Available online at www.sciencedirect.com
ScienceDirect
International Journal of Multiphase Flow 34 (2008) 325–332
International Journal of Multiphase Flow
www.elsevier.com/locate/ijmulflow

Flow-induced vibration in two-phase flow with wire coil inserts

Dae Hun Kim *, Soon Heung Chang

Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology, 335 Gwahangno, Yuseong-gu, Daejeon 305-701, Republic of Korea

Received 14 February 2007; received in revised form 14 May 2007

Abstract

Information of flow-induced vibration (FIV) in two-phase flow with wire coil inserts at atmospheric pressure, is presented in this study. FIV was measured in an upward vertical tube for four different wire coil inserts using an air–water mixture as process fluid. Vibration increased along with mass flux and quality. The narrower wire coils produced more vibration. The FIV prediction correlation for two-phase flow with wire coil inserts was experimentally developed with coefficient correlation value of 0.956.

Keywords: Flow-induced vibration; Two-phase flow; Wire coil

1. Introduction

Flow-induced vibration (FIV) of power and process plant components is a relatively unregulated technology by industry codes and standards. To a large extent FIV is an operational problem that has relatively little direct impact on public safety. Yet flow-induced vibration is often viewed as too mysterious one for the average practicing engineers to understand. The investigating method of predicting the vibrations of stable tubes and rods in response to external turbulent flows is important. At any instant of time, the surface pressures will exert a net lateral force on the rod and make turbulence-induced vibration. The vibration of the fuel rods contacting with the spacer grid makes scratch and damage on the cladding cover that results radioactive material release. A spacer grid with mixing vane and ribbed tube are designed to make high turbulence for higher heat transfer rate and critical heat flux (CHF) enhancement, that induces more vibration in the channel.

The purpose of this study is to develop FIV prediction correlation which includes geometric effect of wire coil designed to generate swirl flow, under two-phase flow condition.

2. Background

Many studies have been carried out on gas–liquid two-phase flow, because heat transfer enhancement is an important theme in order to improve performance of heat exchangers and steam generators. The bubble departure from the tube wall is retarded in subcooled flow boiling and low-quality region under microgravity. Therefore, it is necessary to positively remove the bubbles near the wall surface, because departure from nucleate boiling (DNB), in which there is a shift to film boiling from nucleate boiling, is apt to occur. When DNB occurs, the wall temperature rises rapidly. For this purpose, it is possible to improve the heat transfer coefficient and the critical heat flux pressing against the wall surface of the liquid phase and the droplet by the centrifugal force due to the swirl flow. When a swirl flow generator such as a twisted tape and a wire coil is inserted into a circular tube, the realization is possible. However, an increase of the energy consumption in the entire system including the pumping poser of the heating medium is generated, because the flow resistance also increases.

* Corresponding author. Tel.: +82 42 869 3856; fax: +82 42 869 3810.
E-mail address: daehunkim@kaeri.re.kr (D.H. Kim).

0301-9322/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijmultiphaseflow.2007.08.009

Many studies have been published on the flow characteristics of gas–liquid two-phase flows in circular tubes using experimental and theoretical analysis. Studies of the flow characteristics in the circular tube with a swirl flow generator have been made: the study of the flow patterns and flow characteristics in a vertical twisted-tape-inserted tube by Lee et al. (1996, 1998), the study of the vertical upward flow in a grooved tube by Nishikawa et al. (1973), the studies of the flow characteristics in a horizontal tube with helical ribs of a rectangular or a circular shape installed on the inner surface by Lan et al. (1997), and the study of the suppression of droplet entrainment with the aim of improving evaporative heat transfer by Namie and Shiozaki (1990). Takeshima et al. (2002) investigated flow pattern, average void fraction, and pressure drop of an upward air–water two-phase flow in vertical tubes.

