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Simulation of Wet Scrubbers for Flue Gas Desulfurization

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Abstract : Wet scrubbers are used for flue gas desulfurization by injecting water directly into the flue gas stream from a set of sprayers. The water droplets will flow freely inside the scrubber, and flow down along the scrubber walls as a thin wall film while reacting with the gas phase to remove SO_2. This complex multiphase phenomenon can be divided into three main contributions: the continuous gas phase, the liquid droplet phase, and the liquid wall film phase. This study proposes a complete model, where all three main contributions are taken into account and resolved using OpenFOAM for the continuous gas phase, and MATLAB for the liquid droplet and wall film phases. The 3D continuous gas phase is composed of five species: CO_2, H_2O, O_2, SO_2, and N_2, which are resolved along with momentum, energy, and turbulence. Source terms are present for four species, energy and momentum, which are affecting the steady-state solution. The liquid droplet phase experiences breakup, collisions, dynamics, internal chemistry, evaporation and condensation, species mass transfer, energy transfer and wall film interactions. Numerous sub-models have been implemented and coupled to realise the above-mentioned phenomena. The liquid wall film experiences impingement, acceleration, atomization, separation, internal chemistry, evaporation and condensation, species mass transfer, and energy transfer, which have all been resolved using numerous sub-models as well. The continuous gas phase has been coupled with the liquid phases using source terms by an approach, where the two software packages are couples using a link-structure. The complete CFD model has been verified using 16 experimental tests from an existing scrubber installation, where a gradient-based pattern search optimization algorithm has been used to tune numerous model parameters to match the experimental results. The CFD model needed to be fast for evaluation in order to apply this optimization routine, where approximately 1000 simulations were needed. The results show that the complex multiphase phenomena governing wet scrubbers can be resolved in a single model. The optimization routine was able to tune the model to accurately predict the performance of an existing installation. Furthermore, the study shows that a coupling between OpenFOAM and MATLAB is realizable, where the data and source term exchange increases the computational requirements by approximately 5%. This allows for exploiting the benefits of both software programs.

Keywords : desulfurization, discrete phase, scrubber, wall film
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