Construction of Solid-liquid Coupling Interfaces for Ultralow friction and Stable Drag Reduction

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Developing ultralow friction and drag reduction techniques have attracted great attention because of their urgent needs in the field of mechanic engineering. However, many of the proposed strategies exhibit some inevitable limitations, especially for the long period of adhibition. In this study, the dynamic coupling interactions between the solid-liquid interface have been investigated deliberately. Some thermodynamical stable techniques were reported for construction of functionalized surfaces with super-low friction and excellent fluid drag reduction. It is believed that these effective strategies will provide some novel preliminary protocols for the development of new lubrication system and durable drag reduction technology.

Keywords: surface/interface, solid-liquid coupling, special wetting, ultralow friction, fluid drag reduction

1. Introduction

Over the years, different interface phenomena have been investigated because of their impact on most fields of science and technology, especially for super-wettability, adhesion, lubrication and boundary slippery. In order to achieve an in-depth study of the dynamic coupling effects of these typical interfacial phenomena, this study aimed to reveal the key factors influencing interface lubrication and boundary slippery ranging from the solid-solid interfaces to solid-liquid interfaces. Consequently, some novel strategies have been proposed for durability engineering application, including the mechanical friction and fluid drag reduction.

2. Methods

In order to obtain a comprehensive investigation of dynamic coupling mechanism between solid and liquid interfaces, rheological measurement and falling sphere strategy were applied to acquire the various boundary conditions (Figure 1).

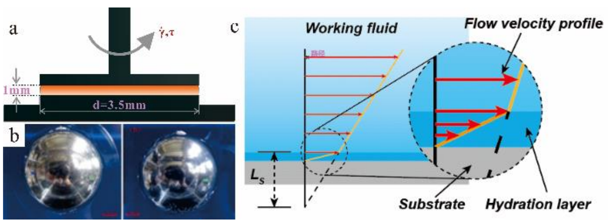

Figure 1: Construction of thermodynamic solid-liquid interface and the characterization of coupling effect.

2.1. Basic equation

Dependence of experimental velocity of falling sphere *vs.* time

$$U = U_T\left(1 - e^{t/\tau}\right) \quad (1)$$

2.2. Boundary conditions and falling velocity

We use classical Basset-Boussinesq-Oseen (BBO) equation to determine the drag coefficient: C_D.

$$C_D = \frac{4D}{3\rho U^2}\left((\rho_S - \rho)g - (\rho_S + 0.5\rho)\frac{dU}{dt}\right) \quad (2)$$

Sphere falling at terminal velocity U_T

$$C_D = \frac{4D}{3\rho {U_T}^2}(\rho_S - \rho)g \quad (3)$$

2.3. Results

The super-hydrophilic surfaces were fabricated through facile surface self-catalyzed polymerization *in situ*. A thermodynamic stable boundary condition was expected for the steady-state Couette flow geometry to obtain ultralow friction (10^{-3}) as well as the fluid drag reduction capability (60%).

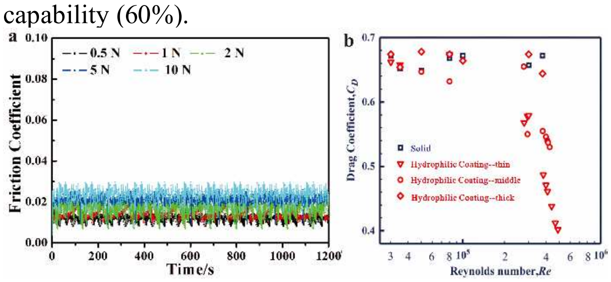

Figure 2: Super-hydrophilic surface with ultralow friction character and fluid drag reduction behavior.

3. Discussion

Notably, solid-liquid coupling phenomenon revealed the superior frictional property and drag reduction capability were mainly attributed to its super-hydrophilicity and robust hydration ability of boundary layer, by which the lubricants or flow field stabilizers could be maintained and prevented being squeezed out. Besides, these experimental results were expected to broaden the comprehension of interaction among different interface phenomena.

4. References

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