

### **399d The Unsteady Drag Force on a Cylinder Immersed in a Dilute Granular Flow**

*Carl R. Wassgren, Rahul Bharadwaj, and Roberto Zenit*

This paper presents results from hard-particle discrete element simulations of a two-dimensional dilute stream of particles accelerating past an immersed fixed cylinder. Simulation measurements of the drag force are expressed in terms of a dimensionless drag coefficient. Measurements indicate that the cylinder's unsteady drag coefficient does not vary significantly from its steady (non-accelerating) drag coefficient implying that the added mass for the flow is zero. However, the drag coefficient is larger than its nominal value during an initial transient stage during which a shock wave develops in front of the cylinder. Once the shock has developed, the drag coefficient remains constant despite the stream's acceleration. The duration of the shock development transient state is a function of the number of particle/cylinder collisions.