

External Mass Transfer of a Single Particle in Nonlinear Extensional Flow

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Extended Abstract

The fundamental research on the transfer phenomena (momentum, heat and mass transfer) of a single particle is of great importance in practical application in chemical and processing industry. The nonlinear flow that is produced in industrial rotary devices is very common and plays important roles on the particle transfer phenomena. Unfortunately, most works neglecting the effect of nonlinear term are dedicated to study a single particle (bubble, liquid drop, or solid particle) immersed in a simplified linear flow, such as in simple shear flow or in simple extensional flow. In order to explore the nonlinear problem, Favelukis [1,2] theoretically analysed the flow field and external mass transfer of a single spherical particle in the nonlinear extensional flow field. However, Favelukis [2] just explored the problem at large Peclet ($Pe \gg 1$) numbers. So, this numerical work firstly verified Favelukis' [2] theoretical formula and then studied the external mass transfer of a spherical particle in the uniaxial and biaxial nonlinear extensional flows in a more wide range of $1 \leq Pe \leq 100000$, $-5 \leq E$ (the nonlinear intensity of the extensional flow) ≤ 10 .

For all Peclet numbers, the simulation results show that the mass transfer rate of the nonlinear case is lower than that of the linear case in the range of $-1.04 < E < 0$ (bubble and droplet) and $-0.49 < E < 0$ (solid particle). Outside these ranges, the mass transfer rate is enhanced by the nonlinear flow.

For a spherical droplet/bubble in the non-linear flow, the simulated Sherwood number (Sh) absolutely agrees with the Favelukis' [2] theoretical results at the convection-dominated cases ($Pe > 1000$). For the diffusion-dominated cases and the transitional zone ($1 \leq Pe \leq 1000$), the empirical correlations of the external mass transfer rate of a single spherical bubble or droplet in the nonlinear extensional flow which Favelukis [2] cannot solve theoretically are proposed to predict Sh in the range of $-5 \leq E \leq 10$.

But for that of a spherical solid in the non-linear flow, when $E > 5/4$, the simulated Sh of a solid sphere in the nonlinear extensional flow is larger than the results given by Favelukis [2]. The reason is the effect of vortex formed outside particles on mass transfer, which is considered in this work. And Sh was provided in an extended range ($-5/17 \leq E \leq 5/4$, $E \neq 0$) that Favelukis [2] did not list as a theoretical correlation. In addition, the empirical correlations of the external mass transfer of a single solid sphere are proposed to predict Sh in the whole range of Pe ($1 \leq Pe \leq 100000$).

Acknowledgment: This work was supported by the National Key Research and Development Program (2016YFB0301701), National Natural Science Foundation of China (21606234, 21490584) and Key Research Program of Frontier Sciences of CAS (QYZDJ-SSW-JSC030).

References

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