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New Strategies For The Characterization Of Size, Shape And Terminal Velocity Of Irregular Particles

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The characterization of particle size, shape and velocity is crucial to many fields of science, but is often associated with large uncertainties. In this study, first, size and shape characteristics of 115 lapilli particles (11-37mm) and 12 volcanic-ash particles (155-930 microns) were measured based on different techniques including calliper, image analysis, laser scanning (LS) and SEM micro-computed tomography (CT). A new strategy for measuring particle form dimensions (three-dimensional lengths of the particle) is suggested that is associated with the lowest operator-related errors. Corresponding form dimensions perform better for both the correlation and estimation of particle volume and surface area. In addition, a systematic approach was used to investigate the effects of particle orientation and number of particle projections on the characterization of size and shape of irregular particles through image analysis. It was found that using three perpendicular particle projections for measuring 2D quantities is the best comprise between analysis time and obtained accuracy. Shape descriptors have been calculated for our particle population to evaluate the variability and correlations between them. We have also investigated how conventional methods that are commonly used to characterize particle size and shape are differing from accurate 3D measurements. Finally, the methods commonly used to determine 3D quantities, such as volume, surface area and sphericity, from 1D and 2D measurements have been investigated. Whereas 1D measurements enable reliable volume estimates, they turn out to be inappropriate for the calculation of surface area and sphericity, for which 2D measurements provide the lowest average errors.

Second, we present a new model for the prediction of the drag of non-spherical solid particles of regular and irregular shape that travel in air (particle Reynolds numbers between 10 and 10^5, i.e. laminar to turbulent regimes). The results are obtained based on precise characterization shape of particles and experimental measurements of their terminal velocity in a vertical wind tunnel and falling columns of various heights (between 0.45-3.6 m). Performance of the model is compared against well-known spherical and non-spherical models. As an example, we have found that both existing spherical and non-spherical models can estimate settling velocity of volcanic particles with an average error of about 30%. We have also found that the effect of surface roughness on terminal velocity of non-spherical particles traveling at high Reynolds numbers is almost negligible. In addition, we observed that secondary motions of particles are considerably higher at high Reynolds numbers, which implies that particles falling in the turbulent regime are better characterized by a range of terminal velocities instead of a single value. Finally, new models based on easy-to-measure shape factors are introduced for estimating drag coefficient of non-spherical particles of various shapes in a wide range of Reynolds number.