Journal of Advanced Mechanical Sciences (JAMS)
ISSN: 2583-3790 (Online)
"J. Adv. Mech. Sci., vol. 1, no. 2, pp. 63-67, June 2022"

Studies on Numerical Analysis in Electrostatic Precipitator – A Review

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Article received: 05/05/2022, Article Revised: 31/05/2022, Article Accepted: 02/06/2022
Doi: 10.5281/zenodo.6802876

Abstract

Electrostatic precipitators (ESP) have gotten a lot of attention lately because of their great efficiency and low cost. Designing ESP for applications in the industry, numerical simulation is generally used as it is a powerful, cost-effective, as well as an adaptable tool. The numerical models of ESP that are available simulate different physical processes, such as electric field ionization, movement of air, charging of particles and their motion, are summarized in this paper. We know that existing models could produce results within acceptable range, and computing power needed for applications in industry are not very large.

Keywords: *Electrostatic precipitator, Electro-hydro dynamic flow, Ionized electric field.*

1. INTRODUCTION

Electrostatic precipitator use electrostatic forces to remove suspended flue gas particles. Wires to plates configuration is the most common used configuration of ESP in the industry. Industrial ESP is structurally complex as well as have a complex transport phenomenon. It involves electric field and gas particles flow and have a strong interaction between them. Correct modelling of ESP is very important for increasing efficiency as well as optimization of ESP. Optimization is done by predicting how the flow field will behave as well as trajectory of particles inside the ESP.

2. NUMERICAL ANALYSIS IN ELECTROSTATIC PRECIPITATOR

Achouri et al. [1] this paper studies corona discharge in two planes wire configuration. Finite element method based iterative calculations were used for determining effect of wire thickness, plate spacing etc on parameters like electric field, space charge density, electric potential distribution. From analysis it was found that electric potential and wire height are in proportion directly and inversely proportional to distance, electric field and current density decreases away from wire. From the study we can see types of analysis that are possible using FEM on COMSOL Multi-physics software.

Haque et al. [2] the authors present a CFD model of wire plate electrostatic precipitator. k-ε turbulence model is used for modelling the turbulence and for calculation of gas flow Reynolds-averaged Navier-Stokes equations are used. DPM (Discrete Phase Model) is used for particle phase simulation. The numerical analysis outcome is compared from literature data and it is found to be within reasonable agreement.

In this paper the Guoa et al. [3] try to develop a full scale electrostatic precipitation prediction tool as over-simplified Deutsch equation is still used by engineers. It also investigates the applicability of developed model in optimization of electrostatic precipitator with wire plate design. Aesp model with two stages is used. It was found that with proper modifications in design efficiency can be increased by more than 20% and turbulent gas flow patterns can be regulated.

Wen et al. [4] shows the electrical characteristics and flow characteristics of guidance plate covered electrostatic precipitators. Perforated guidance plates are used to cover the electrodes which reduce chances of particulate matters returning to environment. From the results it can be seen that hole diameter affects the flow characteristics and electrical characteristics and any type of particles entering the esp are entrapped by guiding plates. The paper uses numerical modelling for esp characteristics which can be used as a reference for design optimization in future.

Zhao et al. [5] analyse the hydrodynamic (EHD) flow of electrostatic precipitator using finite element method and FLUENT 6.2. She predicts parameters which define both electric field as well as flow field. The discovery was made that at lower Reynolds no ($Re < 15$) and higher EHD ($EHD > 2000$), EHD flow is dominant and decreases as Re increases. In another study[6] they found that with increase in pressure ion convection effect increases and under high pressure conditions the corona current and mobility of ions is not proportional.

Findings of particle image velocimetry flow velocity field measurements in an ESP that has wire to plate with intermediate spacing are provided in this work by Podlinski et al. [7] . Because of the unusually huge EHD number, the results reveal that the EHD forces have a considerable impact on flow patterns.

Adamiak et al. [8] describes a novel method of modelling the corona. This novel technology, which is derived from hybrid BEM-MOC method, can forecast the conditions of electricity in appliance that use the effect produced by to charge particles. The experiment data was compared to the numerical results. It was found that the experimental data and numerical data are very close.

In the case of a positive corona discharge in gas in point–plane geometry, a numerical method is proposed by Adamiak and Atten [9] to find electric field distribution and density of charge present a hybrid approach is presented by the paper to solving monopolar corona modelling i.e. solution of electric field by combined BEM-FEM technique.

In this paper the efficiency of collection of dust particles of electrostatic precipitators is calculated using a Computational Fluid Dynamics model that considers the relationship between flow of gas, resistivity due to dust particles, and electric field. Guo et al. [10] have tried to find relation between above parameters and dust collection efficiency as not all of them are independent factors.

Chun et al. [11] have modelled field of flow that are found near corona wire EHD flow using SIMPLEST algorithm for differential equations. The experiment has been done on flow that is EHD flow study in electrostatic precipitator by PIV thus outcomes were concluded.

Lei et al. [12] perform a 3d numerical simulation of wire-plate electrostatic precipitator to predict the complex physical phenomenon taking place inside. As per the analysis it was found that circulatory cells near grounded plate cause flow distortion and turbulent intensity in an ESP is much lower when it is provided with some inlet velocity.

Lin and Tsai [13] point out that very few numerical modelling have been done that can be used to determine the efficiency of ESP for small particle sizes that range from 0.3 to 10 micrometers. A 2 dimensional model was made by numerical modelling to determine the efficiency in collecting very small particles in ESPs with single stage and wire in plate configuration. On comparing it was found that the developed model agrees with existing experimental results.

Farnoosh et al. [14] developed numerical method and simulation process for predicting how ions, gases and dust particles travel inside ESP. They tried to determine electrical conditions, flow patterns due to ionic wind along with gas flows. It was confirmed that for larger particles the higher particle collection efficiencies is obtained and ESP performance is not affected by EHD flow.

Ghazanchaei et al. [15] investigate how electrostatic field interact with flow of fluid in an esp with electrode setup where plates are non parallel. From numerical results it was found that high velocity and high pressure is produced due to high voltage. A discovery was also made that the volumetric flow rate of air from the pump attains maximum value at a specific angle of the wall.

3. CONCLUSION

In this review various numerical models that are used for simulating ESP and its performance. Various conditions and variations were simulated to include ionized electrostatic field, EHD flow etc. Following conclusions can be drawn from above results-

- The conventional wire plate electrostatic precipitator models can be accurately simulated by available models. The models were validated by various experiments involving corona discharge.
- But still there are few limitations in the available simulation models. It is very difficult to choose a suitable turbulence model for electro hydrodynamic flow (EHD).
- Different types of electrostatic precipitators have been developed recently. These ESPs are highly efficient and produce small amount of waste by-product. Accurate simulation is required for these new types of ESP.

Acknowledgement/Funding Acknowledgement

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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