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Numerical Simulation of the Alumina Distribution in the Pot Room and the Surrounding Ambient Environment

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Abstract: *Although the modern pot line was well designed in environmental protection, the alumina still took the chance to release in the air during alumina transporting, storing and anode changing process. Due to its abrasiveness, the alumina is harmful for the moving joints in facilities. To evaluate the influence, it is significant in positioning the space that the alumina can reach. A numerical model of the alumina distribution was established based on the air flows. The CFD model was developed in which the basement, pot room, roof venting and the surrounding ambient environment were included. The thermal and fluid flow profiles and alumina particle distribution were investigated under different winds and the atmospheric temperature. The results of the CFD modeling were analyzed and suggestion was proposed.*

Keywords: *Pot room; Numerical simulation; Alumina distribution; Fluid flow profile*

1. Introduction

The main equipment in the pot room of aluminum electrolysis plant was the electrolytic cells, which continuously emit heat, gases (mainly fluorides) and particulate pollutants to the surrounding environment. If a large amount of waste heat and pollutants could not be effectively discharged and dissipated to the work area, workers would be affected by high temperature and dirty airflow, and their health would be greatly threatened. Most of the flue gas and pollutants were collected by the cleaning system tubes. However, some of the flue gas mixed with fine alumina particles could not be effectively exiled by the flue gas purification system, especially when the hoods of cell were open.

In the electrolysis pot room, alumina particles were emitted outside due to operations such as feeding or anode replacement, and mixed with the air in the pot room. Since alumina particles are wear-resistant materials, they would greatly promote the corrosion of operating equipment, increase equipment failures, and reduce equipment life. Therefore, it is of great significance to study the spatial distribution of alumina powder in the pot room.

Lin et al [1] used numerical simulation to study the transport and deposition of nano- and micro-particles in turbulence flow field. Simulations of the instantaneous turbulence fluctuation with and without turbulence near wall correction, and particle trajectory analysis were performed. The simulation results for different cases were compared with the available experimental data, and the accuracy of various turbulence model and near wall function was proved. Dehhi et al [2] used the Lagrangian continuous stochastic model to study the diffusion behavior of particles under the action of thermophoresis. Hryb et al [3] presented both Lagrangian and Eulerian models for particle transport by a turbulent fluid phase. In the Lagrangian formulation the dynamic equation for the particles was solved. A discrete random walk model was used to account for the turbulent effects. In the Eulerian formulation, the particle concentration was calculated from a convection–diffusion equation using the terminal particles' velocity and turbulent diffusivity. Both models were compared to experimental measurements and analytical results and good agreement was observed.

There are little open literature on the simulation study of alumina particles in pot room. In this paper, the Lagrangian method will be used to study the diffusion and spatial distribution of alumina in pot room and surrounding ambient environment.

2. Model

2.1. Physical model

In the actual project, an aluminum electrolysis pot lines consisted of two two-story workshops with a span of about 30m and a length of about 1000m, which were parallel to each other. The distance between the two workshops was more than 40 meters. The facilities inside the workshop were extremely complex. The model established entirely in accordance with the real electrolysis workshop required a considerable amount of computing resource, which beyond the current computer power. In addition, some factors had little influence on the calculation results (such as the thickness of the operating floor). Therefore, in order to establish a CFD simulation model of the pot room that could be solved, this paper reasonably simplified the factors that had less influence on the ventilation of the factory building on the following assumptions.

(1) In the actual production of the aluminum electrolysis plant, there were process operations such as anode replacement and aluminum siphoning. During these operations, additional heat would be dissipated into the environment. However, the operation was a short-term process. If the dynamic simulation was used, the calculation time was quite large. Therefore, this paper selected the state of most of the time in the workshop, that was, the stable state when there was no process operation and no operator movement.

(2) The butts replaced in the actual operation would be cooled and dissipated in the workshop, but the time of heat dissipation was uncertain and the heat dissipation could not be calculated, so the model didn't consider the cooling process of the butts.

(3) The flue gas generated by the electrolytic cell was discharged from the pot room through the tubes. The flow of the flue gas in the electrolytic cell had little effect on the gas flow in the pot room and was not considered by the model.

(4) The steel roof trusses of the pot room building was very complicated, so the model did not consider the effective blocking of the steel frames.

(5) The actual length of pot room was about 1 km, it was too long for computing. Therefore section segment of the pot room including one cell was used the model.

