Thin liquid film flow on a rotating annular disk: asymptotic solution

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We consider the axisymmetric flow of a Newtonian fluid associated with the spreading of a thin liquid film on a rotating annular disk. The effects of surface tension and gravity terms are included. The asymptotic solution for the free surface of the thin film is found using an expansion for the film thickness in powers of a small parameter characterizing the thickness of the film and applying the method of matched asymptotic expansion. Our asymptotic solution predicts the breaking of wave at the free surface of the thin film as it evolves and provides an estimate for the wave breaking time of the free surface. These and other features of the spin-coating thinning process are captured by our asymptotic solution. Our solution also predicts that surface tension accelerates film thinning and the gravity does not. Our results show that the final film thickness does not depend on the initial distribution of the film thickness (be it uniform or non-uniform) and on the initial amount of liquid deposited which are in agreement with the experimental findings of Daughton and Givens. We find that most of the liquid initially deposited on the disk flows out of the disk in a very short time at initial stages of spinning, regardless of the type of initial distribution of the film thickness, and the retention of fluid for non-uniform initial distribution is more than that for uniform distribution at early stages of the spreading of the thin film. This result is in excellent agreement with the findings of Hwang and Ma.

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