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# Large-scale Flow Pulsation in Tight Square Arrayed Rod Bundles of Nuclear Reactor

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## 1. Introduction

As a major component of modern nuclear reactor, the nuclear fuel rod bundles with liquid coolant have been studied by a lot of researchers to understand the flow structure between the fuel rods. Recently, rod arrays with much small pitch-to-diameter ratio have been being tried to increase performance of the nuclear reactor. The liquid coolant flowing axially through these small spaces between the rods is known to show some peculiar phenomena including large-scale, quasi-periodic flow pulsation [1]. These flow pulsation phenomena dominate mixing process in the subchannels [2,3]. Thus, precise understating of the flow structure is essential to predict thermal-hydraulic phenomena in nuclear rod bundles.

In this present paper, the turbulent flow in tight square arrayed rod bundles is investigated with Hot-wire anemometry. Then, the measured velocity data are analyzed by using Fast Fourier Transform analysis to find characteristic frequency of the pulsation.

## 2. Methods and Results

In this section the experimental model and some of the flow measuring techniques are described. Then, the velocity history and spectrum analysis results will be followed.

### *2.1 Apparatus*

Air was provided to the test section by a discharge type blower and through an orifice to measure pressure difference. The flow rate was calculated based on the pressure difference and air temperature obtained by k-type thermocouple. Several mesh screens and honey combs were installed in the stagnation chamber to reduce the non-uniformity of the working fluid and prevent external influence. The working fluid was fully developed by passing through 3 m long rod bundle subchannel. A schematic of the tested model cross-section is shown in Fig. 1. In this schematic P is the pitch between adjacent rods, D is the rod diameter and S is the gap width. The channel size was magnified about 7 times to insert hot-wire probe. The term P/D ratio is important parameter which represents geometrical effect of the rod array. The momentum transfer between the fluids in the subchannels is more intense with smaller P/D ratio [4].

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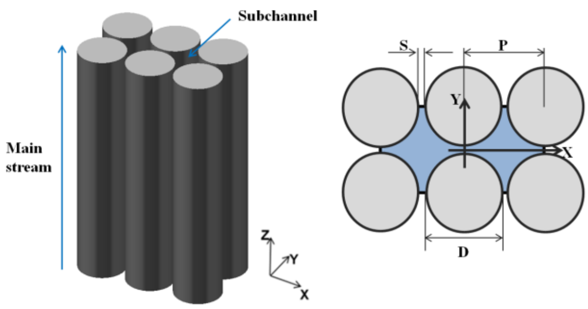


(a) Flow direction (b) cross section

Fig. 1. Flow direction and cross section of the channel.

Rod diameter was 100 mm and the gap space width was 8 mm. Hot-wire measurements in turbulent flow through a square arrayed (P/D = 1.08) six rod bundles were performed about 100 mm before the outlet. A single hot-wire perpendicular to the main stream was used to measure velocity and turbulent intensity in the axial (z) direction. The cross (x) direction components were measured by a single hot-wire parallel to the main stream. The Reynolds number was maintained 43,000 during the experiment and calculated by using hydraulic diameter. Hot-wire data were obtained by IFA-300 system, the sampling rate was 10 kHz, and the sample size was 128 Kpts/ch. 300 Hz low pass filter was used to frequency analysis.

### *2.2 Time history of the cross velocity*

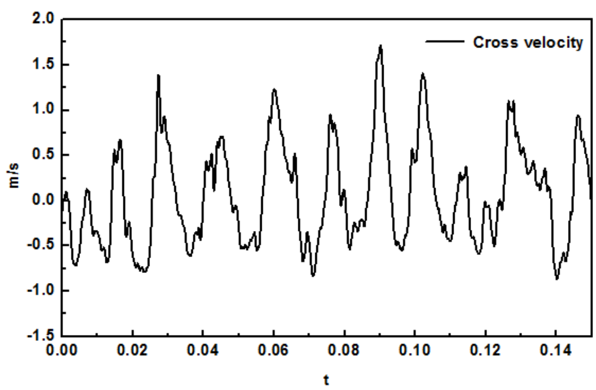


Fig. 2. Time history of the cross velocity (P/D=1.08, Re=43,000).

