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Multiphase Flow Modelling Using Surrogate Model

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Extended Abstract

The continuous development of technology, particularly in the field of energy, requires increasingly accurate tools for simulating various processes. One of these, used in the combustion of fuels or the mixing of materials, is the phenomenon of fluidization, characterized by the large number of colliding particles. For this purpose, the computational fluid dynamics is widely used, more specifically hybrid Euler-Lagrange (HEL)_approach and Discrete Element Method (DEM). In HEL approach the particle collisions are determined from solid volume fraction in computational cell. The interactions are calculated on the basis of Kinetic Theory of Granular Flow (KTGF) [1]. Such approach, in spite of the speed of the results obtained and their relative accuracy, is associated with problems in the determination of the closure terms (i.e. granular temperature), which is used to determine the force resulting from the collision of particles in the numerical cell. Also, the model does not detect collisions between particles, even if position and the velocity vector components make the particles move in exactly the same direction which makes it certain for the collision to occur. In DEM possible collisions are determined based on their relative position in computational domain. Having such information the collision forces are calculated directly, also taking into account the particles deformation resulting from the contact. However, despite high collision detection accuracy, is highly computationally expensive and time consuming. The simulations performed, under the same initial conditions, with the same number of spheres and the time step proved, the calculation time can be up to 20 times longer using the DEM.

Therefore, the idea arose to combine both models and create a new approach - Hybrid-Euler Lagrange Surrogate Collision Model (HELSCM), by applying surrogate model (SM). For that purpose machine learning algorithms were used. To collect the results, the DEM model was used. The goal was to collect the values of the velocity components of two particles before and after collision. With the data collected in this way, the new model used in the HEL simulations is able to determine the post-collision components on the basis of the pre-collision components. The combination of these two elements was possible by creating a User Defined Function (UDF), which is called at the end of each time step to check the positions of the particles. If the distance of the two particle centers is less than the sum of their radii, a collision is detected. The geometry used for the validation of simulations corresponds to the geometry of the experimental test-rig, which consists of transparent main core, with two side inlets attached, ended up with particle containers. The collected measurement images (captured by high speed camera) were used to quantitatively and qualitatively validate the obtained simulation results. For comparison 10 cross sections along the length of the main channel were set, where the velocity profiles of particles, averaged in time were determined.

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References

[1] S. Chapman and T. Cowling, *The mathematical theory of non-uniform gases*. Cambridge, Cambridge Univ. Press, 3rd ed., 1970.