Optimization of SCR Denitration Reactors' Flow Field Uniformity and Design of Its Splitters

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Abstract: Based on CFD (Computational Fluid Dynamics), the internal flow of SCR(Selective Catalytic Reduction) denitrification column is simulated. With the application of standard k-ε two equation model and porous media model, the velocity field of smoke movement is represented. The influence rules deflector put on smoke movement can be concluded from the numerical simulation. Therefore, with adjusting the optimum combination scheme of multi splitters, the velocity deviation coefficient of first-layer catalyst is decreased to 15%.

Introduction

With the continuous advocacy and attention to the green economy, in the combustion of coal to obtain energy to promote the economy, at the same time, the release of a large number of NO_X caused by air pollution problems are increasingly serious, nitrogen oxides NO_X pollution of the atmosphere can not be ignored, its governance is imminent, flue gas denitration technology came into being.Compared to other denitration technologies. SCR denitration system is compact, high reliability of equipment operation, reduction of nitrogen can be directly discharged into the air, there is no secondary pollution[1].

After many years of experience,it was found that there was a problem of internal flow field inhomogeneity in SCR denitration reactor : due to the centrifugal force, when the high speed flue gas passing through steering angle, and the flue gas reaches the upper surface of the catalyst, it is concentrated on one side, resulting in the use of the catalyst is not complete,replacement frequency increases, directly caused the denitration tower equipment operating costs. In the domestic, the flow field uniformity is improved by adding splitters in the non-uniform position of flue gas, this article is designed for the 390 thousand m^3/h SCR denitration tower deflector , making the device flow uniformity to meet the requirements of enterprises and customers.

The object of study and the determination of numerical simulation model

The working principle of the SCR denitration reactor. This topic research by 390 thousand m^3/h SCR denitration reactor structure is shown in fig. 1. Its working principle is that the gas arrives the reactor inlet through the boiler flue, then exports into the reactor along a horizontal flue, finally after the first 90° bend into the vertical flue. The gas mixed with ammonia sprayed with ammonia spraying system in flue gas containing high concentration of nitrogen oxides (NO_X).At this point, nitrogen oxides and ammonia is basically not reaction, because the reaction temperature is generally controlled at around 980℃ in the absence of catalyst[2]. The mixed gas is rectified through the rectifying grid so that the flue gas can vertically reach the surface of the first stage catalyst. Then after three stages of catalysis, the chemical reaction mainly for $4NH_3+4NO+O_2 \rightarrow 4N_2+6H_2O$, nitrogen oxides in flue gas was reduced to N_2. Finally the gas arrive the boiler inlet and into the next process system through the air filter.

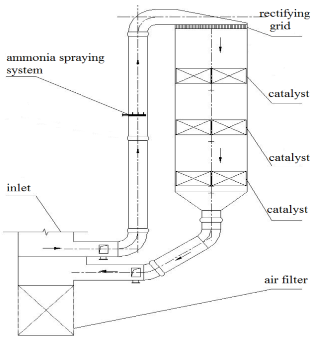

Fig.1 SCR denitration reactor

Mathematical model controling equation. This research is the three-dimensional turbulent flow of SCR denitrification system, turbulence model is standard *k*-*ε* two equation model. In numerical simulation of flue gas flow field, We make the following assumptions: (1)All gases are ideal gases; (2)Without considering the chemical reaction and influence in the process of flue gas flow; (3)The whole system is adiabatic, and no leakage; (4)Simplify or ignore the internal parts that have little effect on the flue gas flow in the equipment.Based on these assumptions, the governing equations can be expressed as follows[3]

$$\frac{\partial(rf)}{\partial t}+div(ruf)=div(\Gamma grad f)+S \qquad (1)$$

Here, f is universal variable, Γ is generalized diffusion coefficient and S is generalized source term. r is fluid density, u is speed, t is time. There are transient term, convection term, diffusion term and source term.

Model of porous medi. When simulating the honeycomb catalyst bed, in the numerical simulation, according to the actual size of the catalyst,t he mesh number will reach tens of millions so that the computer cannot simulate. Therefore, the catalyst bed is setted up as a porous media model, which is not so demanding on the grid,and can meet the requirements of simulation calculation. The momentum equation of porous media model has additional momentum source term. which a simple uniform porous medium can be expressed as follows[4]

$$S_i=\frac{u}{a}v_i+C_2\frac{1}{2}r\left|v_j\right|v_j \qquad (2)$$

Here, S_i is i direction momentum source term, u is laminar viscosity, a is medium permeability, v_i is i direction velocity component, r is density, C_2 is internal resistance factor.

Numerical simulation of SCR denitration reactor and optimization of splitters

Optimization goal. The enterprise requirements is that speed deviation coefficient value is less than 15% in the first catalyst upstream 200mm, namely C_V <15%. The velocity deviation value C_V is calculated as follows[5]

$$C_V=\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{V_i-\bar{V}}{\bar{V}}\right)}\times100\% \qquad (3)$$

Here, V_i is Velocity value for each measurement point, $\bar{V}$ is Average velocity on the measuring surface.