(6) The outer surface of the electrolytic cell was complex, however, the heat dissipation was relatively stable. The surface was divided into several parts according to the location and each part was assumed as isothermal surface in the model.

(7) Although the hoods of the electrolytic cell was separated by gaps in reality, it was tightly placed ideally in the model.

2.2. Boundary conditions

(1) Ambient air inlet boundary

The external natural wind had an important influence on the air flow in the pot room. In this study, the boundary condition of the air inlet was set to a given speed. In order to examine the influence of wind speed, the inlet horizontal wind speed was set to 0m/s, 1m/s separately, the temperature was 300K, and the pressure was 101325Pa.

(2) Ambient air outlet boundary

The ambient air outlets was at the top and the downwind side. It was set as free interface that the air could go in and out freely. The temperature was 300K, and the pressure was 101325Pa.

(3) Cell surfaces boundary

The bottom, side, hoods, and superstructure of the electrolytic cell were set as different isothermal surfaces. The temperature was taken from the average value of the measurement.

(4) Alumina source

There was some leakage of alumina in the conveying process of air slide and silo, etc. In the process of feeding, anode changing and other operations, alumina particles would be released into the environment. In order to simplify, the alumina source point of this model was placed at the hood at on each side of current upward and current downward.

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2.3. Simulation model

The simulation model comprise of ambient air, pot room, cell and ground was shown in Figure 1.

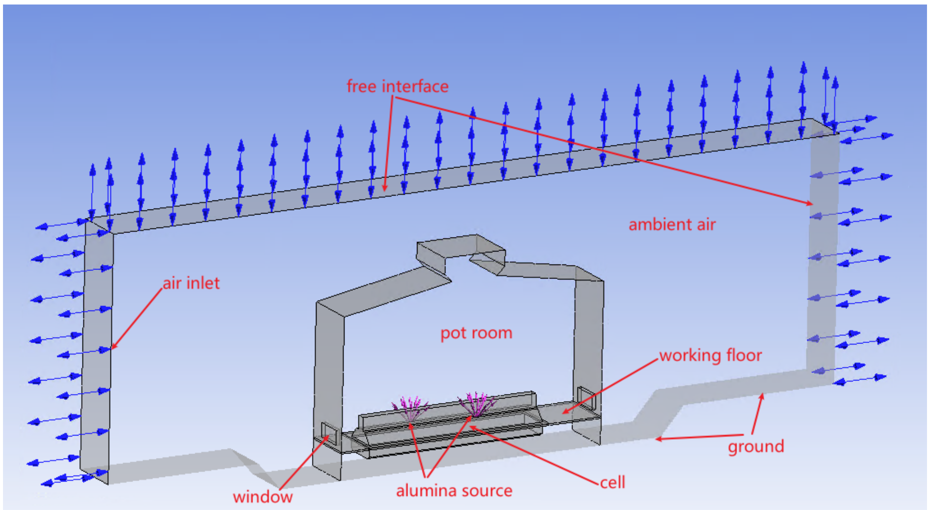

Figure 1: The simulation model.

3. Results and discussion

By analyzing the air flow pattern, alumina distribution and external wind speed in the pot room, different factors affecting the spatial distribution of alumina were studied.

3.1. Without outside wind

When there was no wind outside, the velocity vector of the wind flow in the pot room was shown in Figure 2 below. The electrolytic cell were powerful heat sources that constantly heat the surrounding air, creating a chimney effect. Outdoor air entered from the lower window of the ground floor, flows through the grilles around the electrolytic cell, and exited through the ceiling windows, carrying away heat and pollutants. The indoor air forms two large vortexes, which rose above the electrolytic cell to the top window of the ceiling. Except for part of the flue gas emitted out of the pot room, part of the flue gas flowed back , and went down along the walls on both sides, and then flowed to the electrolytic cell near the working surface. And finally it reached the cell and joined the rising flow to form another cycle.

