Effect of char combustion reactions on drag force coefficient

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Abstract: In this study, a particle-resolved simulation is performed using the ghost cell immersed boundary method to analyze the effect of char combustion reactions on the drag force. The effect of heterogeneous and gaseous reactions and the particle temperature are considered. The flow pattern is observably changed due to the Stefan flow induced by the heterogeneous reaction. The wall normal velocity is non-zero and therefore the boundary layer is thickened. As a result, the viscous stress is influenced. The recirculating wake becomes shorter and detached to the particle and the exact separation point doesn't exist. The heterogeneous and gaseous reactions change the species distribution around the particle and cause a considerable effect on the drag force. The particle with only heterogeneous reactions is compared with the particle with outflow. It shows that the effect of Stefan flow is offset by the larger pressure drop caused by the species distribution. The drag force is even slightly aggravated by the heterogeneous reactions and this result is opposite to the effect of the Stefan flow. The gaseous reaction significantly aggravates the drag force. In the process of char combustion, the CO_2 accumulates at the rear of the particle and causes a remarkable pressure drop, which is the main reason why the drag force increases significantly. Besides, the drag force is also influenced by the temperature difference of particle and inlet flow. The properties of the fluid at the ambient of the particle are influenced by the heat transfer at the surface. The high/low kinematic viscosity caused by the heated/cooled particle results in the variation of the drag force. The results indicate that the char particle cannot be simplified as a particle with outflow when calculating the drag force. The heat and mass transfer also plays an important role.