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Behavior of Instantaneous Lateral Velocity and Flow Pulsation in Duct Flow with Cylindrical Rod

Chi Young Lee [a*], Chang Hwan Shin [a], Ju Yong Park [a], Dong Seok Oh [a], Tae Hyun Chun [a], Wang Kee In [a]
[a] *KAERI, 989-111 Daedeok-daero, Yuseong-gu, Daejeon 305-353, Republic of Korea*
[*] *Corresponding author: chiyounglee@kaeri.re.kr*

1. Introduction

Recently, KAERI (Korea Atomic Energy Research Institute) has examined and developed a dual-cooled annular fuel [1]. Dual-cooled annular fuel allows the coolant to flow through the inner channel as well as the outer channel. Due to inner channel, the outer diameter of dual-cooled annular fuel (15.9 mm) is larger than that of conventional cylindrical solid fuel (9.5 mm). Hence, dual-cooled annular fuel assembly becomes a tight-lattice fuel bundle configuration to maintain the same array size and guide tube locations as cylindrical solid fuel assembly. *P*/*D*s (pitch between rods to rod diameter ratio) of dual-cooled annular and cylindrical solid fuel assemblies are 1.08 and 1.35, respectively. This difference of *P*/*D* could change the behavior of turbulent flow in rod bundle.

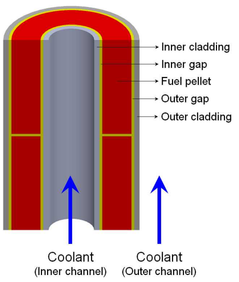

Fig. 1 Illustration of dual-cooled annular fuel [2].

Our research group has investigated a turbulent flow parallel to the fuel rods using two kinds of simulated 3×3 rod bundles [3]. To measure the turbulent rod bundle flow, PIV (Particle Image Velocimetry) and MIR (Matching Index of Refraction) techniques were used. In a simulated dual-cooled annular fuel bundle (i.e., *P*/*D*=1.08), the quasi-periodic oscillating flow motion in the lateral direction, called the flow pulsation, was observed, which significantly increased the lateral turbulence intensity at the rod gap center. The flow pulsation was visualized and measured clearly and successfully by PIV and MIR techniques. Such a flow motion may have influence on the fluid induced vibration, heat transfer, CHF (Critical Heat Flux), and flow mixing between subchannels in rod bundle flow. On the other hand, in a simulated cylindrical solid fuel bundle (i.e., *P*/*D*=1.35), the peak of turbulence intensity at the gap center was not measured due to an irregular motion of the lateral flow. This study implies that the behavior of lateral velocity in rod bundle flow is greatly influenced by the *P*/*D* (i.e., gap distance).

In this work, the influence of gap distance on behavior of instantaneous lateral velocity and flow pulsation in single rod-inserted duct flow is reported and discussed, using various *W*/*D* (wall distance between wall and rod to rod diameter ratio) cases.

2. Experimental Set-up

The schematic diagram of experimental loop, SOFEL (Small Omni Flow Experimental Loop), is depicted in Fig. 2. It consists of water tank, centrifugal pump, turbine flow meter and test section. To carefully control the flow rate, the bypass loop was installed around pump. As the test fluid, the pure water was used.

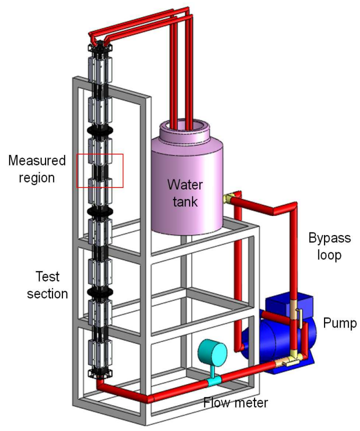

Fig. 2 Schematic diagram of SOFEL [2].

In Fig. 3, the cross-sectional view of test section is shown. To change the gap distance, the single cylindrical rods with four different outer diameters were installed in a transparent polycarbonate square duct of 26.9 mm (width)×26.9 mm (height)×1,650 mm (length). *W*/*D* cases tested in this work were 1.06, 1.08. 1.10 and 1.14, and the instantaneous lateral velocities at rod gap center were measured at a given Reynolds number condition (i.e., Re≈20500).

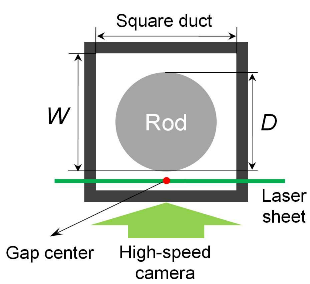

Fig. 3 Cross-sectional view of test section.

To measure the rod bundle flow, PIV technique was adapted. A continuous laser with a wavelength of 532 nm and an output power of 4 W was used. The PIV images were obtained using a high-speed camera (Dantec Dynamics) with the maximum frame rate of 2190 fps (frames/sec) at 1280×800 full resolution. To get the higher frame rate, the size of image was reduced properly. As the seeding particle, the hollow silver-coated glass spheres of 10 μm in diameter were flowed.

