SOME ASPECTS OF PRESSURE ATOMIZING NOZZLES

ABSTRACT

Atomization of Newtonian and non-Newtonian liquids finds application in air breathing engines, furnaces, spray drying, spray painting, and spraying of insecticides. The areas of application extend also to the realm of cooling towers. In the atomization process the high speed jet, or the sheet, emanating from a nozzle disintegrates into very fine droplets whose size, distribution and range are dictated by the application. The performance of the nozzle depends to a great extent on entrance- kinematics of the high pressure liquid. The fluid momentum at the entry to the nozzle may be axial, tangential or a combination of the two. In this thesis the following four aspects of atomizing nozzles have been investigated.

(a) Initiation of air core in a swirl spray pressure nozzle.

(b) Coefficient of discharge and spray cone angle of a pressure nozzle with combined axial and tangential entry of liquids.

(c) Dispersion of liquid from swirl spray pressure nozzles.

(d) Instability of a moving liquid sheet.

I. INITIATION OF AIR CORE IN A SWIRL SPRAY PRESSURE NOZZLE

In earlier investigations a swirl nozzle was characterized by the presence of a central air core. Later investigations revealed that this core is not mandatory for the operation of a swirl nozzle. In this investigation theoretical and experimental analyses have been carried out for determining the limiting injection condition below which the formation of air core does not take place in the course of flow of a time-independent power-law fluid through a swirl nozzle. Analytical solution provides one distinct value of generalized Reynolds number at the inlet to a nozzle, below which the air core is not formed. Experiments reveal that there exist two limiting values of such generalized Reynolds number regarding the formation of air core in a nozzle. One value is the upper limit below which steady flow occurs without air core and the other one is the lower limit above which steady flow with fully developed air core persists. In between these two limiting values, there prevails a transition zone through which fully developed air core is gradually set up within the nozzle. For all the nozzles, studied in the present analysis, theoretical results are in fair agreement with the experimental values of upper limit of generalized Reynolds numbers with respect to steady flow without air core. Amongst all the pertinent independent geometrical parameters of a nozzle, the orifice-to-swirl-chamber-diameter ratio has the remarkable influence on generalized Reynolds number describing the initiation of air core.

II. COEFFICIENT OF DISCHARGE AND SPRAY CONE ANGLE OF A PRESSURE NOZZLE WITH COMBINED AXIAL AND TANGENTIAL ENTRY OF LIQUIDS

In some combustion processes and industrial applications wide range of penetration and coverage are required. Varying combinations of axial and conventional tangential entry of liquids to a pressure nozzle provide a wider range of penetration, spread and throughput of the spray. The pertinent parameters which govern the flow field are the generalized Reynolds number based on the tangential velocity of injection, the ratio of axial-to-tangential velocity at the nozzle inlet, the flow behaviour index of the fluid, length-to-diameter ratio of the swirl chamber, spin chamber angle, and the orifice-to-swirl-chamber-diameter ratio. Theoretical predictions of coefficient of discharge and spray cone angle were made through an approximate analytical solution of hydrodynamics of flow inside the nozzle. In the converging section of the nozzle ,the boundary layer equations have been derived with modified order approximation of Navier-Stokes equations for a better accuracy. Smoother attainment of the free stream condition at the edge of the boundary layer was ensured by requring the appropriate shear rate terms to be compatible with above order analysis. Experiments reported in the chapter corroborate the analytical results.

III. DISPERSION OF LIQUID FROM SWIRL SPRAY PRESSURE NOZZLES

Dispersion of spray from a swirl nozzle consists of disintegration of the high speed conical liquid sheet into a spectrum of droplets and the dynamics of these droplets in ambient atmosphere. The pertinent parameters governing the spray dispersion are the velocity, viscosity and the surface tension of the liquid apart from density of ambient atmosphere and nozzle dimensions. Two sets of experiments were conducted, the first set to determine the droplet size and the second set to determine the mass flow distribution of dispersed spray over a horizontal plane at a given vertical distance below the orifice. The analytical solution of the droplet trajectories was obtained from the experimental values of droplet size, initial velocity and direction of the droplets determined from the internal hydrodynamics of the nozzle. Theoretical predictions of the droplet trajectories have been made with the assumption that the break-up of the liquid sheet takes place very close to the nozzle orifice. Theoretical and experimental results were found to be within a good agreement regarding the 'spread' of the spray.

IV. INSTABILITY OF A MOVING LIQUID SHEET

Instability of liquid sheet due to its interaction with air or gas as surrounding atmosphere is of special interest in studying atmozation of liquids. Interfacial instability of liquid sheets occur owing to formation of waves caused by a velocity difference between the sheet and the surrounding gas. The instability of a cylindrical liquid sheet of finite thickness moving with a uniform velocity in still air has been investigated to study the mechanism of the break-up of films or sheets during atomization. It has been shown that instability occurs for axisymmetric disturbances when the wavelength exceeds the outer circumference of the sheet. For small values of Weber number (Wb_a), a sheet of given thickness tends to become unstable for disturbances of large wavelengths although it is completely stabilized when Wb_a is less than 2.5 (approx.) . In the unstable regime the amplitudes show maxima for a given value of Weber number and sheet thickness. This maximum growth rate increases with Wb_a for a fixed value of the sheet thickness. For fixed Wb_a , it is found that $\bar{\lambda}_m$ (the wavelength corresponding to maximum growth rate) increases rather slowly with the increase in the sheet thickness. The value of $\bar{\lambda}_m$ decays rapidly from a high value as Weber number increases for a fixed sheet thickness. Further as $Wb_a \longrightarrow \infty$, $\bar{\lambda}_m$ approaches asymptotically the value 10 (approx.) which agrees with the corresponding value due to Rayleigh in his study of capillary instability of a jet.