Measurement of Rheological Fluid Properties using MEMS

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Abstract

The classical way to measure the rheological properties of fluids is either to use a viscometer (involving a falling or rolling ball) or a rheometer (utilizing the rotational motion of a cone/plate or Couette flow). Whereas viscometers can only characterize the viscous component of the deformation, rheometers can characterize both elastic and viscous responses. However, the latter have also several drawbacks: the measurement cannot be made in situ (a fluid sample is needed), the amount of fluid necessary to make the measurement is quite large (a few milliliters) and the measurement is limited to low frequency (less than 200 Hz due to inertial issues). To overcome the frequency range limitation, some alternative methods have been developed over the two last decades, giving raise to the field of 'microrheology', which involves the measurement of the movement of monodispersed beads (microspheres) immersed in the fluid. In the presentation we will present two alternative methods based on the use of silicon MicroElectroMechanical Systems (MEMS). Both methods are based on the measurement of the hydrodynamic force exerted on a solid body moving in a fluid, which depends on the fluid's rheological properties. In the first method the moving solid body is a sphere attached to the microcantilever and the force measurement is made using the microcantilever, similar to what is done in AFM systems. In the second method the microcantilever has a dual role: it is used to actuate the fluid flow as well as to measure the hydrodynamic force. Thus, both methods are based on the ability to relate the free-end cantilever deflection to the fluid's rheological properties through analytical equations. Both principles have already been used by the authors or other teams to measure the viscosity of Newtonian fluids (fluids with constant real part of viscosity and no imaginary part of viscosity). The originality of the presented work comes from the fact that thanks to analytical modeling these methods have been extended to the measurement of the complex viscosity or of the complex shear modulus which characterize both the elastic and viscous behavior of complex fluids.

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