Before designing the guide plate , we first to simulate non-optimized the denitration tower flow field , as shown on the Fig.1.The velocity deviation coefficient is 40% at this time. Obviously, This is not in line with the requirements of the work. It can be seen that the velocity is large on the right side of catalyst, it is consistent with the actual situation at the scene.We need to develop a draft plan to guide the more uniform distribution of flue gas.

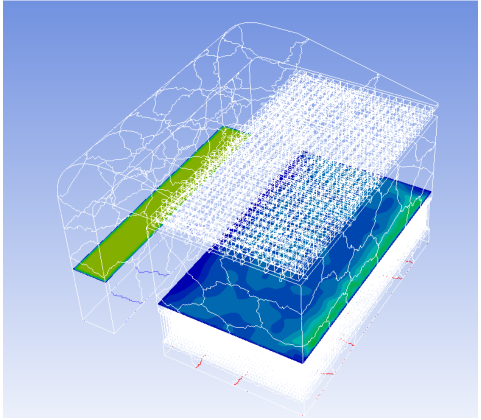

Fig.2 non-optimized the denitration reactor flow field

Design of the single splitter. Before multi splitters combination optimization, we first designed the single guide plate, I can get the influence factors and influence rules of deflectors on smoke movement. The single plate installation diagram is shown in Fig.3. The length of plate is 400 mm and its angle is 37°. The numerical simulation results of the reactor with the single plate is shown in Fig.4.

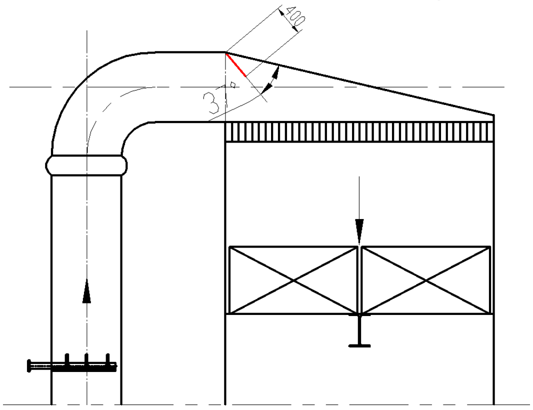

Fig.3 the denitration reactor with the single splitter

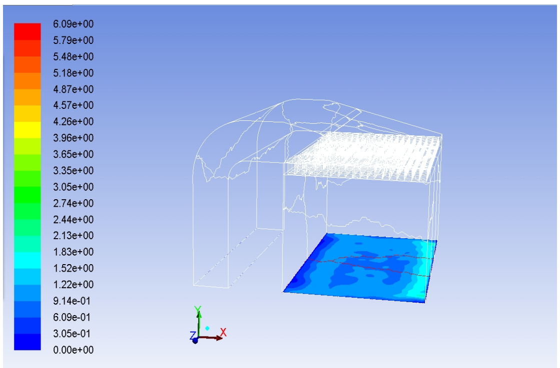

Fig.4 the finite element analysis of the single splitter

As can be seen from Fig. 4, the uniformity of flue gas has been optimized.The velocity deviation coefficient is 23% at this time.The experiment of single guide plate provides the basis for the subsequent optimization of multi guide plate combination, but it can also be found that the effect of single diversion plate is limited. The velocity deviation coefficient is still high. Thus, it shows the necessity of multi diversion plate combination scheme.

Optimization of multiple flow guide plates combination. A plurality of guide plates are arranged at the elbow of the SCR denitration tower, and the flue gas is guided by adjusting their angle, position and length. The function of the deflector is to adjust the high speed flue gas, so that the flue gas does not enter directly to the right side of the reactor.The numerical simulation results of the reactor with the multiple splitters is shown in Fig.5.

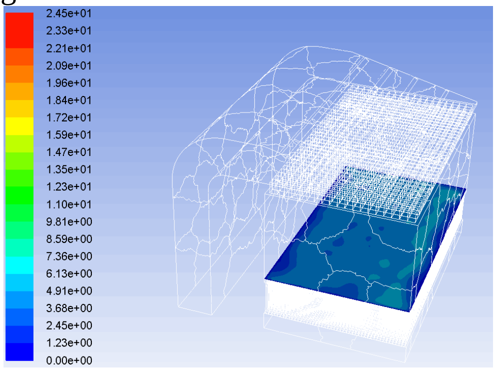

Fig.5 the numerical simulation of the multiple flow guide plates

As can be seen from the finite element nephogram (Fig. 5), The velocity concentration of catalyst in the right side is obviously improved, and the condition which there is no smoke on the left side of the reactor is also perfected. At this time, the velocity deviation coefficient is 14.7%, and the optimal rate is 63%. It met the requirements of the work.

Conclusions

The distribution of the gas velocity field can not meet its working requirements in the non-optimized.The speed deviation coefficient is high so that we need to improve its internal flow through adding splitters.From the simulation results, we can see that the velocity deviation coefficient has been greatly reduced, however, the optimization scheme is very ordinary and feasible.

The numerical results are in good agreement with the actual working conditions of SCR denitration tower.Therefore, we using numerical simulation method can easily get different design scheme, its advantages are low cost and short cycle-time.The simulation results have some reference value. Compared with other test methods, it have obvious advantages.

Acknowledgements

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