THE BASSET-BOUSSINESQ HISTORY FORCE ACTING ON A SPHERICAL DROP

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We consider the Basset-Boussinesq (history) force experienced by a fluid sphere of radius *R*, viscosity μ_i and density ρ_i moving with relative velocity *W*(*t*) in an unbounded fluid of viscosity μ_e and density ρ_e. This force is usually expressed as

$$F_H(t) = 6\pi\mu_e R \int_0^t K(t-t') \frac{dW}{dt'} dt'$$

where expressions of the memory kernel K(t) have been derived for a solid sphere [1,2] and for a spherical bubble [3]. Considering a fluid sphere, these expressions can be considered as the limit at respectively large and small viscosity ratio $\Phi = \mu_e/\mu_i$, respectively. The general expression of the memory kernel K has not been derived so far for a fluid sphere. The solution has been obtained in the Fourier-transform space but the transform from the frequency domain to the time domain can only be achieved under the two limits of solid sphere and spherical bubble [3,4].

We show that the Kernel for a fluid sphere can be described using the kernel obtained for a sphere with a uniform slip along the surface [4,5]

$$K(t^*,\lambda) = \frac{(1+2\lambda/R)^2}{\lambda/R(1+3\lambda/R)} \exp\left[\frac{(1+3\lambda/R)^2}{\lambda^2/R^2} t^*\right] \operatorname{erfc}\left[\frac{(1+3\lambda/R)}{\lambda/R} t^{*1/2}\right]$$

where $t^*=t/t_e$ is the time normalized by the charateristic time of diffusion $t_e=R^2/\nu_e$, $\nu_e=\mu_e/\rho_e$ being the kinematic viscosity of the external fluid, and where the slip length λ is related to the viscosity ratio by $\lambda=R/(3\Phi)$. Thanks to direct numerical simulations, we show that such an expression can be used when the caracteristic time τ of the flow is less than 0.15 t_e. Thus, combining the analytical expression of the Basset-Boussinesq kernel for a slip sphere and the description of the slip at the interface of a fluid sphere, we are able to describe for the first time the Basset-Boussinesq history force for a fluid sphere whatever the viscosity ratio considered, i.e. for bubbles, drops and particles.

REFERENCES:

[1] Basset, A. B., 1888. On the motion of a sphere in a viscous liquid. Phil. Trans. Roy. Soc. 179, 43–63.

[2] Boussinesq, J., 1885. Sur la resistance qu'oppose un liquide indefini en repos. C. R. Acad. SCI. 100, 935–937.

[3] Yang, S.-M., Leal, L. G., 1991. A note on memory-integral contributions to the force on an accelerating spherical drop at low reynolds number. Physics of Fluids 3(7), 1822–1824.

[4] Michaelides, E. E., Feng, Z.-G., 1995. The equation of motion of a small viscous sphere in an unsteady flow with interface slip. International Journal of Multiphase Flow 21, 315–321.

[5] Gatignol, R., 2007. On the history term of boussinesq-basset when the viscous fluid slips on the particle. C. R. Mecanique 335.