Figure 2 shows the time varying cross velocity at the center of the gap. The velocity data were obtained for 13.1 seconds. In Fig. 2 the time history includes just 0.15 seconds of the velocity change to show the flow pulsation phenomena clearly. The mean velocity was removed by the same token. The velocity fluctuation, which is identifiable in Fig. 2, is responsible for the mixing phenomena with large-scale pulsation. To find its characteristic frequency, FFT analysis was conducted.

*2.3 Frequency Analysis*

The periodic feature of the cross velocity fluctuation can be detected by using FFT analysis method [5]. If the velocity data have periodic signal, the result from the FFT analysis shows pronounce peak at specific frequency. As shown in Fig. 3, the cross velocity spectrum present band shape peak about 74.5 Hz. The band shape of peaks indicates that the turbulent flow between narrow gaps includes not large-scale periodic pulsation but also non-periodic small eddies. Therefore, the flow pulsation has quasi-periodic feature.

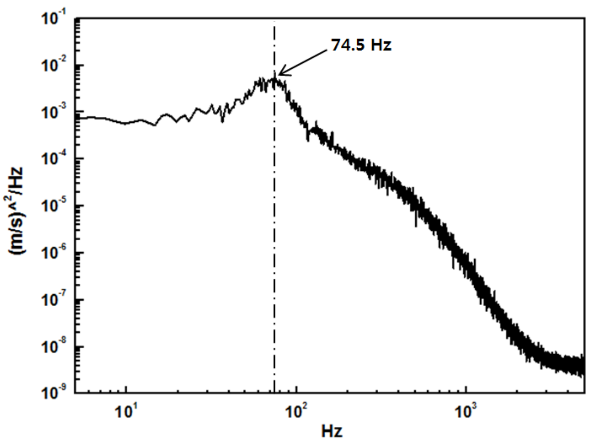


Fig. 3. Power spectrum of the cross components of the fluctuation velocity at the center of the gap (P/D=1.08, Re=43,000).

## 3. Conclusions

In this paper, the measurements of the turbulent flow in tight (P/D = 1.08) square arrayed rod bundles were performed by single hot-wire anemometry. The cross velocity at the center of the gap shows quasi-periodic pulsation which increase mixing rate between the adjacent subchannels. The results from FFT analysis indicates that the dominant characteristic frequency was 74.5 Hz for Re =43,000 condition. These results can be applied to safety design of the nuclear reactor including prediction of CHF, validation of simulation, and prevention of flow-induced vibrations.

**Acknowledgments**

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## REFERENCES

[1] D.S. Rowe, B.M. Johnson, and J.G. Knudsen, Implications concerning rod bundle crossflow mixing based on measurements of turbulent flow structure, International Journal of Heat and Mass Transfer, Vol. 17, No. 3, pp. 407-419, 1974.

[2] M. S. Guellouz, S. Tavoularis, The structure of turbulent flow in a rectangular channel containing a cylindrical rod - Part 1: Reynolds-averaged measurements, Experimental Thermal and Fluid Science, Vol. 23, No. 1-2, pp. 59-73, 2000.

[3] J.D. Hooper, D.H. Wood, Fully developed rod bundle flow over a large range of Reynolds number, Nuclear Engineering and Design, Vol. 83, No. 1, pp. 31-46, 1984.

[4] S.V. Moller, On phenomena of turbulent flow through rod bundles, *Experimental thermal and fluid science*, Vol. 4, No.1, January, pp. 25-35, 1991.

[5] L. Meyer, From discovery to recognition of periodic large scale vortices in rod bundles as source of natural mixing between subchannels--A review, *Nuclear Engineering and Design*, Vol., No.6, pp.1575-1588, 2010.