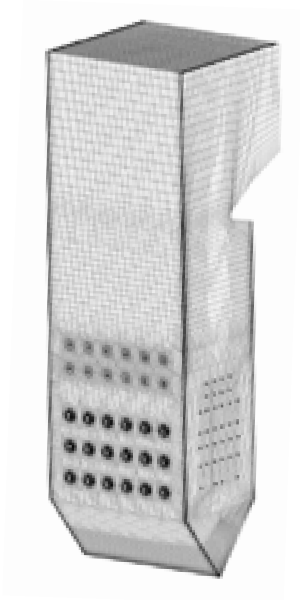
project update

CFD Modelling of Biogas co-firing in a coal-fired boiler

AN ECN KEMA COMPANY

Challenge

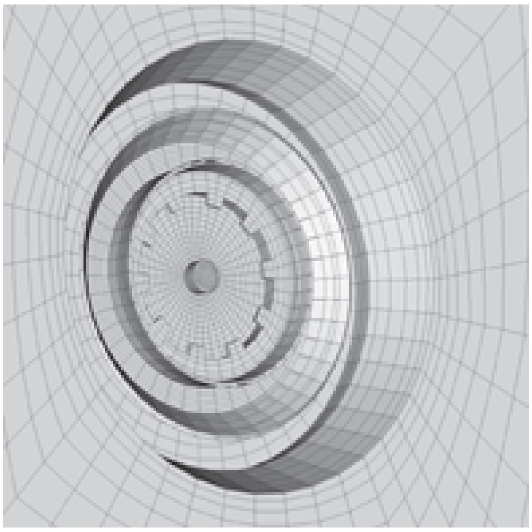
Hemweg Power Station unit 8 (640 MWe) near Amsterdam is a supercritical pulverised coal plant owned by Reliant Energy Power Generation Benelux. The plant came into operation in 1993 and has been upgraded over the years. Biogas co-firing of the plant recently came into consideration after the Dutch power industry and government established a convenant on the reduction of CO2 emissions. Biogas co-firing allows the use of existing installations with flue-gas cleaning and associated infrastructure and realises a relatively high efficiency of over 40%. However, boiler wall temperature distributions, NOx emissions, and CO induced corrosion may be adversely affected. CFD modelling of the furnace was applied in order to determine safe levels of biogas co-firing.



Computational mesh of the boiler

Plant

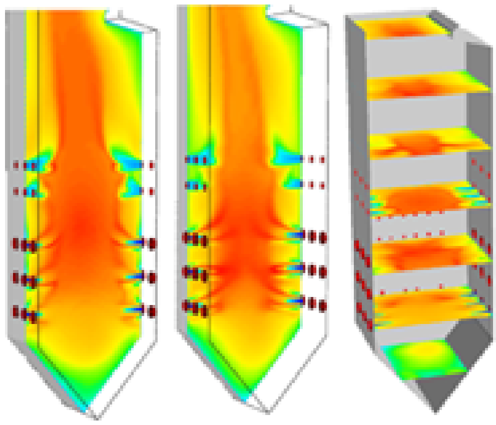
The boiler is a front-fired boiler, designed by Mitsui Babcock Energy Ltd and constructed by Stork Ketels BV under licence. It is of the radiant supercritical 'once through' type and is designed for firing a range of bituminous coals or natural gas to full load. The furnace dimensions were chosen to meet the requirements of low-NOx emissions in the flue gases whilst minimising the amount of unburned carbon-in-fly-ash; the performance specification for NOx emissions is 300 mg/Nm3. The front and rear walls each have three rows of six low NOx burners in an opposed arrangement. The pulverised coal is delivered to the burners through a pressurised piping system. The combustion air is drawn into the boiler system by two axial-flow fans and is heated up by two regenerative air heaters, in which the boiler flue gases heat both the primary and secondary plus tertiary combustion airs. To maximise NOx reduction, the combustion is two-stage with 24 over fire air ports (OFAs) arranged in two rows of six on the front and rear walls.



