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## Experimental measurement of kinematic behavior of particle collisions in ambient liquid

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The collisions of a particle against other particles or walls in the ambient fluid are one of the key processes in debris flow. Understanding the kinematics of this process, especially the role of particle rotation, is of great significance. We conducted a series of experiments studying the kinematics of a free-falling sphere colliding with a flat wall in the ambient fluids. Seven water-glycerol mixtures of different viscosities and densities are used. The kinematic behavior of the sphere is measured using both MEMS and optical techniques. The relationships between the coefficient of restitution (CR), contact time, and the Stokes number (St) are obtained. We found that when the St is greater than the upper critical value (448), the coefficient of restitution is stable at around 0.63. With the decrease of St, the CR drops rapidly before it approaches 0 when St is less than the lower critical value. The rotation process leads to wider distribution of CR. These results implicit the particle-particle collision might be significantly different when the viscosity of the liquid phase in debris flow varies and the particle scale kinematics of the particle phase is not trivial.