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Computational fluid dynamics modeling and simulations of fluidized beds for chemical looping combustion

Chemical-looping combustion (CLC) is a next generation combustion technology that has shown great promise in addressing the need for high-efficiency low-cost carbon capture from fossil fueled power plants to address rising carbon emissions. A computational fluid dynamics (CFD) simulation is developed using the Eulerian approach based on a laboratory-scale experiment with a dual fluidized bed CLC reactor. The salient features of the fluidization behavior in the air reactor and fuel reactor beds are accurately captured in the simulation. The results highlight the need for more accurate empirical reaction rate data for future CLC simulations. The spouted fluidized bed setup provides several advantages when solid coal is used as fuel for CLC. The Lagrangian approach known as Discrete Element Method (DEM) coupled with the CFD solution of the flow field provides an effective means of simulating the behavior of such a bed. The overall results using Fe-based oxygen carriers reacting with gaseous CH_4 confirm that chemical reactions have been successfully incorporated into the coupled CFD-DEM simulations. The results indicate a strong dependence of the fluidization behavior on the density of bed material and provide important insight into selecting the right oxygen carrier to improve performance. This work provides a basis for future simulations of CD-CLC systems using solid coal as fuel. Given the high computing cost of CFD-DEM, it is necessary to develop a scaling methodology based on the principles of dynamic similarity that can be applied to a CFD-DEM simulation to expand the scope of this approach to larger CLC systems up to the industrial scale. A new scaling methodology based on the terminal velocity is proposed for spouted fluidized beds. Simulations of a laboratory-scale spouted fluidized bed are used to characterize the performance of the new scaling law in comparison with existing scaling laws in the literature. It is shown that the proposed law improves the accuracy of the simulation results compared to the other scaling methodologies while also providing the largest reduction in the number of particles.

Biography

Ramesh K Agarwal is the Professor William Palm of Engineering at Washington University in St. Louis, USA. His expertise is in computational fluid dynamics and heat transfer and its applications to the problems in aerodynamics, energy and environment. He is the author and coauthor of over 500 publications and serves on the Editorial Board of 20+ journals. He has given many plenary, keynote and invited lectures at various national and international conferences worldwide. He is a Fellow of AAAS, ASME, AIAA, IEEE, SAE and SME.

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