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Thermo-Chemical Euler-Lagrange CFD analysis applied to Wet Flue Gas Desulphurisation technology

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ABSTRACT

Wet Flue Gas Desulphurisation (FGD) technology is the most frequently used scrubbing process for sulfur dioxide (SO_2) reduction from coal-fired utility boilers.

A thermo-chemical computational fluid dynamic (CFD) model has been developed to describe the gas- and hydrodynamics of the scrubber, the liquid-wall interaction, the slurry evaporation and the sulphur dioxide absorption process in the slurry droplets. The continuous phase (gas) is modeled in the Eulerian framework while the discrete phase (liquid droplets) in the Lagrangian frame of reference.

The injected spray can be altered through droplet-wall interaction, droplet evaporation, droplet-droplet collisions and nucleation. The first two mechanisms are the most important in terms of the total volume flux of the sprayed liquid being affected. Therefore they are the only two considered and they are treated in separately developed submodels.

The empirical droplet-wall interaction handles impact, deposition and splashing events occurring when the liquid hits internal elements of the scrubber, i.e. wall rings, spray banks, guide vanes or scrubber walls.

The absorption rate of a droplet is a function of the physical mass transfer, the partial pressure of SO_2 in the gas phase and at the liquid surface and the chemical composition of the droplet. The Ranz-Marshall correlation has been used for the gas-side mass transfer coefficient, while the liquid-side coefficient has been predicted through the penetration theory. The SO_2-air binary diffusion coefficient is evaluated through the Fuller-Schettler-Giddings correlation while for the SO_2 diffusion coefficient in aqueous solution the value given by Gage has been used.

The chemical absorption model considers instantaneous equilibrium reactions of the slurry, i.e. acid-base reactions. At each trajectory calculation step of a droplet inside the scrubber, a non-linear algebraic system of eight equations is solved to calculate the liquid phase composition, which is given by the concentration of the following eight species: SO_{2aq}, CO_{2aq}, H^+, OH^-, HSO_3^-, SO_3^{2-}, HCO_3^-, CO_3^{2-} .

The k-ε model has been used for the continuous phase turbulence. Because of the low particle concentration (volume), the effect of the droplets on turbulence has been disregarded.

Simulation results show good agreement with measurements of industrial and pilot plant flue gas cleaning units.

The commercial code Fluent 6.3.26 has been used for the calculations, completed with the necessary subroutines for physical-chemical absorption and slurry wall interaction.

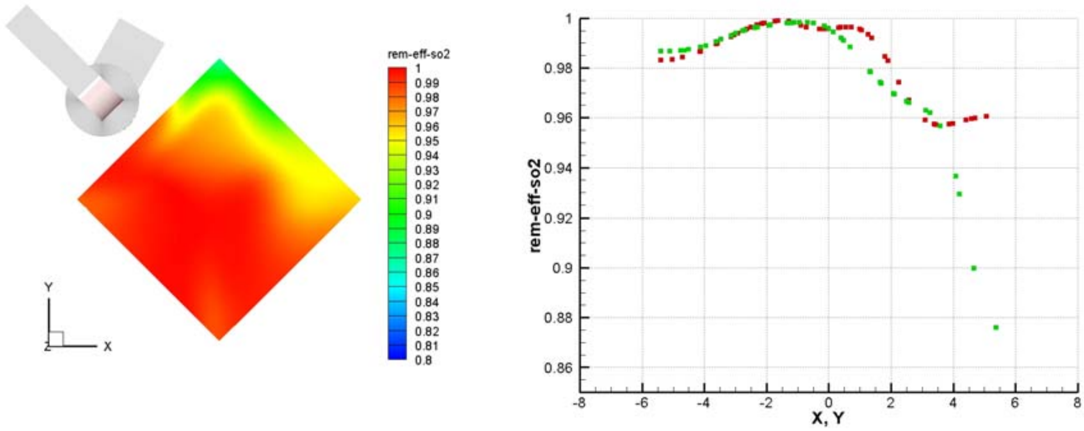

Figure 1: SO_2 field at FGD outlet; SO_2 distribution on two perpendicular axis

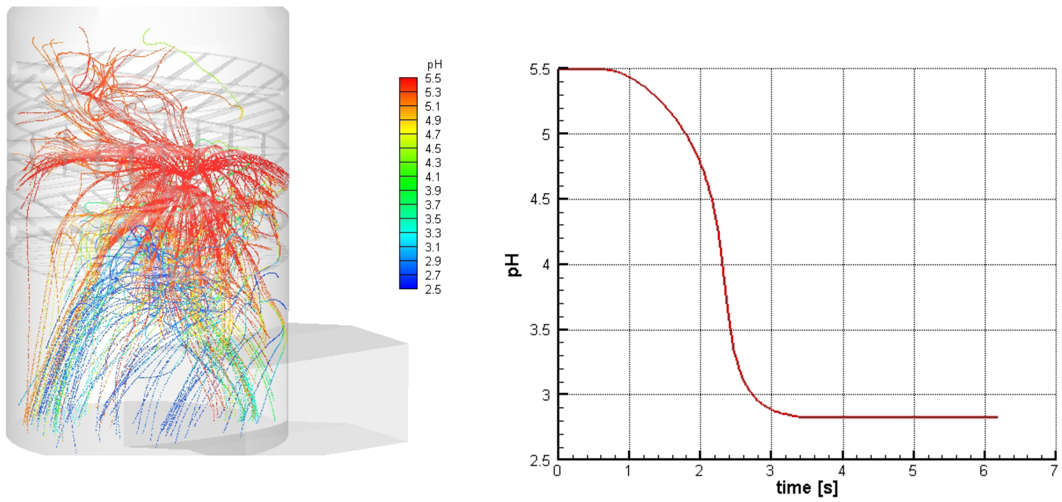

Figure 2: Droplets discharge from a hollow cone nozzle colored with pH; pH of a falling droplet

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