Turbulent mixing in DeNOx plants

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Industrial plant designers guarantee certain efficiency. In DeNOx plants for example the mixing process has a major influence on the efficiency. Sulzer Innotec can revert to several years experience in the simulation of turbulent mixing allowing us to quantitatively predict such applications.

DeNOx plants

In the last quarter century, air pollution has become a global environmental problem. NOx emitted from thermal power plants can be decomposed into harmless N_2 and H_2O in DeNOx plants through the addition of ammonia and the action of the catalyst (see figure 1). In the design of the reactor, it is important to obtain uniform gas flow to improve DeNOx performance and prevent erosion and plugging of the catalyst with dust. A uniform distribution of the injected NH_3 is also important for an efficient DeNOx performance. Numerical simulations can help to optimize the mixing process and, thus, to increase the efficiency of a DeNOx plant.

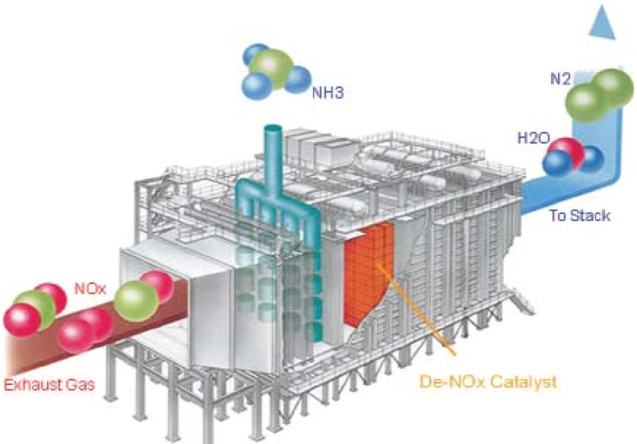
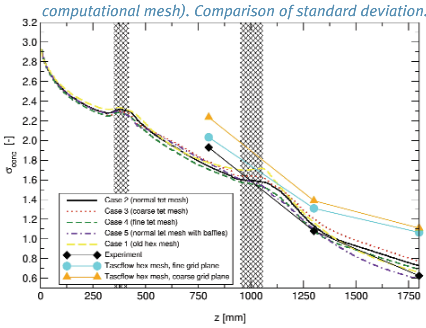


Fig 1: Schematic view of DeNOx plant

Turbulent mixing

Static mixers have been developed by Sulzer Chemtech for many years and cover several types such as SMI, SMV and Compact mixers. The optimization of such static mixers concerning the mixing efficiency and pressure loss is supported by Sulzer Innotec with numerical flow simulations. Measurements for most mixers and different flow conditions have been carried out by Sulzer Chemtech allowing for validations

Fig 2: Validation of CFD for SMV mixing device (variation of computational mesh). Comparison of standard deviation.



concerning grid topology and resolution as well as turbulence models, Schmidt number, etc.

Extended validations of an isolated mixing device with two SMV mixing elements have been undertaken. Numerical simulations have been performed on different grids such as three different resolution levels on a tetrahedral mesh and two different resolution levels on a hexahedral mesh. For simplicity, a tracer with identical fluid properties as the carrier gas has been injected at the upper side of the inlet. The standard deviations of the tracer in cross sections along the mean flow direction have been compared to measurements. Figure 2 shows the results of this study revealing that the measured standard deviations could be reproduced by computations. However, grid dependency could be shown as well, revealing the importance of choosing ➲