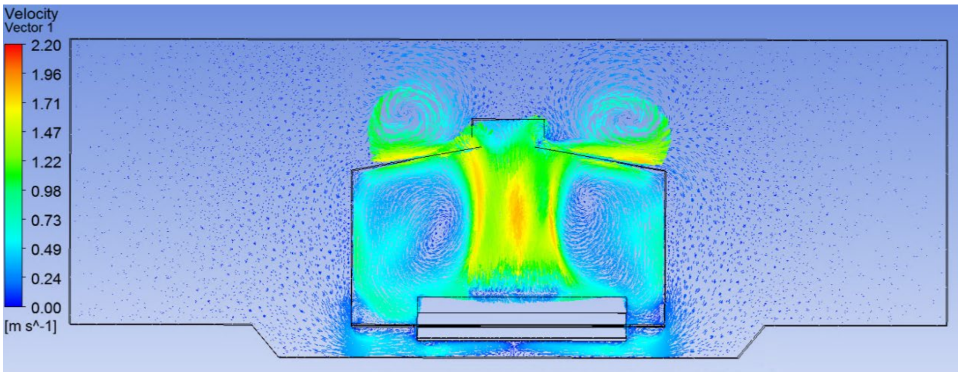

Figure 2: The velocity vector of the middle plane at no wind condition.

The flow pattern of alumina particles was shown in Figure 3. Most of the alumina particles fall down to the hoods and slides down, then settled right down the electrolytic cell. The top view of alumina volume fraction at ground was shown in Figure 4. It showed that volume fraction of the alumina locates along two side the electrolytic cell on the ground. However, after being captured by the flue flow, part of alumina particles flied along with flue air as shown in Figure 3. In the half part near the tape end, a small amount of alumina particles drifted with the flue gas. And in the other half part near the duct end, a large amount of alumina particles drifted with the flue gas.

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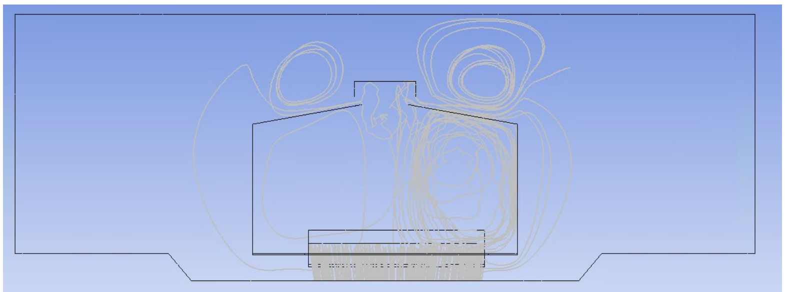

Figure 3: The alumina particle moving track at no wind condition.

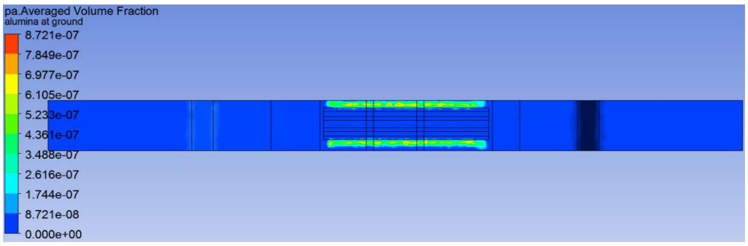

Figure 4: The top view of alumina volume fraction at ground.

The alumina volume fraction at the horizontal section of the crane rail height was shown in Figure 5. Since there was dense volume fraction of alumina at the duct end, at the height of the crane rail, the alumina particles tended to be piled up on the rail plane as shown in Figure 3 and Figure 5. To avoiding powder problem, it was suggested that the equipment fixed on the crane be air tighten.

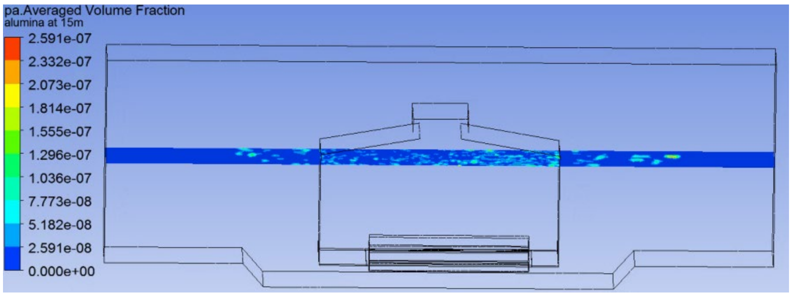

Figure 5: The alumina volume fraction at the horizontal section of the crane rail height.

3.2. The influence of wind

When there was horizontal wind outside from tape end, the velocity vector of the wind flow in the pot room was shown in Figure 6 below. Outdoor air entered from both the lower window of the ground floor and the upper window of the working floor in the upwind side, flowed through the grilles around the electrolytic cell, and exited through the ceiling windows, carrying away heat and pollutants. Other than the flue circulated mainly in the pot room in Figure 3, the air outside of the pot room flowed through the pot room with little wind circulated in the pot room.