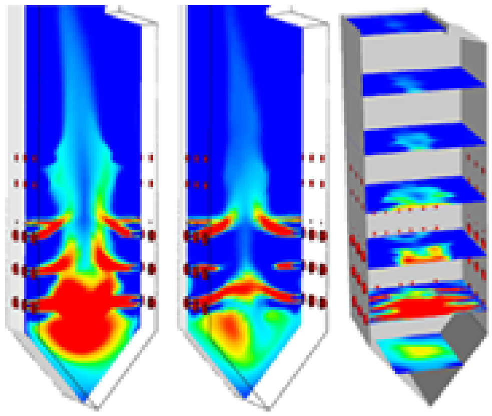
Mesh detail of the burner outlets

Approach

CFD provides an excellent method for quantifying the effects of efficiency improving and cost reducing measures, NOx reducing measures and co-firing of alternative fuels. The CFD geometrical model of the boiler covers the furnace section up to the first evaporator. In addition, separate models were made for a normal burner, a corner burner and a biogas burner, in order to obtain the correct boundary conditions for the full boiler model. A computational mesh of 1.6 million cells provided sufficient detail of the boiler model, including the outlets of the 36 lower burners and the 24 OFAs. The crucial elements in the physical CFD modelling were the two-phase flow model for capturing the flow trajectories of burning coal



Temperature distributions in the boiler

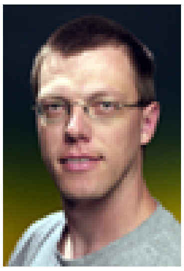


Concentration distributions of NH3 (intermediate in NOx formation)

particles in the multicomponent gas (air, volatiles, combustion products), the coal combustion model and the radiation model. For example, the presently applied combustion modelling included particle heating to correctly predict devolatilisation, and this requires modelling of convective and radiative heat transfer, combustion at the particle surface and inside the particle. NRG always pays attention to model validation, which is often hampered because of limited available plant data. In the present case, the computed positions of hot regions on the walls (and therefore of high thermal heat fluxes) matched with the picture available from operational experience. Even more convincing was that positions of enhanced damage could be traced back to origins based on the calculated process conditions.

Solutions

The CFD model enabled analysis of the effects of biogas co-firing on boiler process conditions. The optimum location for biogas co-firing ports can be established with the model. Effects of biogas co-firing on burn-out, thermal wall load, reducing condition at the wall and NOx emission could all be established. In addition, valuable insight was obtained into the combustion process in the furnace, on the basis of the detailed three-dimensional computed data. These comprised the velocity and temperature fields of the gas and particle phases; the concentation field of the coal particles; the residence times and trajectories of the coal particles; the CO and oxygen concentrations near the walls and the NOx production. Based on this information, the local thermal loads on the furnace walls could be established, and in particular regions of high thermal load. An additional result was the explanation of the mechanism of high wear in the primary burner duct, with the predicted location perfectly matching practical experience.



About the author:

Michiel Houkema has been working with NRG for five years. He has performed many projects on the design of innovative systems for energy generation and energy regeneration, including thermal acoustic cooling and Stirling engines and projects for the nuclear industry on hydrogen combustion reactor safety issues. His current main field of activity is CFD modelling of coal combustion. Michiel holds an M.Sc. in Applied Physics.

About NRG CAE's group:

NRG's Computer Aided Engineering (CAE) group has successfully applied CAE technology for customers in the power, offshore, petrochemical and machinery industries. The core competencies of the group are Processes-CFD, Structures-FEM, and Design-CAD. The expertise of the Processes-CFD team includes combustion technology for coal burners and gas turbines, two-phase separation and filtration processes, and reactive systems. The Structures-FEM team has proven expertise in plant integrity management for high temperature/high pressure applications. Some of our services in this field are: damage assessments, (probabilistic) residual life assessments, ageing management.

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