CFD Modelling of Particle-Laden Gas Flow and Filtration Through Porous Media

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Abstract

Particle-laden flows are quite common in industry. In some cases, a reaction takes place between a component of the gas and the particles. Then, the particles are filtered through a porous media to avoid their emission to the environment. In aluminum industry, filter bags are used to retain particles. After validation, a mathematical model for such systems could be a highly useful tool to test various operational and design parameters. However, the representation of the particle deposition on a filter media is highly complex to model.

A three-dimensional transient mathematical model was developed to represent a system in which a gas flow enters, a certain concentration of small particles is injected into the gas stream, and the gas leaves through a porous media where the particles are to be filtered. The porous media with a certain thickness represents the filter bag. The conservation equations for the gas flow and solid particles are obtained using the phase equations of the Algebraic Slip Model (ASM). The turbulence model used is the standard k-ε model with the wall function treatment. The porous media settings are defined according to the Ergun equation. The model equations are solved numerically by the commercial code ANSYS-CFX19.5. A parametric study was carried out to determine the effect of some parameters such as particle injection velocity and concentration. In this paper, the model will be described, and the results are presented for some cases.

Keywords: Gas flow, CFD simulation, Porous media, Algebraic slip model.

1. Introduction

Commercial aluminum production is based on the Hall-Héroult process during which alumina is reduced to metallic aluminum in an electrolysis cell. The exhaust gas contains SO_2 coming from carbon anodes which are regularly consumed and replaced after 20–25 days. SO_2 can be removed from the exhaust gas by using dry hydrated lime. The study consists of a simulation of a laboratory scale reactor in which hydrated lime and SO_2 are brought in contact to achieve the target SO_2 removal level.

This paper describes a work in progress. The flow field within the reactor as well as the concentration distributions of various gas components - air, $Ca(OH)_2$ particles, and SO_2 - in the reactor are presented. The particle filtration and the reaction between SO_2 and hydrated lime are not yet incorporated into the model.

2. Mathematical Formulation

The model considers a simple reactor in cubic form which contains a filter bag. Figure 1 shows the geometry of the physical problem. There is one inlet for the mixture which is composed of two gas phases (air and SO_2) and one dispersed phase of solid $Ca(OH)_2$ particles, and one outlet. The filter is defined as a porous media (shown in green on Figure 1). The adopted approach in this study consists of solving the flow and the mass fraction of SO_2 and $Ca(OH)_2$ using the Algebraic Slip Model (ASM) under isothermal conditions.

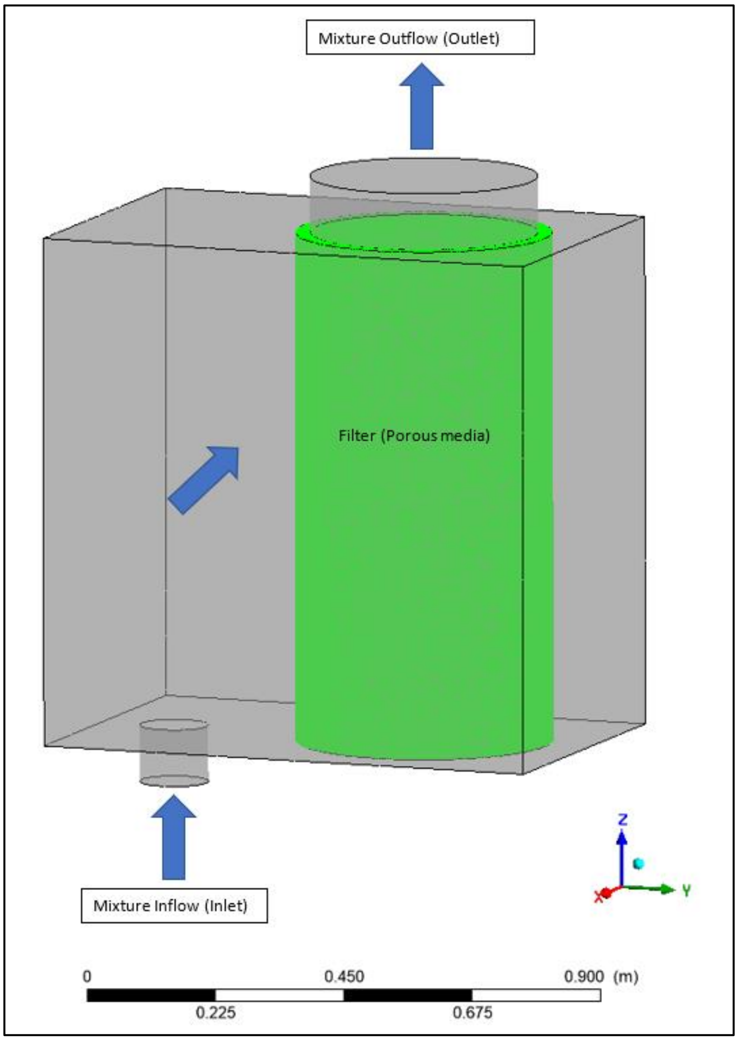

Figure 1. Schematic representation of the physical model.

