Dynamic wetting and beyond

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An undeniable fact about dynamic wetting is that, as a result of this process, an initially dry solid surface becomes 'wet'. In other words, this is a process of creating a new/fresh liquid-solid interface, i.e. a process of interface formation. This premise has the following two corollaries: (i) an adequate mathematical model of dynamic wetting must have the process of interface formation at its core, and (ii) the same model, without any ad hoc alterations, should be able to describe other flows where interfaces form or disappear and for which the standard model leads to results that are unacceptable from a physical point of view. In the present work we examine the performance of an earlier developed theory of flows with forming/disappearing interfaces in two situations: (a) curtain coating in microfluidics and (b) the breakup of a liquid thread. The results show that, for the same wetting speed and the same materials of the system, the model predicts that the actual contact angle formed by the free surface with the solid substrate can be manipulated by altering the flow conditions. This effect has been observed previously in macroscopic experiments, and the present study investigates the conditions for its occurrence in microfluidics, where inertial effects are negligible and the phenomenon becomes more transparent. In particular, it has been shown that for sufficiently thin curtains the dynamic contact angle can be reduced by increasing the fluid velocity at the free surface near the moving contact line. The latter can be achieved by increasing the inlet velocity, reducing the curtain height or a suitable choice of the angle between the solid substrate and the falling curtain.

When the same interface formation theory was applied to the jet breakup phenomenon, where, as is known, the standard model leads to unphysical singularities, it not only regularized the problem but also explained an experimentally observed paradox, namely that the thread breaks when its diameter reaches a certain value which is independent of the fluid's viscosity. It is also interesting to note that the estimates for material constants of the theory obtained from experiments on dynamic wetting and applied in the analysis of the jet breakup problem make it possible to predict this minimum diameter in excellent agreement with experimental data.