It is widely known that the heat transfer coefficient and the CHF are improved when swirl flow generators such as wire coils and twisted tapes are used. In regard to wire coil inserts, there are recent reports by Inaba et al. (1994) and Shoji et al. (1998) dealing with the heat transfer coefficient and the flow resistance in the transition region from laminar flow to turbulent flow for single-phase flows. An experimental investigation of the critical heat flux in subcooled flow boiling of water has been carried out by Celata et al. (1994) who found that use of turbulence promoters in a tube with a wire coil is an effective method for subcooled flow boiling CHF. Takeshima et al. (2002) investigated average void fraction, the local void fraction distribution and liquid film thickness of an upward air–water flow in vertical tubes, and reported that the average void fraction in tubes with wire coils is lower than in a smooth tube and decreases with the wire diameter owing to the centrifugal force of the swirl flow which concentrates bubbles at the center of the tube, that the local liquid film thickness becomes more uniform with a decrease in the pitch of the wire coil, and that the liquid film becomes thicker after the passage through the wire coil with an increase in the wire diameter.

Prediction of FIV is very important to prevent fuel damage in nuclear reactor. But, it is very complicated problem for mixture of fluid and vibration mechanism. Au-Yang (1975) performed vibration measurement in water flowing pipe and suggested empirical prediction correlation. FIV can be easily predicted using this correlation after measuring dynamic pressure fluctuation. This correlation is based on the experiment data of single phase pipe flow only.

Swirl flow is a hot issue for turbulent mixing and heat transfer. Swirl flow has centrifugal force that concentrates bubble at the center resulting liquid film thickening and CHF enhancement. There is little information about the vibration generated by swirl flow especially in two-phase flow condition. This study may provide information of vibration production by two-phase flow with swirl generator.

3. Experiments

The experimental study has been carried out under the conditions of atmospheric pressure. The test loop consists of a tube type test section, an air–water separator, a displacement pump, a surge tank, a turbine flow meter, ball and needle valves and an air blower. The schematic diagram of the test loop is drawn in Fig. 1. Each part is made of SUS-304 for the prevention of corrosion and connected with SUS-316 tubes of 2 in and 1 in.

The test section is constructed with circular acryl pipe of 25 mm inner diameter. Total length of the test section is 2 m. Entrance part for fully developed flow is 1 m, test part is 50 cm and outgoing section is 50 cm. The schematic diagram of the test section is drawn in Fig. 2. Four type swirl generating wire coils can be inserted in the middle part of test section changing wire thickness and twisting pitch length. Thickness is 2 mm and 3 mm, and pitch length is 25 mm and 50 mm. Wire coils are made of steel. Honey comb is inserted at the water inlet to stabilize flow.

Two B&K vibration accelerometers are attached at the center position of measure part of test section. All sensors

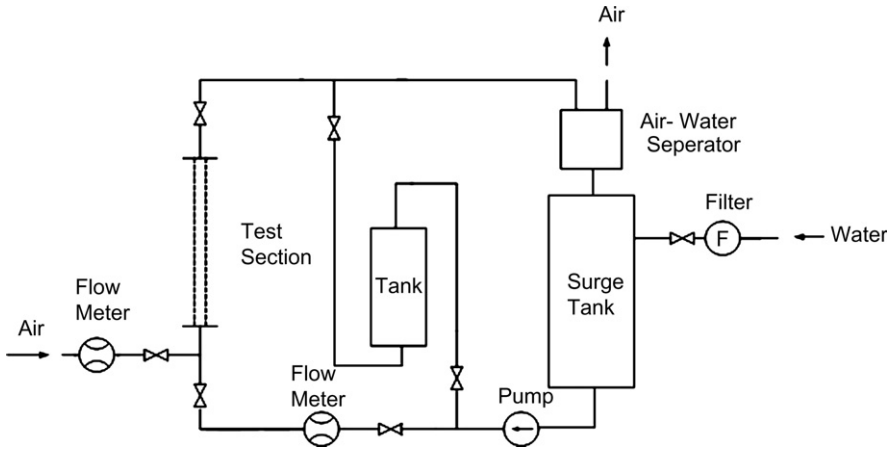

Fig. 1. Schemetic diagram of the experimental test loop.