Collisions of wet particles

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Collisions of wet particles occur in natural phenomena such as avalanches, mudslides, and pollen capture. They are also important in industrial processes such as agglomeration, fluidization, and wet granular flow. Early work extended the Hertz theory for dry, elastic collisions to head-on, wet collisions between two spherical particles or a particle and a surface. It was called "elastohydrodynamics," due to the coupling between the elastic deformation of the approaching surfaces and the hydrodynamic pressure to squeeze the viscous fluid out from between them [1]. A key finding is the critical Stokes number, below which sticking occurs due to viscous dissipation and above which bouncing occurs (but with a reduced coefficient of restitution compared to dry collisions, due to the loss of a portion of the particle kinetic energy to viscous dissipation). The Stokes number is a ratio of particle inertia to viscous forces, $St = mv_0/(6\pi\mu a^2)$, where m is the reduced mass of the particles, a their reduced radius, v_0 their relative impact velocity, and μ the fluid viscosity.

In this presentation, we extend the earlier work to first consider head-on, wet collisions of three spherical particles, using a pendulum apparatus called the Stokes' cradle [2]. It is similar to the desk-top toy, Newton's cradle, except only three spheres are used and the two target spheres are coated with a thin layer of viscous liquid. Four different outcomes are possible (depending on which adjacent pairs stick together and which separate after collisions), and all four outcomes have been achieved by varying the impact velocity and liquid-layer thickness.

We next consider oblique collisions between wet particles [3]. Here, three different outcomes are observed: (1) "Stick" at small Stokes numbers, where the particles stick together due to viscous forces, (2) "Bounce" at large Stokes numbers, where the particles rebound apart due to elastic deformation, and (3) "Stick-Rotate-Separate" at intermediate Stokes numbers and large impact angles, where the particles initially stick together, rotate as a doublet, and then separate due to "centrifugal" forces. For both problems, modeling as well as experimental results are presented.

References

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