A two fluid data analysis scheme for the Magnetic needle interfacial shear rheometer (MNISR): the effect of the air drag

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Interfacial shear rheometry data obtained on interfacial systems confined between two bulk fluid phases contain information on the hydrodynamic resistance of both adjacent bulk phases [1, 2]. This contribution may be relatively important depending on the actual value of the Boussinesq number (ratio of interfacial drag and bulk phases drag) [3] and the sensitivity required [4] to study the target interfacial system. Consequently, the two bulk phases contributions must be carefully separated from the total drag to obtain an accurate value of the interfacial rheological variables.

Different approximations have been used in the analysis of the experimental data of the MNISR [5]. In the first approach a linear approximation was used for the interfacial velocity profile and the contributions to the response due to the interface and the rest of the system were considered as simply additive [6]. Sophisticated data analysis schemes were proposed later [7, 8, 9, 10] that rely on an iterative solution of the hydrodynamics equations for just the subphase and the interface, coupled to the probes equation of motion.

However, the data analysis schemes that consider just the subphase and the interface are limited in two fundamental aspects: on the one hand, they cannot deal appropriately with experimental data on interfacial systems confined between two liquid bulk phases that are receiving progressively more attention, and, on the other hand, they cannot account for the drag of the air layer inherent to the most often studied case of air/water interfaces. In fact, the air layer drag must impose a lower threshold in the resolution of the conventional, single bulk phase, data analysis schemes for modern high resolution interfacial rheometers (DWR, MNISR, micro-button).

Here we report on the development of a flow field-based data analysis scheme for the MNISR geometry considering the upper bulk fluid layer. We will illustrate the performance of the data analysis scheme on two bulk fluids interfacial systems, with particular emphasis on the case of air/water interfaces in order to clarify in what conditions the contribution of the upper air phase is relevant. We will show a comparative analysis of the three levels of approximation mentioned, carried out through numerical simulations. We will discuss the different flow configurations obtained as a function of the characteristic length scales [3] and we will illustrate how the operating windows of the MNISR are affected by the air layer drag at low values of the interfacial viscosity.

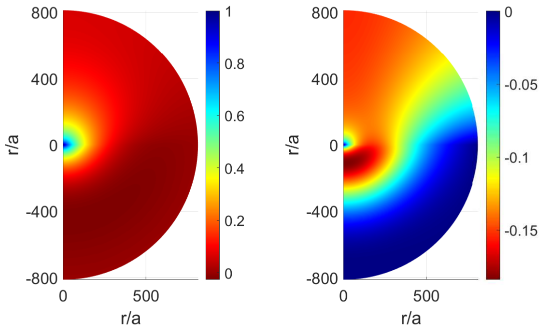

Fig. 1. Color coded graphics of the real (left) and imaginary (right) parts of the hydrodynamic velocity fields for the MNISR geometry with a microwire probe, for a purely viscous interface with interfacial viscosity, $\eta_s^* = 10^{-6}$ N·s/m at an oscillation frequency $f = 0.05$ Hz.

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