Project Title:

Multiscale modeling of ultrasonic-controlled drug delivery system processing

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1. Background and purpose of the project, relationship of the project with other projects

Drug delivery systems (DDS) are designed to transfer the drug from the drug reservoir to the specialized tissue or blood vessel, and the drug carrier is the core part of the DDS. We have found that the ultrasound can control drag force around the sphere in the shear-thinning fluid, including reducing or increasing the drag based on various needs. However, the application of the control of the drag force on drug carriers by ultrasound has not been fully revealed.

We consider an oscillatory sphere travelling in shear-thinning power-law fluid, which is shown in Figure 1. We will consider the effects of the oscillatory frequency on the drag force on the oscillatory sphere and respectively consider the effect of oscillatory frequency on the pressure component and the viscous component of the drag force. Our results shed light on the drag control involved in DDS which is driven by ultrasonic irradiation.

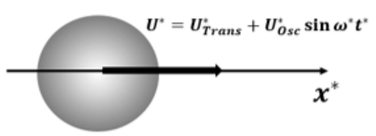

Figure 1 The schematic of the oscillatory sphere

2. Specific usage status of the system and calculation method

We perform numerical prediction of shear-thinning fluid flow around an oscillating sphere. The numerical simulations treat shear-thinning viscosity obeying a power-law, and fluid flows induced by translational motion of a spherical bubble or particle with oscillation. To exactly impose the boundary condition, and to exactly evaluate the fluid force acting on the sphere, the basic equations are described in a spherical coordinates system, and discretized in a finite-difference manner. Thread parallelization (OpenMP) is applied to all the loop operations over the entire grid points in the code.

3. Result

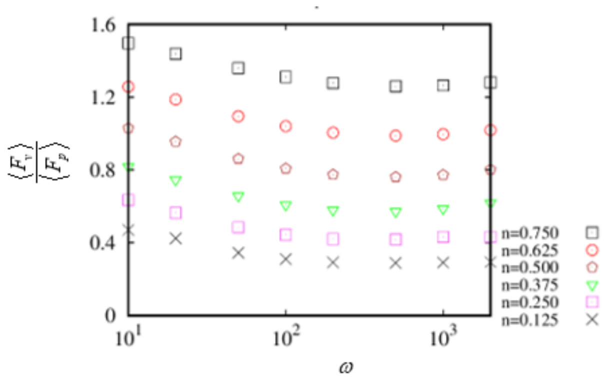

Figure 2 The relationship between $\langle F_v \rangle / \langle F_p \rangle$ and ω at different n

Figure 2 shows the relationship between $\langle F_v \rangle / \langle F_p \rangle$ and ω at different n. With the increasing of ω, the value of $\langle F_v \rangle / \langle F_p \rangle$ is slightly reduced, especially when $\omega \in [10^1, 10^2]$. As we all know, the value of $\langle F_v \rangle / \langle F_p \rangle$ for Newtonian fluid is 2, for shear-thinning fluid, the value of $\langle F_v \rangle / \langle F_p \rangle$ indicates the characteristics of the fluid. When the power-law index n is large, the value of $\langle F_v \rangle / \langle F_p \rangle$ tends to be large. In all, the tendency of

$\langle F_v \rangle / \langle F_p \rangle$ □ ω indicates the drag reduction of ω on the shear-thinning fluid, and the value of $\langle F_v \rangle / \langle F_p \rangle$ indicates the characteristic of the fluid.

4. Conclusion

Due to the nonlinear correlation between the velocity gradient and ω, and the nonlinear correlation between the viscosity and velocity gradient, there does not exist concise mathematical relationship between $\langle F_v \rangle / \langle F_p \rangle$ and ω. The effect of ω on the time-averaged drag force D is the combination of the effects of ω on $\langle F_v \rangle$ and on $\langle F_p \rangle$.

5. Schedule and prospect for the future

The future plan for FY2021: We will investigate the drag reduction effect of ultrasonic irradiation on a sphere freely falling in non-Newtonian fluid in FY2021.