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Particulate Matter: Research and Management

Abstracts of Keynote Invited Lectures and Contributed Papers

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Vinča Institute of Nuclear Sciences

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11.15 NUMERICAL SIMULATION OF GAS FLOW THROUGH PERFORATED PLATES INCLINED TO THE MAIN FLOW

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Background and Aims: The new, restrictive best available technology requirements posed by EU Decision 2017/1442 clearly define the need to take measures to improve existing flue gas treatment installations. The process of removing particulate matter from the flue gas generated in coal-fired boilers of thermal power plants, by electrostatic precipitators (ESP), or by using filter bags, is significantly affected by uniformity of flue gas flow through the dedusting zone (Bäck, 2017). In order to improve the flue gas flow distribution through the ESP, perforated plates are used to establish as uniform as possible flow over the cross-section of the wide-angle diffuser exit. A computational Fluid Dynamics (CFD) method with source terms in the momentum equation defined according to the porous medium model is widely used for numerical simulation of flow through the perforated plate. Permeability and internal resistance per unit thickness of the perforated plate, considered as homogenous porous material, are usually calculated based on results of experiments. With these parameters defined for the streamwise direction, the porous medium model is useful in cases where the incoming velocity is almost perpendicular to the perforated plate. But this model loses prediction accuracy for the velocity distribution behind the perforated plate, as well as for the pressure drop through the plate, when the direction of the incoming fluid velocity deviates from the perpendicular (Guo et al, 2013), which is always the case for the wide-angle diffuser of one ESP. The aim of the present work is to add to the existing porous medium model when used in modelling a perforated plate by introducing a new approach for determination of the momentum losses regarding both streamwise and transverse directions for wide range of yaw and pitch angles of incoming flow.

Methods: The permeabilities and loss coefficients are calculated based on the results of CFD numerical simulations for different angles of incoming flow. The numerical calculations were performed by using ANSYS CFX finite-volume-based software to resolve the RANS equation for the solution domain. The key simulation properties are defined to be parameters representing one design point. The output parameters for all design points are solved by using Design of Experiments (DOE) technique. The permeability and loss coefficient algebraic dependencies on the angle are defined and implemented in the porous medium model. The proposed procedure is applied on the case of a plate of thickness 5mm, with face porosity 0.3 formed of circular openings in quadrilateral pitch.

Key results of the study: The results obtained for several pitch and yaw angles by applying the proposed approach are compared to the results of the full-scale CFD numerical simulations as well as to the CFD simulations relying on the standard porous medium model with permeability and loss coefficient defined in the direction orthogonal to the perforated plate An acceptable correlation was obtained and directions for future work highlighted (influence of the wall and other structural elements).

Conclusions: The study shows that the proposed approach is suited to predict pressure drop and velocity distribution behind the perforated plate for a wide range of yaw and pitch angles of incoming flow. More reliable prediction of the flow distribution in the exit of the wide-angle diffuser allows optimization of the flow through the ESP, and therefore a decrease in particulate matter emission.

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Keywords: perforated plate, porous medium model, CFD, DOE.

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