3. Experimental Results

It is known that FFT (Fast Fourier Transform) is the effective way to examine the characteristics of (quasi-)periodic oscillating flow motion. In Fig. 4, The FFT results of instantaneous lateral velocities measured at gap center were exemplified. At the similar Reynolds number condition (i.e., Re≈20500), in *W*/*D*=1.06 and 1.10, the peak of power spectral density was observed at a certain frequency range. However, in *W*/*D*=1.14, the peaks of power spectral density and frequency were not measured. In other words, the flow pulsation occurred at *W*/*D*≤1.10 for the present experimental ranges. The peaks of power spectral density and frequency in *W*/*D*=1.06 became larger and higher than those in *W*/*D*=1.10, respectively.

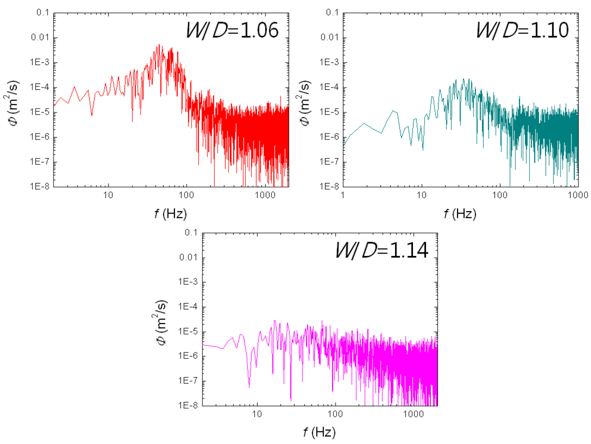

Fig. 4 FFT results of instantaneous lateral velocities measured at Re≈20500.

In Fig. 5, the RMS (Root-Mean-Square) values (w_{rms}) of lateral velocities, defined as Eq. (1), are shown.

$$w_{rms} = \sqrt{\left(w - w_{ave}\right)^2 / N} \qquad (1)$$

Here, w and w_{ave} are the instantaneous and time-average lateral velocities at the gap center, respectively. N is the number of samples.

At a given Reynolds number condition, an increase in *W*/*D* decreased the RMS value of lateral velocity. In the range of *W*/*D*=1.06–1.10, the RMS value of lateral velocity decreased drastically with an increase in *W*/*D*. On the other hand, within the range of *W*/*D*=1.10–1.14, the RMS value of lateral velocity gradually decreased. The decreasing rate in the RMS value of lateral velocity was dramatically changed near *W*/*D*≈1.10, which corresponded to the criterion of flow pulsation. Based on the present experimental data, it was found that *W*/*D* strongly affects the flow structure (i.e., flow pulsation), which contributes to a change in the RMS value of the lateral velocity.

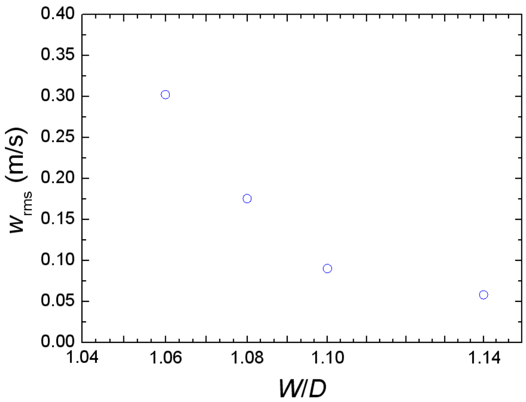

Fig. 5 Effect of *W*/*D* on RMS value of lateral velocity at Re≈20500.

4. Conclusions

In this study, the influence of gap distance on behavior of instantaneous lateral velocity and flow pulsation in single rod-inserted duct flow was investigated under various *W*/*D* cases. Reynolds number condition was about 20500, and the PIV technique was used to measure the instantaneous lateral velocity at gap center.

For the present experimental ranges, in *W*/*D*≤1.10, the flow pulsation, a quasi-periodic oscillating flow motion, appeared, and the peaks of power spectral density and frequency increased with decreasing *W*/*D*. On the other hand, *W*/*D*>1.0, the flow pulsation was not observed. The flow pulsation has much influence on the RMS value of lateral velocity.

REFERENCES

[1] T.H. Chun, C.H. Shin, W.K. In, K.H. Lee, S.Y. Park, H.T. Kim, K.H. Bae, K.W. Song, A Potential of Dual-cooled Annular Fuel for OPR-1000 Power Uprate, In: 2009 LWR Fuel Performance, Paris, France, Paper 2185, 2009.

[2] C.Y. Lee, C.H. Shin, J.Y. Park, W.K. In, An Experimental Study on Turbulent Flow between Subchannels in a Square Channel with a Single Rod, Proceedings of KSME (Korean Society of Mechanical Engineers) 2012 Spring Annual Conference: Thermal Engineering Division, pp. 201–202, 2012.

[3] C.Y. Lee, C.H. Shin, J.Y. Park, W.K. In, An Experimental Investigation on Turbulent Flow Mixing in a Simulated 3×3 Dual-cooled Annular Fuel Bundle using Particle Image Velocimetry, Nuclear Engineering and Design (Under review).