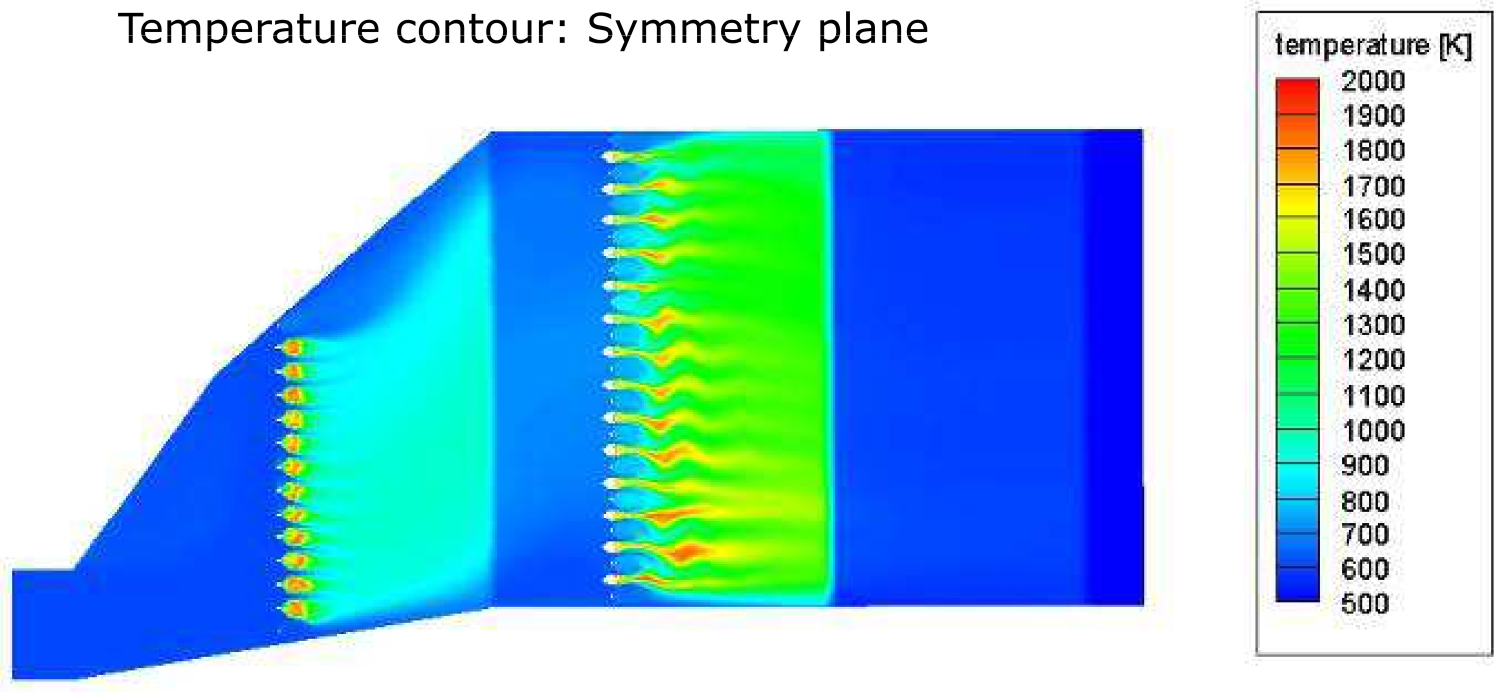
Results analisys

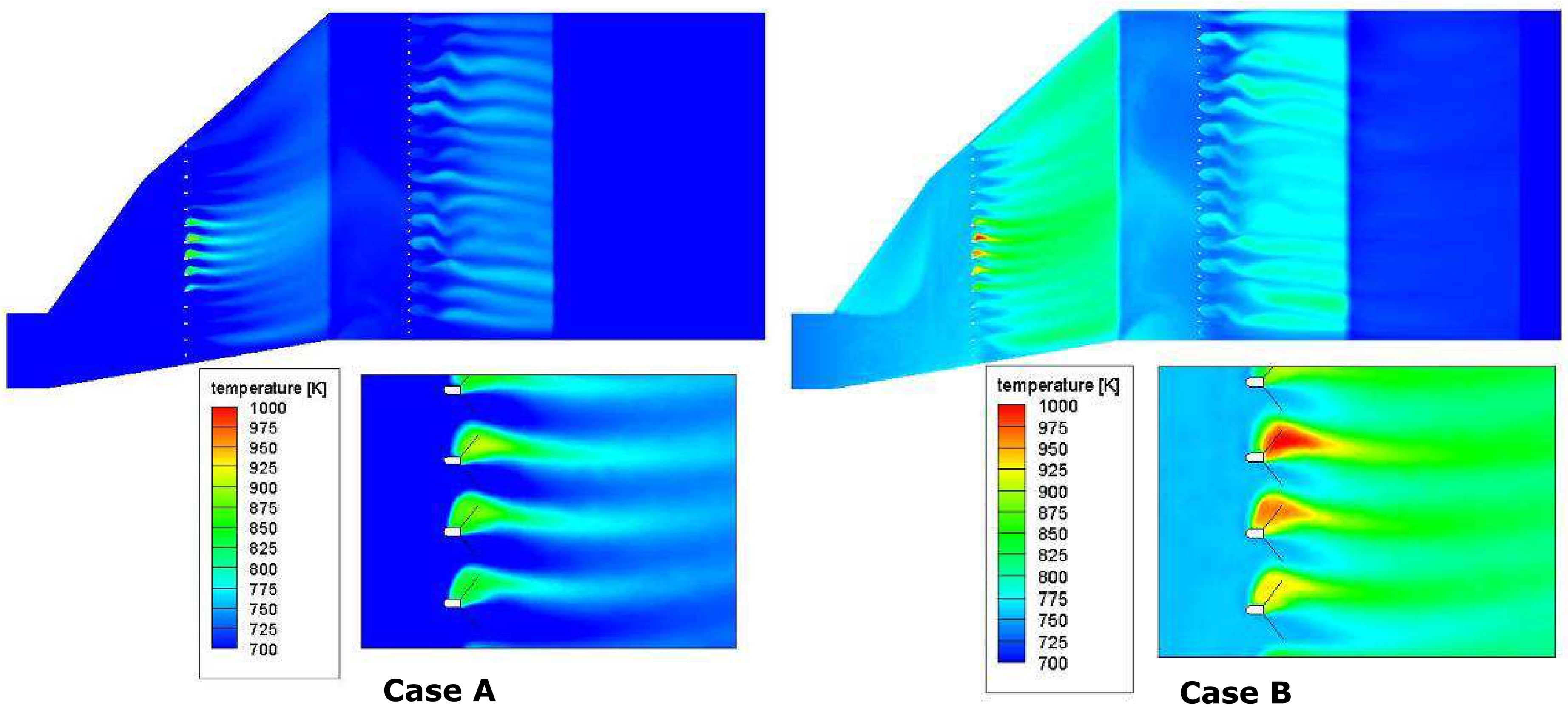
Case A

Velocity contour: Symmetry plane



Temperature contour: Symmetry plane

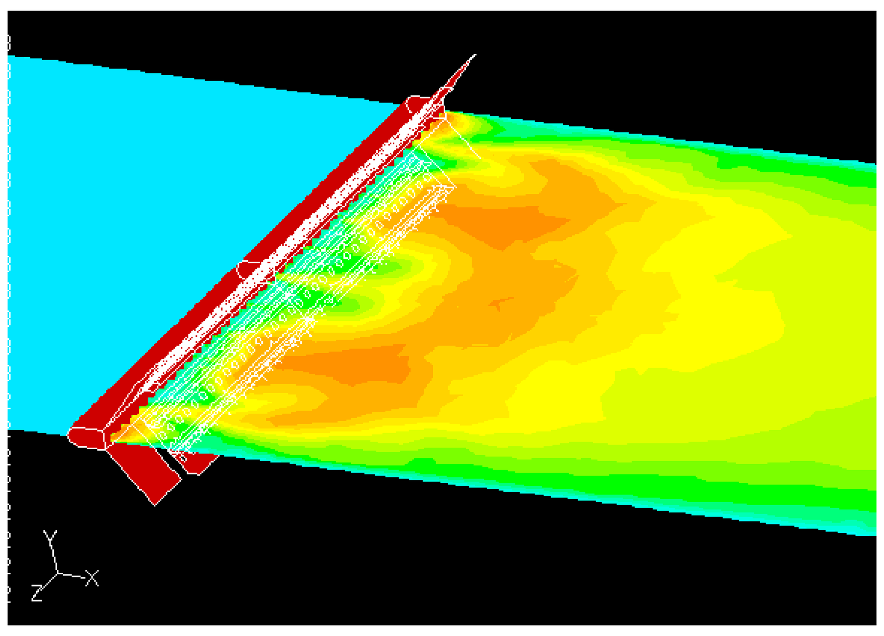




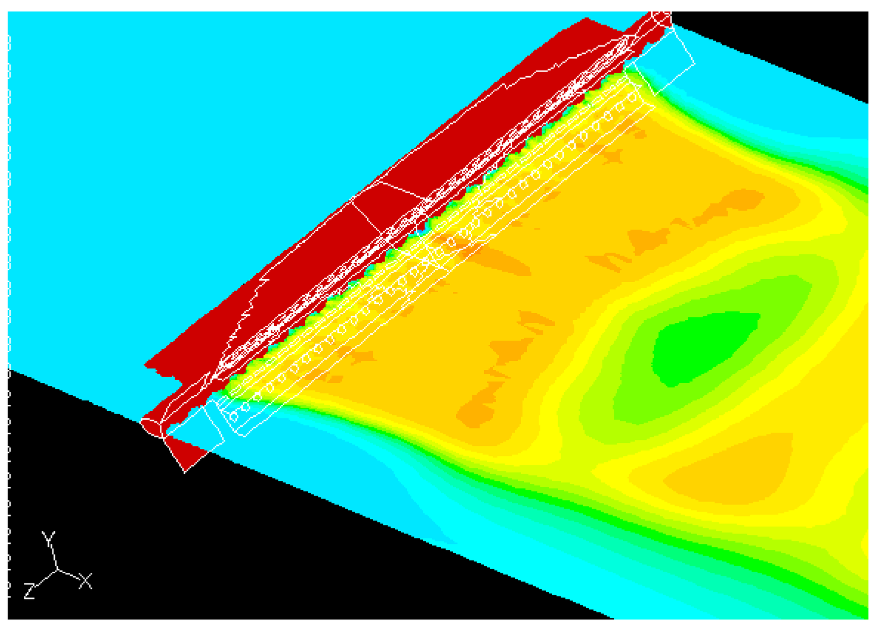
Temperature on side liner

Conclusion

The temperature of the liners are different in Case A and Case B but both seems to respect the upper limit of the used material (maximum allowed 1100 K).
The study underlines that special attention need to be given to the burners and their positioning with respect to the direction of the flow field. Indeed, how the burners are fed by the flue gas highly effects the combustion process.



Burner DB #1, 7th row - temperature contours (see hot spot close to the liner)



Burner DB #2, 7th row - temperature contours (no hot spot close to the liner)