It was assumed that:

- The flow field is turbulent, and
- The gravity effects are negligible.

The ASM formulation of a multi-phase model for n-interpenetrated phases of a multi-fluid model was first introduced by Ishii [1]. In this model, a system is represented with a mass and a momentum balance for the whole mixture and a mass conservation equation for the n-1 phases. Manninen and Taivassalo [2] presented the complete derivation of the model.

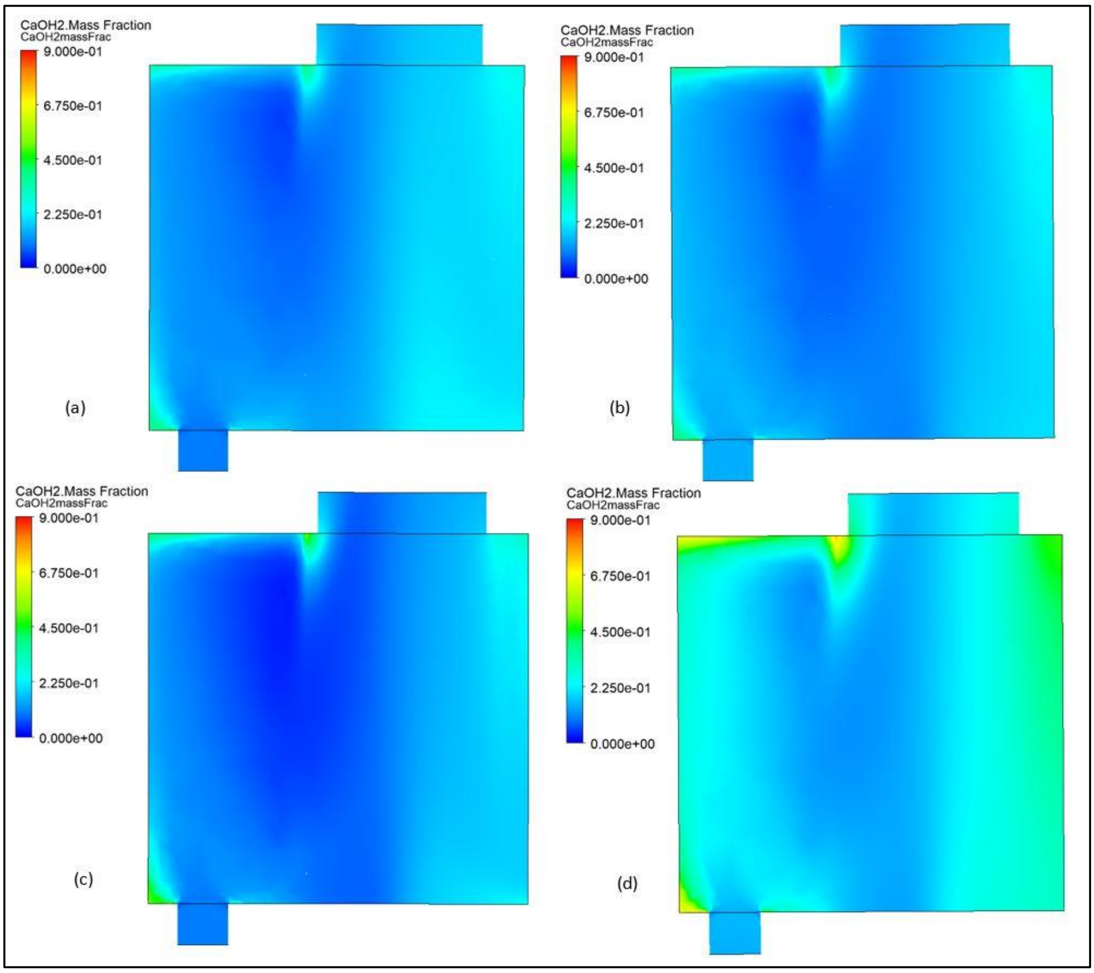

Figure 4. $Ca(OH)_2$ mass fractions for different inlet velocities and $Ca(OH)_2$ inlet mass fractions, respectively. (a) 7 m/s and 10 %, (b) 7 m/s and 15 %, (c) 10 m/s and 10 %, and (d) 10 m/s and 15 %.

5. Conclusions

A numerical simulation of a fluid flow through a filter (porous media) has been carried out by solving the algebraic slip model equations for a mixture of a gas phase (air) containing SO_2 and a dispersed phase for $Ca(OH)_2$. The computational fluid dynamic software, ANSYS CFX19 is employed to solve the system of continuity and momentum equations for the mixture and each phase. The results show expected trends. Work is continuing to incorporate the particle filtration and the chemical reaction for sulfur removal.

6. References

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