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ScienceDirect

Energy Procedia 126 (201709) 66–73

Energy Procedia

www.elsevier.com/locate/procedia

72nd Conference of the Italian Thermal Machines Engineering Association, ATI2017, 6–8 September 2017, Lecce, Italy

Characterization of water-air dispersed two phase flow

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Abstract

The analysis of two phase flow has a great relevance in many industrial sectors such as nuclear and process industry. The study and the measurement of the related phenomena are particularly difficult due to the variety of the parameters that affect the flow (void fraction, flow regime, orientation, etc.). Measurement instrumentation for two phase flow is nowadays very limited even if it would be highly useful in the industrial field. Before approaching the research and development toward the realization of innovative instrumentation for two-phase flow measurement, it is fundamental a precise description of the particular flow regime of interest. Dispersed water droplets in air/gas is a possible flow regime at high gas void fractions; therefore it is important to characterize this particular flow pattern in a detailed way. To reproduce this condition in a laboratory environment it is possible to use nozzles with very small outlet diameters and high pressure water supply. In this paper the characterization of dispersed flow is performed as function of the nozzle characteristic and water inlet pressure. The tests are performed using an experimental setup realized at the Energy Department at Politecnico di Torino. The water jet is observed in a PMMA (PolyMethylMethacrylate) pipe 1.8 meters long with an inner diameter of 78 mm. High pressure water is obtained using a plunger pump and pump inlet water pressure is adjustable in the range 1-4 bar. Water pressure upstream the nozzle and air entrainment flow rate are measured and used as primary parameters of the study. A sensitivity analysis on these two parameters is performed with the purpose to find the conditions that are optimal to reproduce a dispersed flow.

Peer-review under responsibility of the scientific committee of the 72nd Conference of the Italian Thermal Machines Engineering Association

Keywords: two-phase flow; dispersed flow; nozzle; spray;

1. Introduction

In many energy and industrial systems, the characterization and the measurement of the mass flow rate is a fundamental aspect, both for performance analysis and for safety issues. Despite its importance, the evaluation of this parameter is not always a trivial problem. Usually, the easiest way is to use a dedicated device that has been previously designed and calibrated for the system of interest. A relevant limitation is that this kind of devices are capable to work only for single phase flow. Moreover, most of them are able to work only with the specific fluid for which they have

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1876-6102
Peer-review under responsibility of the scientific committee of the 72nd Conference of the Italian Thermal Machines Engineering Association
10.1016/j.egypro.2017.08.059

been designed and calibrated. In the design of a thermodynamic system in which the measurement of mass flow rate is needed, for every single process a suitable instrument for the used fluid has to be chosen. The real problem comes up when two-phase flow is present. Historically, the study of the phenomena and the measurement of the related parameters are particularly difficult due to the many variables that affect the flow: the void fraction, the flow regime, the velocity of the two phases, the orientation of the flow, etc. In the past, many studies have been performed and some semi-empirical correlations for the characterization of this problem have been found, but the uncertainties of the results are very high and the range of applicability is limited. Because of the intrinsic complexity of this kind of problem, nowadays the measuring instrumentation for the evaluation of the mass flow rate in two phase condition is almost inexistent. In the last years at the Thermal-hydraulic Laboratory of the Energy Department at Politecnico di Torino several experiments on two-phase flow have been carried out at high void fraction by using different instrumentation for flow rate measurement [1, 2, 3, 4, 5]. The aim of the present paper is to design a device that can produce a dispersed flow regime at high gas void fractions, which is obtained by using nozzles with very small outlet diameters and high pressure water supply, so as to suck an air stream with water droplets dispersed in it. The breakup length, the fragmentation of the liquid jet in droplets, the interaction droplets-wall have been investigated and water pressure upstream the nozzle and air entrainment flow rate have been measured.

2. Dispersed flow

As already mentioned, there are many parameters characterizing the two phase flow. Among them, the direction of the flow is fundamental, since the gravity affects the fluid dynamics: in a vertically oriented pipe, the gravity is in the same direction of the flow and the effect of its action on the fluid is simply related to the way of the flow, i.e. upward or downward. Moreover, since the gravity acts equally on the cross section of the pipe, any symmetry is preserved. The problem is different if the pipe is horizontally oriented. Since the direction of the flow and the gravity are orthogonal, the resulting effect is a tendency to stratification of the two phases, with the liquid phase that tends to accumulate in the lower part of the pipe. The overall effect of pipe orientation, together with the velocity of the two phases and the void fraction, determine the flow pattern that occurs. An example of the possible different flow patterns is shown in Fig. 1.

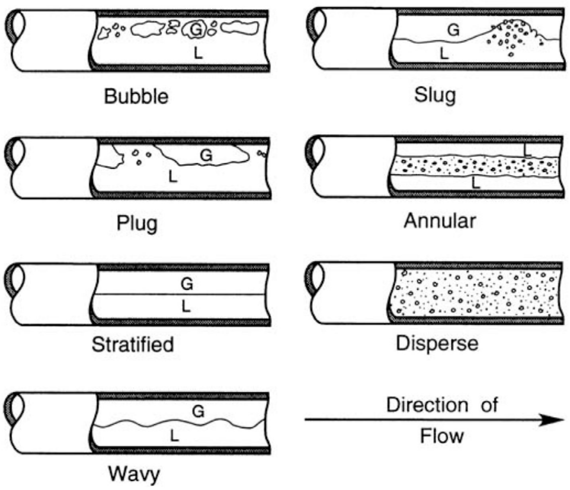

Fig. 1. Flow pattern maps inside a horizontal pipe [6].

They differ depending on the average distribution of one phase with respect to the other. The void fraction is increasing going from the first to the second column, going from the top to the bottom. As we can see, one of the flow patterns associated to high void fractions is the dispersed one. In the dispersed flow pattern one phase or component (such as drops, bubbles, or particles) is widely distributed in the other continuous phase [6].