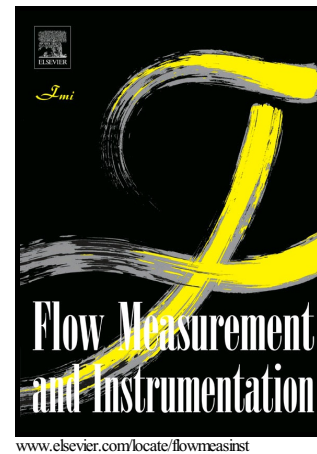


Annular flow in rod-bundle: Effect of spacer on disturbance waves

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Annular flow in rod-bundle: effect of spacer on disturbance wavesSon H. Pham^a, Tomoaki Kunugi^{b,*}^aNuclear Engineering Division, Argonne National Laboratory, Lemont, IL 60439, USA^bDepartment of Nuclear Engineering, Kyoto University, Nishikyo, Kyoto 615-8540, Japan

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Abstract

A high-speed camera technique is used to study the effect of spacers on the disturbance waves present in annular two-phase flow within a rod-bundle geometry. Images obtained using a backlight configuration to visualize the spacer-wave interactions at the micro-scale resolution (in time and space) are discussed. This paper also presents additional images obtained using a reflected light configuration which provides new observations of the disturbance waves. These images show the separation effect caused by the spacer on the liquid film in which the size of generated liquid droplets can be controlled by the gas superficial velocity. Furthermore, the data confirm that the spacer breaks the circumferential coherent structures of the waves.

Keywords: high speed camera; disturbance waves; liquid-film flow; spacer; rod bundle

1. Introduction

Two-phase annular flow occurs in various heat exchange systems such as steam generators and nuclear reactor's core. The mass and heat transfer of this two-phase flow are particularly important to the efficiency and safety of the system because it is the last flow regime before a possible dryout situation takes place. However, the study of such flows presents many difficulties. One challenge comes from the very unstable gas-liquid interfaces where disturbance waves exist which directly affect not only the mass and heat transfers in the system but also the interface friction. Moreover, common but complicated structure of heat exchange systems like a rod-bundle geometry with the presence of spacers makes it difficult for researchers to provide the detail descriptions of the interaction between the flow and the spacer.

A large number of studies have been performed to investigate two-phase annular flow using different methods such as the planar laser-induced fluorescence (Alekseenko et al., 2009; Farias et al., 2012; Schubring et al., 2010), the laser focus displacement (Hazuku et al., 2008), the ultrasonic (Wada et al., 2006), and the liquid electric conductivity (Azzopardi, 1986; Damsohn and Prasser, 2009; Zhao et al., 2013; Velasco Peña and Rodriguez, 2015). Although the characteristics of the flow parameters have been considered carefully (including the wavy liquid film and liquid droplets), most of these experiments have used circular pipe test sections where the role of spacers cannot be taken into account.

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