Geophysical Research Abstracts
Vol. 17, EGU2015-3667, 2015
EGU General Assembly 2015

Drag Coefficient Of Non-Spherical Particles

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We present a new model for the prediction of the drag coefficient of non-spherical solid particles valid in the range of particle Reynolds numbers $\mathrm{Re}_p < 10^5$ (i.e. creeping to turbulent regimes). Results are obtained from analytical solutions for particles moving at Re_p <<1 and experiments on 300 regular and irregular particles both in settling columns with heights between 0.45-3.6 m (10<Re_p <300) and a 4-meter high vertical wind tunnel (10^4 <Re_p <10^5). Size and shape of particles are characterized by using 3D laser scanning, SEM micro-CT and image analysis. Our analyses show how none of existing shape descriptors, such as sphericity, circularity, elongation and flatness, well correlate with the particle drag coefficient. We introduce two new and easy-to-measure shape descriptors, namely Stokes' and Newton's shape descriptors, which are functions of particle form only (i.e. flatness and elongation) and have the highest correlation with the drag coefficient. Our results also indicate that orientation of non-spherical particles can significantly affect the drag coefficient. In particular, at high Reynolds numbers (Re_p >2000), the particle to fluid density is the key parameter controlling the particle orientation and, hence, the drag coefficient. As a result, effect of density ratio and particle orientation are added to our new model and validated with results of Direct Numerical Simulations (DNS) of non-spherical particles available in the literature. In addition, effects of surface roughness (or surface vesicularity) on the drag coefficient of non-spherical particles at various Reynolds numbers are investigated and its effect on the drag coefficient is found to be negligible. We have also found that existing spherical and non-spherical models are associated with an average error of 30% for estimating settling velocity of volcanic particles, while for highly non-spherical particles their errors can be significantly higher. Benchmark tests show that our new model is reliable and easy to apply for estimating drag coefficient of non-spherical particles of various shapes in a wide range of particle to fluid density ratio and Reynolds numbers.