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Numerical simulation of spinning disc atomization

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The generation of drops from jets spiraling out of spinning devices is the key element in a number of atomization technologies where the centrifugal force is used to drive the flow. These technologies range from prilling, where jets come out of orifices in the side of a spinning container, to spinning disc atomization (SDA), where a film spreading over the surface of a spinning disc breaks into jets ('ligaments') as the centrifugal force drives it over the disc's edge. In designing and optimizing such technologies, it is vital to be able to model theoretically (computationally) the entire process, from the appearance of disturbances on the jet's free surface to the formation and detachment of drops and, where this is the case, satellite droplets as experimentation based on estimates and empirical formulae, besides being expensive, time-consuming and imprecise in its outcome, on its own cannot deliver new technological regimes, especially when they correspond to narrow windows in the parameter space.

The computational challenge in dealing with the SDA is that it is an essentially unsteady 3D free-boundary problem with a large aspect ratio of lengths characterizing the flow. The present work addresses the problem by introducing a non-orthogonal coordinate system specific to the flow geometry [1] and, using the multiple-scales method, it was found that close to the inlet, where the disturbances can be regarded as small, their propagation is qualitatively similar to that of a wave propagating down a straight jet stretched by an external body force (e.g. gravity). The dispersion equation has the same parametric dependence on the base flow but the base flow is, of course, different, with the equations describing it being inseparable from those describing the jet's trajectory. Both are derived using the multiple-scales method and solved numerically.

Further down the jet, where the amplitude of the disturbances becomes finite and they eventually result in the drop formation and detachment, the flow appears to be quite complex. In order to compute it, a method is developed based on projecting the centrifugal force on the already calculated trajectory of the jet and hence, while keeping the key effect, allowing one to reduce the problem's dimensionality by neglecting asymptotically small terms in the curvature of the free surface. The accuracy of the developed method is confirmed by comparing the results with the full three-dimensional unsteady simulations performed for relatively short jets where such computations are feasible.

The application of the obtained results to the spinning disc atomization process, where an additional problem of matching the jet with the three-dimensional flow in the film-to-jet transition zone had to be solved, made it possible to compare the results with available experiments. It was demonstrated that the theory is in a very good agreement with experiments in a wide range of controlling parameters.

REFERENCES

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