Flow Induced Vibration Characteristics in 2X3 Bundle Critical Heat Flux experiment

Dae Hun Kim, Soon Heung Chang
KAIST, Nuclear and Quantum Engineering Dept. 373-1 Guseong-dong, Yuseong-gu, Daejeon 305-701,
daehunkim@kaist.ac.kr

1. Introduction

Above a certain heat flux, the liquid can no longer permanently wet the heater surface. This situation leads to an inordinate decrease in the surface heat transfer. This heat flux is commonly referred to as the critical heat flux (CHF). The CHF in nuclear reactors is one of the important thermal hydraulic parameters limiting the available power.

Flow induced vibration (FIV) is the vibration caused by a fluid flowing around a body. In the fluid flowing system, FIV occurred by structures and flow condition. Many structures in nuclear power plant system are designed to prevent from structure failure due to FIV.

Recently, Hibiki and Ishii (1998) carried out an experimental investigation on the effect of flow-induced vibration (FIV) on two-phase flow structure in vertical tube and reported that the FIV drastically changed the void fraction profiles. The void fraction profiles is one of the important parameter for determining CHF.

Therefore, the investigation on the effect of FIV on CHF are needed.

The research on FIV characteristics detection during CHF experiment in 2X3 bundle using R-134a has been carried out in KAIST. Using the results new FIV correlation in 2-pahse turbulent flow are suggested after finding out relation between CHF and dynamic pressure fluctuation value.

2. Background

Most practically, experimental and analytical approach to turbulence-induced vibration suggested FIV prediction equation by Au-Yang (1977).

$$< y^2(\vec{x}) > = \sum_\alpha \frac{A G_p(f_\alpha)\psi_\alpha^2(\vec{x}) \vec{J}_{\alpha\alpha}(f_\alpha)}{64\pi^3 m_\alpha^2 f_\alpha^3 \zeta_\alpha}$$

In turbulent flow condition, the most important vibration forcing factor is fluctuation pressure (G_p). But, this predicting equation is based on single phase turbulent flow experiment. For using in 2-phase turbulent flow regime, correcting factor is used.

For most effective mixing vane which increase CHF and reduce FIV, swirl vane is suggested by Shin after several 2X2 bundle CHF test using R-134a (2003)

3. Experiment

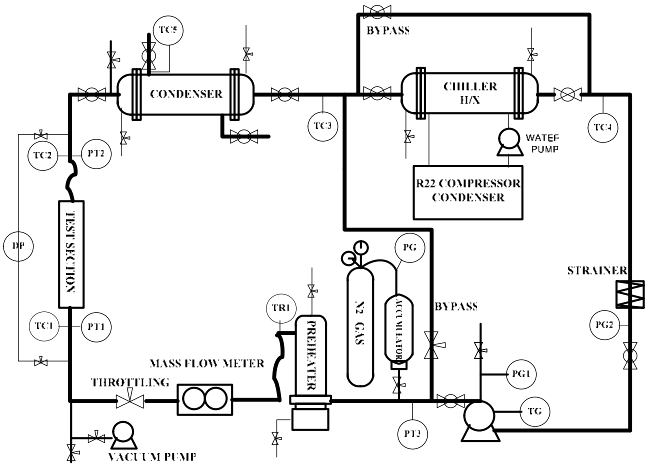

Fig.1 KAIST R-134a test loop

The Experimental loop is a closed circulation loop with R-134a as a working fluid. The loop has a test section, a condenser, a pump, a chiller, a preheater, an accumulator, valves, and instrumentations. The vacuum pump is also provided because air in the test section should be removed after the replacement of spacer grid. The loop is schematically shown in Fig.1. Almost all pipes of the loop are made of 1” SUS 316 tube to prevent corrosion. But pipes for measurements are 1/4” SUS 316 tube.

