Hydrodynamics of Particle-Wall Interaction: AFM Study

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Introdução

Hydrodynamic interaction between solid particle and planar surface is of importance in understanding a range of technological phenomena. In this paper, an atomic force microscope (AFM) has been employed to measure directly the interactive forces for steady motion of a spherical particle towards a planar surface in liquid medium Polystyrene particles of 3 and 5 µm in radius and glass beads of 18 µm in radius were glued to the end of the cantilever to form the colloid probes. The force–distance curves were measured for each individual particle in silicone oil at approach speeds ranging from 0.3 to 6 µm/s. The repulsive interactions observed due solely to the drag force the particle experience were found to increase with increasing particle size and approach speed. Normalised drag coefficients were calculated from the measured hydrodynamic forces against the particle-surface dstances by taking into account the van der Waals attractive forces between the particle and the surface.

Resultados e Discussão

The AFM measured interaction forces versus the separation distance for a particle moving in silicone oil towards a mica surface at approach speeds of 0.3, 0.6, 1.0, 2.0, 3.0 and 6.0 µm/s, the measurements were carried out for polystyrene microspheres of radius of 3, 5 and glass beads of 18 µm in radius, respectively. The influence of the approach speed of the particle driven by the piezoelectric transducer on the drag force acting on the particle is apparently significant and the interaction forces are proportional to the approach speed and positive in all the cases, indicating that the interaction forces between the particle and the surface are dominated by repulsions, which are due solely to the drag force the particle experience. At a given approach speed, it is not hard to find that the measured interaction forces increase with increasing particle size, which is qualitatively in line with both Renolds and Brenner theories. For all experiments studied, the repulsive particle-surface interactions comprise electrical double layer forces and hydrodynamic forces. The former is one of the known force components of the Derjaguin–Landau–Verwey–Overbeek (DLVO) theory and can, in this case, be ruled out as there were no electric charges on the particle and the mica surface in a nonpolar liquid, such as silicone oil. It also can be seen that the hydrodynamic interaction range between two objects varies with the approach speed and the particle size

Conclusões

The hydrodynamic interaction forces between a particle and a solid surface in a nonpolar liquid were directly measured using the AFM in conjunction with the colloidal probe technique. In these measurements, the particles were glued to triangular AFM microfabricated cantilevers, and a planar mica surface placed on a sample holder. Measurements of force-distance curves were made at different approach speeds for three particle sizes. The analysis of the AFM measured force versus separation distance was made in terms of DLVO theory and Brenner's theory, indicating that the hydrodynamic force is significantly dominant compared with the van der Waals force in the systems. It was observed that the interaction force between the spheres and the planar wall was monotonically repulsive and increased with increasing approach speed of the particle; and at a given approach speed the measured hydrodynamic forces increase with increasing particle, which is qualitatively in line with both Renolds and Brenner theories. Normalised drag coefficients determined theoretically show agreement with experimental data in most cases. Deviations between experiemnt and theory at shorter distances for glass beads of 18 µm radius may be attributed to other non-DLVO forces.

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