Collisional dynamics of macroscopic particles in a viscous fluid

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Abstract

This thesis presents experimental measurements of the approach and rebound of a particle colliding with a wall in a viscous fluid. Steel, glass, nylon, and Delrin particles were used, with diameters ranging from 3 to 12 mm. The experiments were performed using a thick Zerodur or Lucite wall with various mixtures of glycerol and water. Normal and tangential coefficients of restitution were defined from the ratios of the respective velocity components at the point of contact just prior to and after impact. These coefficients account for losses due to lubrication effects and inelasticity.

The experiments clearly show that the rebound velocity depends strongly on the impact Stokes number and weakly on the elastic properties of the materials. Below a Stokes number of approximately 10, no rebound of the particle occurs. Above a Stokes number of approximately 500, the normal coefficient of restitution asymptotically approaches the value for a dry collision. The data collapse onto a single curve of restitution coefficient as a function of Stokes number when normalized by the dry coefficient of restitution.

Oblique collisions in a fluid are qualitatively similar to oblique collisions in a dry system, with a lowered friction coefficient dependent on surface roughness. For smooth surfaces the friction coefficient is drastically reduced due to lubrication effects. Values for the friction coefficient are predicted based on elastohydrodynamic lubrication theory. The particle surface roughness was found to affect the repeatability of some measurements, especially for low impact velocities.

A significant retardation of a particle approaching a target at a low Stokes number was observed and quantified. The distance at which the particle's trajectory varies due to the presence of the wall is dependent on the impact Stokes number. The observed slowdown can be predicted from hydrodynamic theory to a good approximation.

An analysis of the erosion of ductile materials during immersed collisions is presented. The size of the crater formed by the impact of a single particle against a ductile target can be estimated from theory, and these estimates agree well with experimental measurements.