Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Dynamic Pressure and Vibration in Turbulent Swirl Flow

Dae Hun Kim, Soon Heung Chang

Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology 373-1, Gusongdong, Yusongu, Daejon 305-701

daehunkim@kaist.ac.kr

1. Introduction

In bare tube, vibration increased as mass flux increase and has different pressure fluctuation profile in laminar flow and turbulent flow. Swirl generator insertion deleted flow characteristic change, and showed no difference between laminar flow and turbulent flow

2. Background

Flow induced vibration prediction is very important to prevent fuel damage in nuclear reactor. But, it is very complicated problem for mixture of fluid mechanism and vibration mechanism. Au-yang et al.(1975) performed vibration measurement in water flowing pipe and suggested empirical prediction correlation.

$$< y^2(\vec{x}) >= \Sigma_\alpha \frac{AG_p(f_\alpha)\psi_\alpha^2(\vec{x})\vec{J}_{\alpha\alpha}(f_\alpha)}{64\pi^3 m_\alpha^2 f_\alpha^3 \zeta_\alpha} \quad (1)$$

The input term is constructed with dynamic force term and structural term. Power spectral density of dynamic pressure fluctuation (G_p) is dynamic force term which represents flow condition and is variable number. Structural term is fixed number. So, flow induced vibration 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.

Pressure fluctuation is important variable to predict flow induced vibration. Many researchers tried to detect pressure fluctuation. Bakewell et al.(1962) and Clinch (1969) performed experiments in pipe flow and Mulcahy et al (1981) performed it in annular flow. L.R. curling (1992) tried to detect pressure fluctuation in bundle flow. Pettigrew and Taylor (1993) wanted to know how two-phase flow effect pressure fluctuation. They detected pressure fluctuation decrease in two-phase flow and concluded it is for damping ratio increase. In the bubble-slug flow, vibration increase as steam quality increase and vibration become stable as it changes to annular flow (Pinton, 1996). P.Abry et al .(1994) detected pressure fluctuation in swirl flow. They reported that normalized power spectral density of pressure fluctuation decreased by sudden pressure drop in low frequency. Today, swirl flow in hot issue for turbulent mixing and heat transfer. Swirl flow has centrifugal force that concentrate bubble at the center resulting liquid film thickening. It make early fow pattern transition (Takeshima et al. 2002)

3. Experiment

Test section is constructed with circle pipe of acryl of 25 mm inner diameter. Total length of test section is 2 m , it is composed with 1 m entrance part for fully developed flow, 50 cm detection part and lasting 50 cm outgoing part . 4 type swirl generator can be inserted in the middle part of test section changing wire thickness and twisting pitch length. Thickness is 2mm and 3mm and pitch length is 25 mm and 50 mm. Swirl generator is twisted wire of steel. Honey comb is inserted at the water inlet to stabilize flow. 3 PCB dynamic pressure gauge is attached at the middle detecting part of test section to detect pressure fluctuation, its position is inlet, middle and outlet having 25 cm distance. 2 B&K vibration accelerometer is attached at center position of middle part of test section for vibration detection. All sensors use B&K NEXUS amplifier for band filtering from 1 Hz to 1 kHz and all signals transfer personal computer with data acquisition book. All random data has sampling rate of 2500 sample/s and total sampling 4 seconds.

4. Results and Conclusion

Dynamic pressure detection is performed in 5 test condition and 2 detection position. Pipe vibration is detected at the center of test section with 2 cross positioned accelerometer.

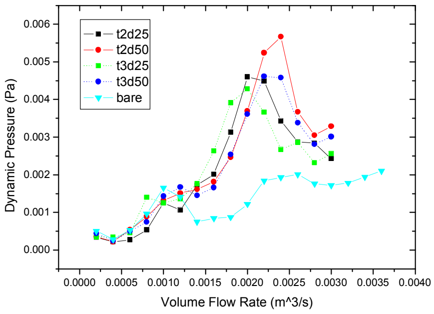

Fig. 1 Dynamic pressure result at inlet position

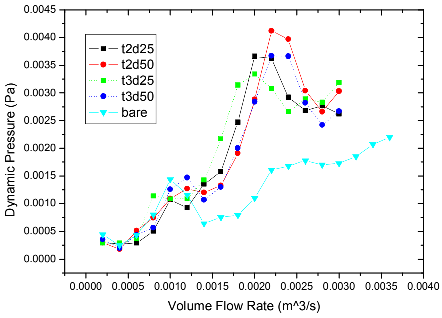

Fig. 2 Dynamic pressure result at center position

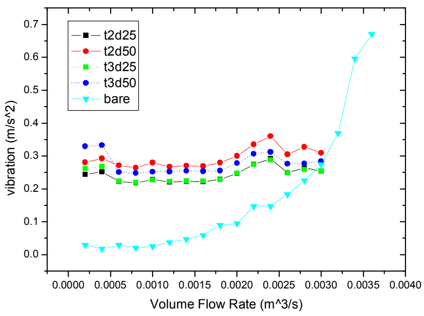

Fig. 3 Pipe vibration result at center position

Fig 1, 2 show the dynamic pressure results increasing volume flow rate from 0 to 0.0040 m^3/s. Wire thickness is represented by 't' and pitch length is 'd'. Dynamic pressure increased as volume flow rate increased, but there was sudden drop as flow changed to turbulent flow at bare condition (without swirl generator) at Re = 2800. Swirl generator make no pressure drop at turbulent flow changing condition, but other dynamic pressure drop is observed at almost twice volume flow rate condition. Fig 3, show the pipe vibration results increasing volume flow rate. Pipe vibration increased as volume flow rate increased at bare condition, but swirl generator insertion made vibration have some constant value comparing with bare condition. In conclusion, swirl generator makes flow turbulent faster, and high dynamic pressure fluctuation, but make almost constant pipe vibration less than bare pipe at high volume flow rate.

Reference

[1] Au-Yang, M.K., 1975, "Response of Reactor Internals to Fluctuating Pressure Forces," Journal Nuclear Engineering and Design, Vol. 35, pp. 361-375

[2] Clinch, J.M., 1969, "Measurements of the wall pressure field at the surface of a smooth-walled pipe containing turbulent water flow," Journal of sound and vibration, Vol. 9, no. 3, pp. 398-419

[3] Mulcahy et al., 1981, "Analysis of a cylindrical shell vibrating in a cylindrical fluid region," Nuclear Engineering and Design, Vol. 63, no.1, pp. 109-120

[4] Curling, L.R., 1991, "Measurements and characterization of wall-pressure fluctuations on cylinders in a bundle in turbulent axial flow; Part 1: Spectral characteristics," Journal of sound and vibration, Vol. 157, no.3, pp. 406-433

[5] Pettigrew, M.J., 1993, "Vibration behavior of nuclear fuel under reactor conditions," Nuclear Science and Engineering : the journal of the ANS, Vol. 114, no. 3, pp. 179-189

[6] Pinton, J.-F. et al, 1996, "Power fluctuations in turbulent swirling flows," Journal de physique : JP. II, vol. 6, no. 7, pp. 1099-1110

[7] Abry, P. et al., 1994, "Analysis of pressure fluctuations in swirling turbulent flows," Journal de physique : JP. II, vol. 4, no. 5, pp. 725-

[8] Takeshima et al., 2002, "The flow characteristics of an upward gas-liquid two-phase flow in a vertical tube with coil : Part 1. Experimental results of flow pattern, void faction, and pressure drop," Heat transfer, Vol. 31, no. 8,