FLOW STRUCTURE OF HIGH REYNOLDS NUMBER FLOW IN A DUAL-ELBOW PIPING SIMULATING COLD-LEGS OF JSFR

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ABSTRACT: Japan Sodium-cooled Fast Reactor (JSFR) in a conceptual design step has two–loop system for the primary cooling having short-radius elbow pipings in which elbow curvature ratio is 1.0 [1]. Their purpose is saving the building cost. One loop system has one hot-leg piping and two cold-leg ones with large diameters. As for the cold-leg piping, there are sterically-connected three elbows and Reynolds number (Re) reaches about 23 x 10^6 due to high flow velocity and large diameter of the piping. In addition to the high Re, vortices shedding from the short-radius elbows make the flow field very complex, which can cause large pressure fluctuation. Flow-induced vibration (FIV) hence needs to be evaluated for the pipings. The evaluation is, however, very difficult because of the extremely high Re condition. It can be done by extrapolating experimental results from low Re cases belonging to the post-critical regime because the actual condition lies in the regime. Moreover, the experimental results can have the role of the reference data of numerical simulation. In the previous studies, time-averaged flow fields have been well analyzed to identify the size of flow separated region and so on. And then it has been elucidated that there is a distinguished periodic component in pressure fluctuation with Strouhal number of about 0.5, and a few ones in velocity fluctuations in the downstream of an elbow by means of frequency analysis. Regarding minute flow structure in a wide range downstream of an elbow, however, there can hardly be seen a comprehensive study to date. In this study, flow experiments with 2-Dimensional Particle Image Velocimetry (2D PIV) are conducted by using 1/7-scale models of the cold-leg piping with single and dual-elbow layouts. The characteristic of velocity fluctuation and the secondary flow are mainly focused on and coherent structures of the fluctuating flow velocity fields are extracted by using Proper Orthogonal Decomposition (POD). Furthermore, the multi-elbow effect is investigated by comparing the flow field of a single and dual short elbow piping. In the experiment, Re is varied from 0.3 x 10^6 to 1.0 x 10^6, which belongs to the post-critical regime. According to experimental results for the characteristic fluid motions extracted from flow fields in dual-elbow piping by POD, a circumferential component near the intrados of the 1st elbow is primary in the secondary flow between the elbows. Actual flow is supposed to appear almost as a superposition of time-averaged flow field, a twin vortex in this case, and this flow structure. As the same manner, a secondary flow downstream of the 2nd elbow can be considered as a superposition of the time-averaged flow, a swirling flow which swirls around the whole cross section, and an unequal twin-vortex whose one vortex size is about half of the pipe diameter appearing in the primary POD mode. The circumferential flow appearing in the primary POD mode is strong and can be inferred to be strongly linked with the separation vortices downstream of the 1st elbow and then pressure fluctuations.

References

[1] H. YAMANO et. Al. *Unsteady Elbow Pipe Flow to Develop a Flow-Induced Vibration Evaluation Methodology for Japan Sodium-Cooled Fast Reactor.* Journal of NUCLEAR SCIENCE and TECHNOLOGY. Vol. 48. No. 4. p. 677-687 (2011)