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Simulation of drop deposition process in annular mist flow using three-dimensional particle method

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Abstract

The three-dimensional moving particle semi-implicit (MPS) method is employed to simulate the deposition process of single droplet on the liquid film. The model accounts for the presence of inertial, gravitation, viscous and surface tension and is validated by comparison with experimental results. The parameters of liquid droplets and film are calculated by a one-dimensional mixture model in which correlations and methods on void fraction, entrainment fraction and droplet velocity and size distribution are employed. The simulation results are analyzed to study the effect of splash on the deposition and re-entrainment processes in annular-mist flow. It is found that splash plays an important role in the deposition and re-entrainment processes in high quality conditions of BWR.

1. Introduction

The annular-mist flow regime exists in the upper portion of the fuel rod bundles in boiling water reactor (BWR). In this regime, part of liquid moves along the wall as a thin film and the other part move as entrained droplets in the gas core. The critical heat flux condition that occurs in BWR is caused by the dryout of the liquid film on the heated wall. Evaporation and entrainment from the film deplete the liquid film. On the other hand, deposition of the mist droplets on the liquid film tends to replenish the film (Fig. 1). When the thickness or the flow flux of the film becomes zero or lower than a critical value, it is thought that dryout occurs. Therefore, the accurate prediction of the deposition and entrainment rates is of particular importance.

The deposition rate has been studied by many experiments and two main techniques have been used to measure the rate of deposition of drops onto the wall film (Azzopardi, 1997). The first is tracer technique (Fig. 2) (Andreussi and Azzopardi, 1983; Schadel et al., 1990); a continuous supply of tracer is injected into the film, and then the concentration of tracer in the film at different location downstream from the point of in-

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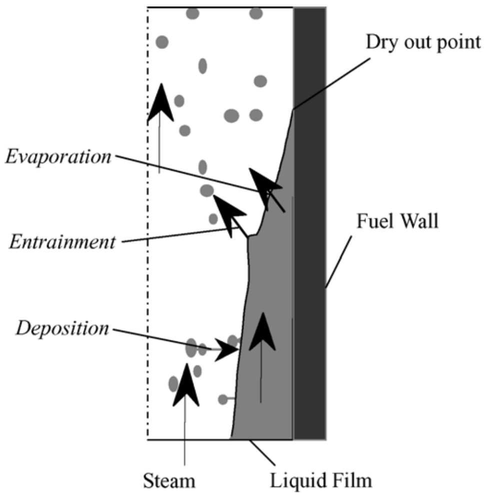

Fig. 1. Schematic of annular mist flow.

jection is measured. Mass balance is used to calculate the deposition rate from the measurement results. In the second technique, the liquid film is removed by extracting through porous wall; the liquid film formed by re-deposition downstream is removed again by extracting in the second porous wall section (Fig. 3) (Lopez de Bertodano et al., 1997; Šikalo et al., 2002). Then the deposition rate can be obtained by measuring the

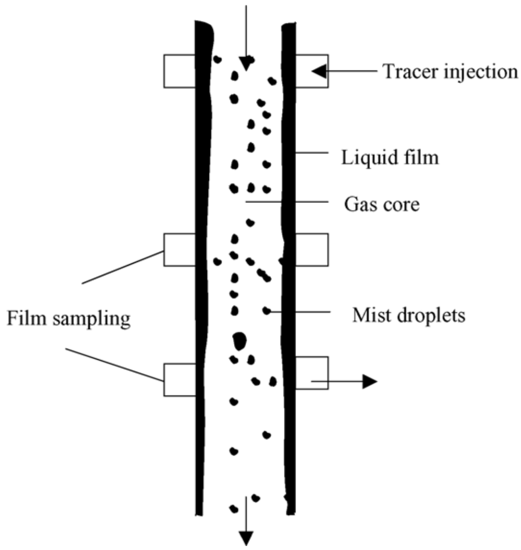

Fig. 2. Schematic of tracer method.

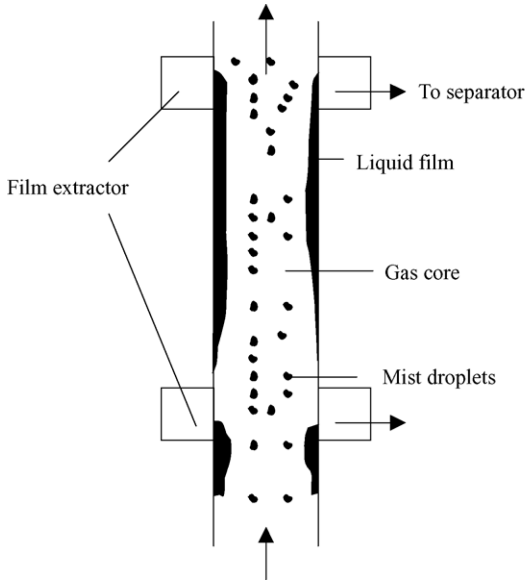

Fig. 3. Schematic of film extraction method.

flowrate of liquid film. From the theory of these two measurement methods it can be found that what they measured should be the mass of droplets that are deposited and stay on the film. In some special conditions, splash may occur in the deposition process and some mass of the deposited drop and film can be re-entrained into the gas core. This factor cannot be measured by above measurement methods. A number of models of the deposition process have been published. Many considered that the deposition was a diffusive mass transport process; turbulence made drops move in a random manner (Hay et al., 1996). It was reported that the larger drop did not move in a random manner but traveled across the test section in straight lines (Andreussi and Azzopardi, 1983). The initial impetus given to the drops by the entrainment process was thought as reason. Azzopardi (1997) reviewed these models. The factor of splash has not been considered in these existing models. In the theoretical models for entrainment, it was usually assumed that the entrainment is created by disturbance wave in the film and the factor of splash has also not been considered. Therefore, there exists a premise that the theoretical models can cover the measurement results; the deposited droplets should totally merge with the film and no splash occurs in the deposition process or the effect of splash