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Modelling of particles deposition in an environment relevant to solid fuel boilers

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ABSTRACT

The paper reports on investigation of some issues in computational modelling of deposition of solid particles on oblique walls washed by a diluted gas-particle turbulent flow. The models and approaches considered are relevant to predicting the dynamics of deposit formation (the growth rate and the shape of the deposit) on tubes and bounding walls of superheaters, heat exchangers and other equipment in which the boiler flue gas is used or processed. This application, involving relatively large particles (over 8 microns) imposes some specific constraints, but also eliminates the need to consider phenomena relevant only to smaller (sub-micron and nano-) particles. Nevertheless, a practically useful model should account for a variety of phenomena. The paper focuses on analysing the performance of a model for deposit growth and effects of temperature on deposit formation for different particle sizes while using Single Particle Tracking (SPT) for modelling the particle dispersion in the fluid flow. Specifically, the particle-sticking probability approach controlled by temperature has been evaluated for three particle sizes in the test case of deposit formation on a cylindrical probe in cross flow, compared with prior simulation results of Zhou et al. (Fuel, 86, 1519–1533, 2007).

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1. Introduction

Deposit formation on heat transfer surfaces is one of the most acute problems encountered in biomass-fired boilers. Depending on operational conditions, fuel characteristics and geometry of the boiler, ash particles entrained by the flue gases can impact and adhere to solid surfaces, aggregate and accumulate in form of a solid deposit that severely affects the boiler operation. Heat transfer is usually strongly impaired, but thick deposits may also reduce the flow passage areas and thus affect and even substantially alter the flow pattern, with grave consequences on the combustion process itself. While the heavy fouling problem is particularly common in equipments exposed to flue gases laden with particles coming from the combustion of biomass, it is also frequent in boilers fired by coal or wastes.

The classical approach to estimate the deposit formation is based on empirical correlations deduced mainly from experiments. A number of indicators were established and used in the past to predict the propensity of a given fuel (especially coal) to form deposit [1–4]. In recent years the numerical modelling and simulation of particle-laden flows and deposit formation have become the standard tool for design, development and optimisation of the operating conditions of various combustion and heat exchange devices (e.g. [5–7].), thus replacing, at least in part, the traditional but outdated correlation/indicators approach.

Particle deposition is affected by a number of factors, such as particle size and shape, composition, turbulent dispersion and particle interactions, temperature, mechanics of impact/adhesion, etc. Depending on their size and shape, particles can be influenced by gravity, drag and/or other mass forces and the particles governing equation should account for all of these forces, if relevant, in order to correctly predict their dynamics [8–10]. On the other hand, particles composition influences strongly their interaction with solid surfaces affecting their propensity to stick or rebound, especially in hot flows [1]. Two-phase flows are usually turbulent, and then identical particles starting from the same position but at different time instants, are spread by turbulence and follow different trajectories. In order to predict particle deposition accounting for this phenomenon, a huge number of particles need to be tracked to obtain statistically independent results. This in turn requires a huge computational time. Different models are available to handle this problem (i.e., Eddy Lifetime model [9,11], Particle Cloud Tracking model [12,13], Particle Number Density model [14], etc.). Finally, temperature becomes important in two-phase flows simulations when it affects the flow or particles viscosity. As a matter of fact, particle deposition within a combustion device occurs in zones

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