COMPUTATIONAL MODELING OF THE ATOMIZATION OF A LIQUID JET IMPINGING ON A SOLID PLATE

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ABSTRACT

Atomization of a liquid jet impinging of a solid plate is studied using a 3D computational model for the simulation of free-surface flows including internal obstacles. The model combines the solution of continuity and momentum equations with an algorithm for free surface tracking in presence of internal obstacles. The effects of the impinging velocity on the disintegration of the liquid jet are investigated. The results of the model are validated by a comparison between the droplet sizes obtained numerically with those reported experimentally. The fluid flow mechanism that causes the disintegration of the liquid jet into small droplets is explained using the numerical results.

INTRODUCTION

The atomization of an impinging liquid jet on a solid surface called splash-plate is used in many industrial applications. Splash-plate atomizers are commonly used in devices where a large diameter orifice is needed to either provide a large mean flow rate, such as in fire sprinklers, or where a highly viscous fluid is used, such as in coal slurry fuel injectors. In such sprays, the liquid jet emerges from a large orifice and impinges on a solid surface. Because of the wide spread application, the impinging jet atomizers have been extensively investigated. Detailed experimental studies of these atomizers are available in the literature [1-5]. Ashgriz et al. [6] performed a set of experiments on the atomization of a liquid jet on a splash-plate and investigated the effect of velocity on the disintegration of the jet into small droplets.

Hagerty and Shea [1] and Fraser et al. [7] described the instability and breakup of liquid sheets as follows. The fluid sheet experiences disturbances due to the aerodynamic forces. Consequently, the sheet becomes wavy, the amplitudes of the waves grow and cause the sheet to break up into ligaments. Finally, the liquid ligaments break up into droplets based on the Rayleigh theory [8].

In this paper, we present an investigation of the impinging jet atomization using a 3D numerical model. The model combines the solution of Navier-Stokes equations with an algorithm for tacking the liquid free surface in presence of an obstacle in the computational domain. To validate the model, the calculated results are compared with available experimental measurements. The effect of jet velocity on droplet sizes is also investigated.

NUMERICAL METHOD

Fluid flow in an impacting jet is modeled using a finite difference solution of the Navier-Stokes equations in a 3D Cartesian coordinate system. The ambient air during jet impact is assumed to be dynamically inactive: i.e., the gas phase is not considered. Other assumptions are that the liquid is incompressible, and the fluid flow is laminar. The surface profile of the impinging jet is defined using the 'Volume of fluid'(VOF)'scheme [9]. In this method, a scalar function f is defined as the fraction of a cell volume occupied by fluid. f is assumed to be unity when a cell is fully occupied by the fluid and zero for an empty cell. Cells with values of $0<f<1$ contain a free surface. Surface tension is modeled as a volume force acting on fluid near the free surface. Tangential stresses at the free surface are neglected. Details of the fluid flow model are given by Bussmann et al. [10].

Internal Obstacle. The solid plate in the computational domain is an internal obstacle that affects the fluid flow. We treat the internal obstacles as a special case of two-phase flow, in which the first phase is the liquid, with volume fraction Θ, and the second phase is the obstacle, with volume fraction (1-Θ). The obstacle is characterized as a fluid of infinite density and zero velocity. The volume fraction Θ is a scalar field whose value is equal to one in the fluid and zero in the obstacle. The definition of Θ