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# New slip model for spherical particle-wall rolling detachment by airflow

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Particle resuspension by turbulent airflow is usually described by models which use classical expression derived by O'Neill (1968) to calculate the drag and the torque on a spherical particle in contact with a wall when held fixed in a shear flow. Such approach does not take account of slip both on the sphere and the wall. Yu & Hu (2021) integrated such slip condition in the Rock'nRoll model using the Navier (1823) slip model on the wall and the Cunningham factor to correct both the drag and the torque on the particle. Nevertheless, these corrections are not supported by fluid mechanics considerations. Thus a new model for a slip motionless sphere at contact with a plane slip wall and immersed in a shear flow is here proposed (see figure 1 insert).

The sphere has a radius  $R$ , a centre  $C$  with distance  $h = \tilde{h} \cdot R$  to the wall. The slip on the surfaces is described by the Navier condition with slip lengths  $\lambda_w = \tilde{\lambda}_w \cdot R$  on the wall and  $\lambda_p = \tilde{\lambda}_p \cdot R$  on the sphere. The creeping flow exerts on the particle a drag force and a torque about its centre with magnitude  $F_d = 6\pi\mu\dot{\gamma}R^2(\tilde{h} + \tilde{\lambda}_p) \times f$  and  $\Gamma(C) = 4\pi\mu\dot{\gamma}R^3 \times c$ , respectively. Here  $\dot{\gamma}$  is the shear rate,  $\mu$  is the dynamic viscosity,  $f$  and  $c$  are key friction coefficients. The Faxén generalized formulae derived by Keh & Chen (1996) show that far from the wall ( $\tilde{h} = \infty$ )  $f_\infty = (1 + 2\tilde{\lambda}_w)/(1 + 3\tilde{\lambda}_w)$  and  $c_\infty = 1/(1 + 3\tilde{\lambda}_w)$ . The friction coefficients  $f^*$  and  $c^*$  for no slip on the sphere ( $\tilde{\lambda}_p = 0$ ) at contact with a slip wall are calculated here by the bipolar coordinates method and thereby interpolated by handy formulae. The slip on the sphere at the contact with the wall ( $\tilde{h} = 1$ ) is here considered by the formulae  $f = f^* \times f_\infty \left[ \frac{16+9f_\infty}{25} \right]$  and  $c = \frac{c^*}{1+3\tilde{\lambda}_s}$  (Sellier *et al.*). We showed that such a simple model is in perfect agreement when extrapolating results obtained by Luo & Pozrikidis (2008) using a quite involved boundary layer method.

Particle detachment occurs when  $\Gamma_t = R \cdot F_d + \Gamma(C) > a \cdot F_{ad}$  where  $a$  is the distance of roughness asperities and  $F_{ad}$  the adhesion force. Finally, we express the ratio  $\beta$  between the hydrodynamic total moment exerted on the sphere with and without slip on the sphere and the wall  $\beta = \frac{\Gamma_t}{\Gamma_t(\tilde{\lambda}_w=0, \tilde{\lambda}_p=0)}$ . This ratio is

plotted in figure 1 for equal dimensionless slip lengths on the wall and the particle  $\tilde{\lambda}_w = \tilde{\lambda}_p$ . The Yu & Hu approach is also represented for comparison using the accommodation coefficient,  $\sigma = 0.93$ , deduced from their paper. Note that Maxwell (1879) relates dimensionless slip length for a plane  $\tilde{\lambda}_w$  to the Knudsen number  $Kn$  as a function of  $\sigma$  ( $\tilde{\lambda}_w = Kn$  for  $\sigma = 1$ ).

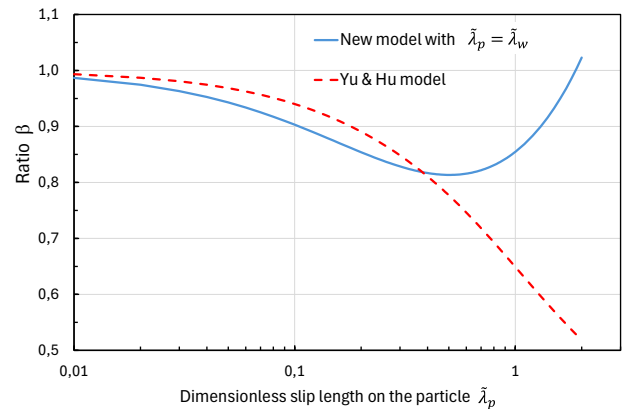


Figure 1.  $\beta$  versus the non-dimensional slip length

The new model predicts a decrease of  $\beta$  when increasing  $\tilde{\lambda}_p$  below 0.5 which means that slip reduces the global hydrodynamic efforts on the particle. For slip length value above 0.5, the  $\beta$  ratio surprisingly increases. This can be explained by an increase of the ambient velocity at the sphere center, due to slip length on the wall, and by a reduction in the torque contribution due to slip on the particle. This trend is not predicted by the Yu & Hu approach because the slip effect on the torque value is not well assessed.

Keh, H., and Chen, S. (1996) *European Journal of Mechanics B-Fluids*, 15, 791-807.

Luo, H. and Pozrikidis, C. (2008) *J. Eng. Math.*, 62, 1-21.

Maxwell, J. C. (1879) *Philos. Trans. R. Soc.*, 170, 231-256.

Navier, C. L. (1823) *Mémoires de l'Académie Royale des Sciences de l'Institut de France*. pp. 389-440.

O'Neill, M. E. (1968) *Chem. Eng. Sci.*, 23, 1293-1298.

Sellier, A. *et al.* In preparation, *to be submitted J. Fluid Mechanics*.

Yu, D. and Hu, F. (2021) *J. Aerosol Sci.*, 151, 105675.