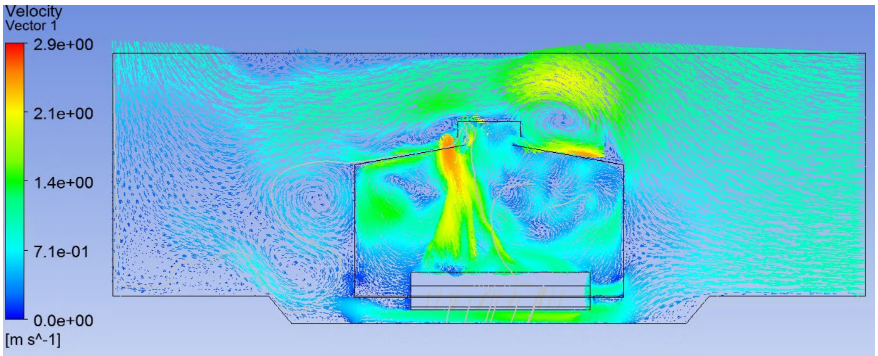

Figure 6: The velocity vector of the middle plane at wind speed of 1m/s.

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The flow pattern of alumina particles was shown in Figure 7. Most of the alumina particles fall down to the hoods and slid down, then settled right down the electrolytic cell. The top view of alumina volume fraction at ground was shown in Figure 8. More alumina particles flied along with flue air and more alumina particles were released from the pot room to the ambient environment.

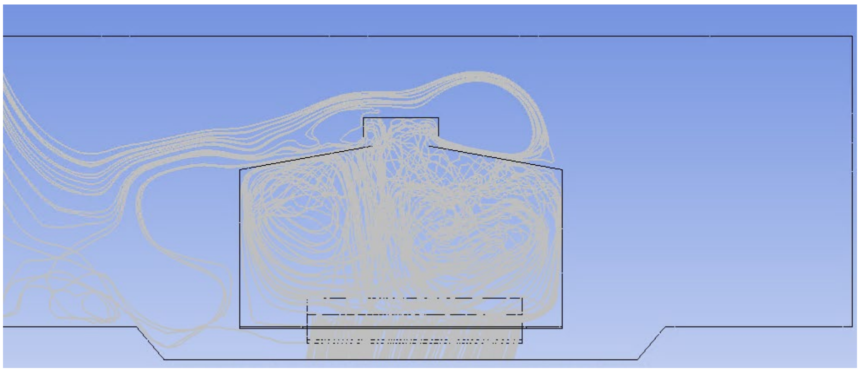

Figure 7: The alumina particle moving track at wind speed of 1m/s.

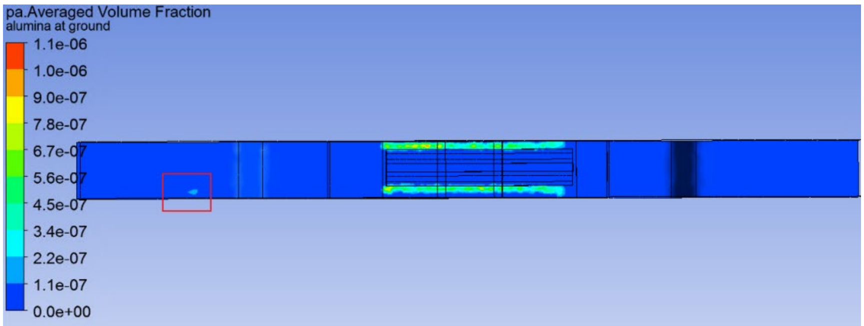

Figure 8: The top view of alumina volume fraction at ground at wind speed of 1m/s.

4. Conclusions

In this paper, the computational fluid dynamics method was used to simulate the distribution of alumina in the pot room and outside natural ventilation under the combined action of thermal pressure and wind pressure, and the following conclusions and suggestions were drawn.

(1) Without wind outside, in the pot room, the alumina particles mainly settled right under the electrolytic cell, part of particles tended to accumulate. It was suggested that the equipment fixed on the crane be air tighten, especially for the equipment at the duct end.

(2) When there was wind outside, the air outside of the pot room dominated the flow pattern. More alumina particles were released from the pot room to the ambient environment.

(3) The particle size distribution of real alumina was wide, wind direction and velocity varied and further research was needed.

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