The main goal of this loop is to control the test section inlet conditions: inlet pressure, inlet temperature, and mass flux. Because R-134a is a compressible liquid, Pressure is coupled with temperature. So it is hard to control these inlet conditions. The components, which control pressure and temperature, are condenser, chiller, accumulator and preheater. Condenser made two-phase flow into single-phase flow. Together with chiller, condenser removes of heat from the working fluid at the test section outlet. Especially, it effect on the inlet pressure. Of course, the main role of condenser is a phase change. On the other hand, that of chiller is a heat removal. Accumulator simply controls the pressure of the loop. Inside accumulator, there is a membrane between N_2 gas and R-134a and pressure is dependent in amount of N_2 gas. Preheater is a component that controls the inlet subcooling (inlet temperature).

Test section’s geometry is a 2X3 rod bundle. It composed of heater rod, copper plate for electrical connection, Bakelite for insulation, SUS 304 circular body. Heater rod diameter is 9.7mm and the pitch is 12.85mm and a side of rectangular flow channel is 25.7mm and heated length is 1200mm. Each rod has a hole. Thermocouples (Type-K) are welded onto the inner surface of the rod at the upper end of heated length.

Rectifier	Power: 200kW
Pump	Flowrate: 60lpm,1.2kg/s
	Head: 50m
Preheater	Capacity: 25kW
	Max. Pressure: 70bar
Condenser	Capacity: 30kW
	Max. Pressure: 70bar
Chiller	Capacity: 46kW
	Pressure: 70bar

Table 1. Instruments in R-134a test loop

Three dynamic pressure gauge (PCB 112A05) are detached beyond inlet point, mixing vane point, CHF point.

4. Results and Discussion

In two mass flux condition (712 kg/m2-s, 1000 kg/m2-s), CHF experiments is performed increasing heat flux step by step. Dynamic fluctuating pressure test results are shown in Fig.2 and Fig.3, and matching vibration results are shown in Fig. 4 and Fig. 5.

Vibration peak is observed at bubbly regime and slug regime and it become stable changing to annular regime. Vibration peak in bubbly flow regime has bubble generation frequency and is effected by cavity damping effect. The other vibration peak in churn flow regime has slug moving frequency and is effected by cavity damping effect. And after perfect separation of flow and bubble in annular flow regime, vibration become stable.

In two phase flow, each flow regime has different pressure fluctuation result which can effect flow induced vibration differently. So, new experimental FIV prediction correlation is needed to develop.

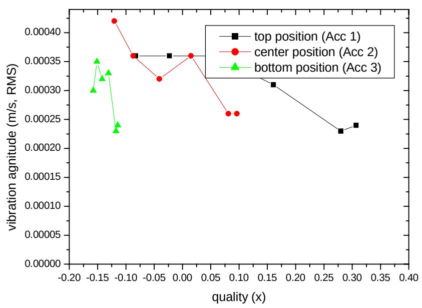

Fig. 2 Vibration Amplitude results (712 kg/m2-s)

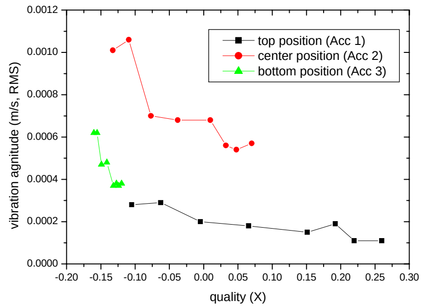

Fig. 3 Vibration Amplitude results (1000 kg/m2-s)

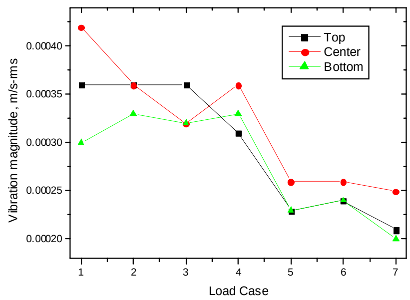

Fig. 4 Vibration Amplitude results (712 kg/m2-s)

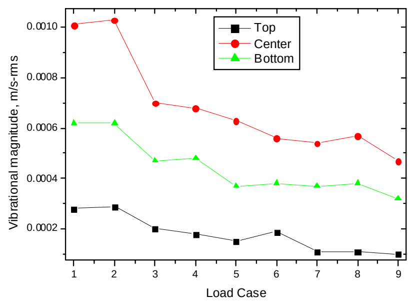

Fig. 5 Vibration Amplitude results (1000 kg/m2-s)

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