WORKGROUP FOR MULTIPHAS FLOWS

Particle deposition considering agglomeration

Grant number

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Project title

Calculation of the particle separation using an Euler-Lagrange Method under consideration of the particle agglomeration

Project leader

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Keywords

agglomeration, turbulent two-phase-flow, mathematical modelling

Problem position

The agglomeration of particles in a turbulent gas flow is very important for many chemical engineering processes, e.g. the production of particles by gas phase reaction (Katzer and Schmidt, 1998). However, in the field of dust separation particle agglomeration is a desired process, too, because fine particles coalesce with bigger particles to form much bigger ones. The importance of particle agglomeration for the separation efficiency of cyclones was analysed by Mothes (1982). Besides, the agglomeration by means of ultrasonic (Silc and Tuma, 1994) or electrical fields (Gutsch, 1995) is used to obtain a particle increa and that's why a better separation. The agglomeration of particles is effected by two physically independent processes: the collision of the particles (the so called collision kinetics) and the adhesion of the particles. The collision of the particles is especia induced by their relative motion in the flow, which can have different reasons (Pearson et al. 1984, Gutsch 1995). In case of the kinematic agglomeration the relative motion is due to the different sedimentation velocities of different sized particles. The turbulent agglomeration is caused by the fluctuation of motion of the particles in a turbulent flow field resulting in a mean relative velocity (Sommerfeld 1999). The thermal agglomeration is important for very fine particles and is due to the Brownian motion of particles. An overview of theoretically deduced equations for the collision rates resulting from the formerly mentioned effects can be found in the work of Pearson et al. (1984). Nowadays, numerical calculation methods are used more and more to dimension optimize technical apparatus. This requires, however, the modelling of all relevant microprocesses to predict the integral propert of the apparatus, e.g. the separation efficiency curve, reliably. Up to now, the calculations, for instance for the particle separatior cyclones, are carried out only with coarse assumptions (Cristea et al. 1996, Frank et al. 1998). Particle agglomeration was not considered in any known work up to now.

Short description of the project

Within the project a particle agglomeration model should be developed and implemented in a numerical calculation program basing on an Euler/Lagrange approach (Sommerfeld, 1996). In this approach the fluid flow is calculated with the Reynolds-mear Navier-Stokes equations in connection with a suitable turbulence model. The disperse phase is calculated by the tracking of mai particles under consideration of the acting forces. Other physical effects, e.g. wall collisions (Sommerfeld und Huber, 1999), hav to be considered with additional model approaches. The modelling of particle agglomeration includes both phenomena: particle collision and adhesion. The particle collision should be described by the stochastic collision model developed by Sommerfeld (1999). This model considers a possible correlation between the velocities of colliding particles in turbulent flows. Using the collision probability, which can be obtained from the particle size, particle concentration and relative velocity, it could be decided a collision takes place. Looking at the collision of very fine particles with much bigger ones the collision probability can be reduce very much (Mothes 1982). This effect should be considered using the collision probability in dependence of an inertia parameter At first relations known from the literature (e.g. Michael and Norey 1969) should be used to calculate the degree of collision as a function of the inertia parameter. Finally, it has to be checked during the modelling of agglomeration, if the adhesion forces are b enough to create an agglomerate consisting of two particles. Using the energy balance the critical value of the collision velocity can be obtained over which the particles rebound (Mothes 1982). If the momentary relative velocity is smaller than this value, agglomeration will take place. For further calculation of this agglomerate the diameter of a volume equivalent sphere consisting o the volumina of both primary particles is used as particle size. If the small particles rebounds, its new velocity will be calculated solving the momentum equations in connection with the Coulomb friction law. At first, the model should be validated using well known theoretical relations for simple flow conditions (Pearson et al. 1984). No experimental data analysing the agglomeration effects exist for complex flow conditions. That's why a simple free jet experiment should be carried out making possible the furth validation of the model. A particle-laden free jet will be blown in a channel flow laden with finer particles to induce the particle agglomeration in turbulent flows. To realize as high collision rates between the particles as possible the velocity inside the chann should be much smaller. Profiles of the particle velocities will be measured using a Laser-Doppler anemometer. A scattered light method allowing the size measurement of nonspherical particles should be used to determine the particle size distribution along the jet. The following parameters should be varied making possible a model validation for a large application:

- solid concentration in the free jet and the outer flow,
- particle size and adhesion properties of the particles,
- velocity ratio between the free jet and the outer flow.

Finally, the developed agglomeration model should be used to calculate the particle separation in a cyclone (Photo 1 and Photo to analyse the influence of this effect on the separation efficiency. The calculations have to be compared with experimental data available from literature (König, 1990).

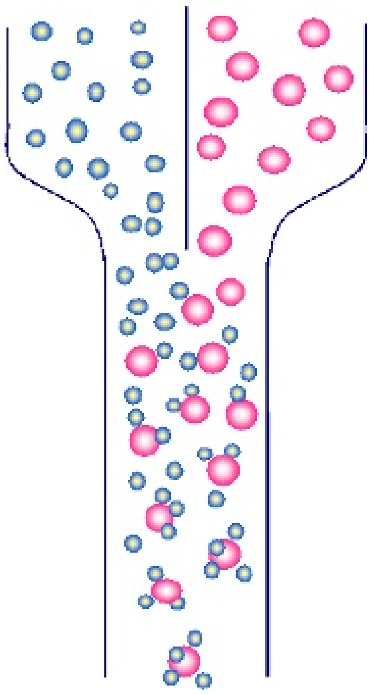

Photo 1: Agglomeration

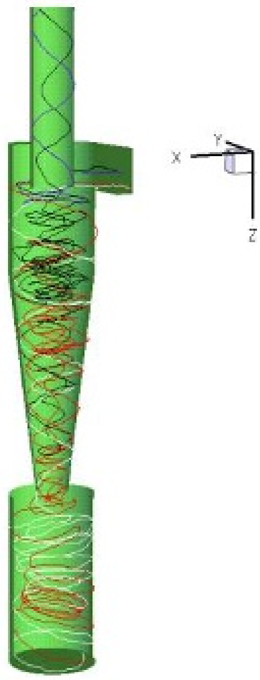

Photo 2: Trajectories in a spray dryer

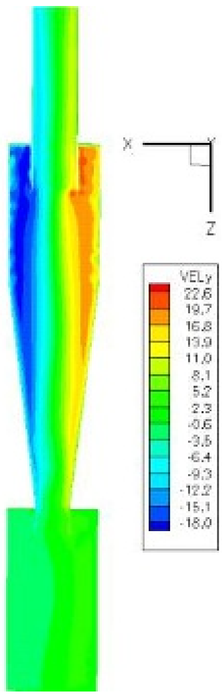

Photo 3: Velocity profile