Noncircular Cross Sections Could Enhance Mixing in Sprays

Preliminary results suggest that elliptical cross sections may be best.

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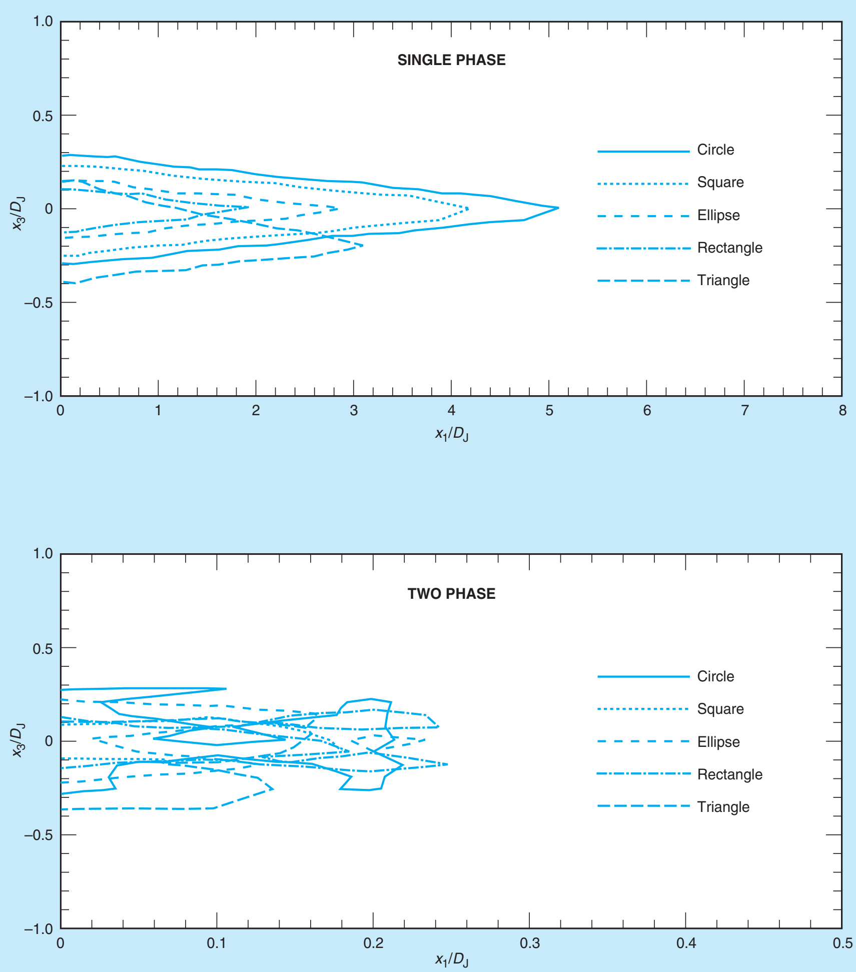
A computational study has shown that by injecting drops in jets of gas having square, elliptical, triangular, or other noncircular injection cross sections, it should be possible to increase (relative to comparable situations having circular cross section) the entrainment and dispersion of liquid drops. This finding has practical significance for a variety of applications in which it is desirable to increase dispersion of drops. For example, in chemical-process sprays, increased dispersion leads to increases in chemical-reaction rates; in diesel engines, increasing the dispersion of drops of sprayed fuel reduces the production of soot; and in household and paint sprays, increasing the dispersion of drops makes it possible to cover larger surfaces.

It has been known for some years that single-phase fluid jets that enter flow fields through noncircular inlets entrain more fluid than do comparable jets entering through circular inlets. The computational study reported here was directed in part toward determining whether and how this superior mixing characteristic of noncircular single-phase jets translates to a similar benefit in cases of two-phase jets (that is, sprays).



The **Potential Core** of a jet is defined as the region beyond which the velocity is no longer equal to that at the inlet. These plots are outlines of computationally simulated potential cores of single- and two-phase jets issuing from inlets with the noted cross sections. D_J denotes the equivalent jet diameter, which, for a noncircular inlet, is defined as the diameter of a circular inlet of equal cross-sectional area. The symbols x_1 and x_3 denote Cartesian coordinates parallel and perpendicular, respectively, to the initial jet axis.

The study involved direct numerical simulations of single- and two-phase free jets with circular, elliptical, rectangular, square, and triangular inlet cross sections. The two-phase jets consisted of gas laden with liquid drops randomly injected at the inlets. To address the more interesting case of evaporating drops, the carrier gas in the jets was specified to be initially unvitiated by the vapor of the liquid chemical species and the initial temperature of the drops was chosen to be smaller than that of the gas. The mathematical model used in the study was constructed from the conservation equations for the two-phase flow and included complete couplings of mass, momentum, and energy based on thermodynamically self-consistent specification of the enthalpy, internal energy, and latent heat of vaporization of the vapor.

The results of the numerical simulations yielded information on (1) the different spreading behaviors occurring for different inlet cross sections and (2) the differences between flow fields in the presence and absence of liquid drops. The most important consequence of interaction of drops with the flows was found to be the production of enhanced streamwise vorticity that alters entrainment and the mixing of species according to the inlet geometry. At the time station corresponding to steady-state entrainment, the potential cores of two-phase jets were found to be shorter than their single-phase counterparts by an order of magnitude (see figure). Whereas the two-phase circular jets were found to exhibit symmetric entrainment patterns at a location well past the streamwise locations of the potential cores, the noncircular jets were found, at the same location, to depart strongly from symmetry. The phenomenon of upstream-vs.-downstream exchange of major and minor axes of elliptical cross sections ("axis switching" for short) of single-phase jets was not observed in the two-phase jets.

Considerations of the distributions of the number density of drops, liquid mass, and evaporated species distributions lead to recommending elliptical cross sections as optimal ones in that they result in optimal combinations of dispersion and mixing. All of the computations were performed for pre-transitional jets (that is, jets on the laminar side of the transition between laminar and turbulent flow). Further investigations would be necessary to elucidate the effects of turbulence.

This work was done by Josette Bellan and Hesham Abdel-Hameed of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
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