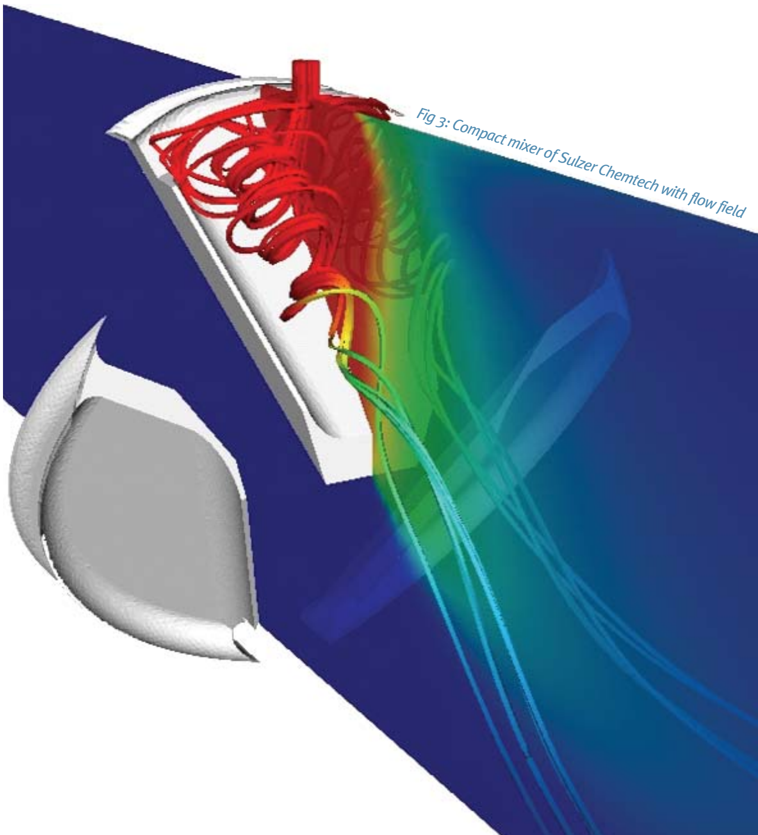


Fig 3: Compact mixer of Sulzer Chemtech with flow field

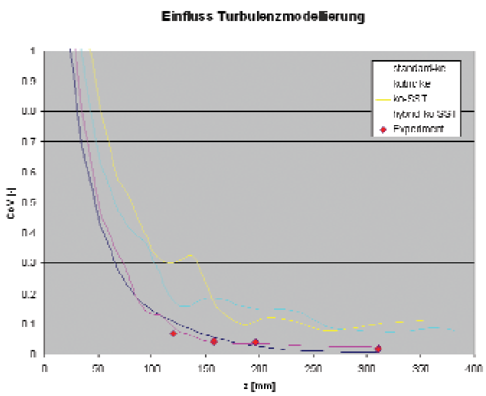


Fig 4: Validation of CFD for Compact mixer (variation of turbulence models). Comparison of "Coefficient of Variation".

the correct resolution for the respective type of grid.

The sensitivity of the turbulence model in the mixing process has been examined on the Compact mixer of Sulzer Chemtech (see Fig 3). The mixing device consists of three guide plates in a channel with a metered addition in the wake of the first plate. The turbulence models tested were the standard and the cubic k-ε model and the k-ω SST model. The k-ω SST model has been performed with the Low-Reynolds formulation as well as with the hybrid wall function approach. The comparison of the coefficient of variation (standard deviation of concentration in cross section divided by the mean concentration) has been reproduced best with the simulations considering the k-ε models (see figure 4). The cubic k-ε model showed instabilities around 100 millimetres behind the plates. Nevertheless, the agreement further downstream is better than in the simulation considering the standard k-ε model. The instabilities in the simulations with the k-ω SST model were larger resulting in a non-physical rise of the coefficient of variation in downstream direction. These instabilities can also indicate transient phenomena in the mixing process, which cannot be captured by the steady-state computations. Recent Laser-induced fluorescence (LIF) measurements on a similar mixing device (SMI mixer) revealed the transient behaviour. An ongoing study examines the transient behaviour and further turbulence models in Sulzer mixers with numerical simulations.

The validations performed on different mixing devices showed that turbulent mixing can quantitatively be predicted. However, they also revealed the importance of defining an appropriate mesh and using a suitable turbulence model. Transient effects may have to be taken into account.

Mixing in DeNOx-facilities

The mixing process plays a key-role in the design of a DeNOx plant as it has a major influence on the efficiency of the plant. The design is usually based on a model experiment to guarantee the promised mixing efficiency, as it is part of the contract. Numerical simulations of the entire plant support this designing process. The example shown here is the DeNOx system TXU in Mountain Creek (figure 5). This system consists of guide vanes, an ammonia-injection grid and the SMV mixer. Six different perforated plates were installed directly upstream of the catalyst. The catalyst itself has been approximated by a porous volume considering the correct pressure loss. No chemical reactions have been accounted in this simulation. The simulations were performed for different operating conditions. Examined parameters were the NH_3 distribution in a cross section upstream of the catalyst as well as the pressure drop over the plant. Adjustments could be made on the guide vanes and the mixing device to obtain a minimal pressure drop for the required NH_3 distribution.

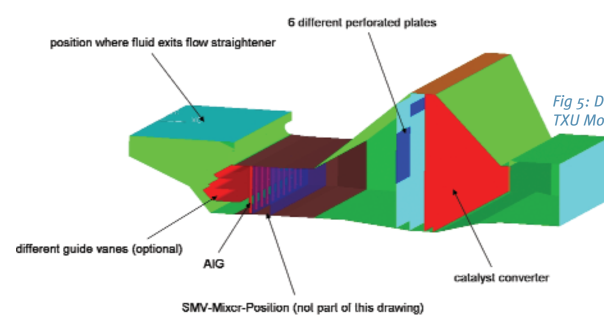


Fig 5: DeNOx system TXU Mountain Creek

Conclusions

Our experience with the simulation of turbulent mixing allows us to quantitatively predict applications like DeNOx systems. A fast mesh generation is essential for the complex geometries of DeNOx systems including hybrid methods with meshes of hexa /prisms /tets and pentas. The generation of pro-STAR meshes is feasible when the use of sublayers is not considered. Unsteady effects in the turbulent mixing process become important and are part on an ongoing study.

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