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Measurement of Flow Distribution at Subchannels in a Wire-Wrapped 37-Rod Bundle for a Sodium Cooled Fast Reactor

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1. Introduction

For a safety analysis in a core thermal design of a sodium-cooled fast reactor (SFR), flow characteristics at subchannels in a wire-wrapped rod bundle are very important. A hexagonally arrayed wire-wrapped fuel rod bundle has been developed [1-2]. In this type of fuel rod, core subchannels are classified with interior, edge, and corner subchannels. Flow distribution of each subchannel is a crucial factor for the core thermal design, and experimental tests for the design code verification and validation in a temperature limitation analysis were conducted.

2. Experimental section

2.1 Test loop

Experiments were conducted at the FIFFA' (Flow Identification test loop for Fast reactor Fuel Assembly) test facility at KAERI. The test loop consists of a water storage tank, pump, and test rig. Fig. 1 shows a schematic of the test loop.

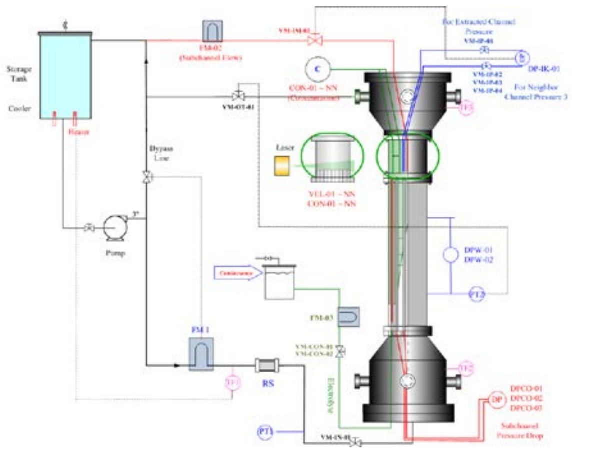

Fig. 1. Schematic drawing of the test loop (FIFFA).

2.2 Test section and condition

A schematic and real assembled image of the test section is shown in Fig. 2. The test section is fabricated as a 37-pin wire-wrapped rod bundle without any scale down analysis. Geometry parameters are designed with a pitch to diameter ration (*P/D)* of 1.14 and wire lead length to diameter ratio (*H/D)* of 27.7. Hydrodynamic similarity with a SFR core is considered by matching these two geometric conditions (i.e., P/D and H/D) and Reynolds number (*Re* = 37,110). The wrapped wires have the same orientation when the rod is assembled (Fig. 2).

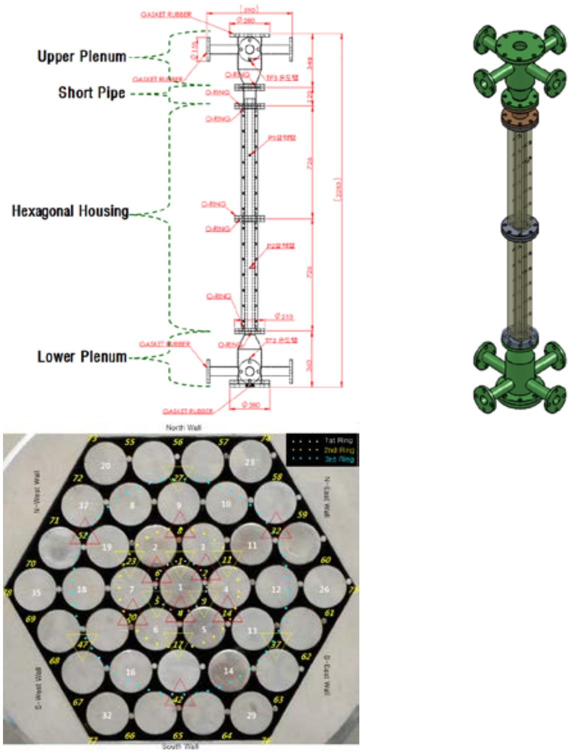

Fig. 2. Test section design and assembled images.

2.3 Iso-kinetic sampling method

An iso-kinetic sampling method was used to measure the flow rates of each subchannel. To eliminate the distortion effect from a sampling probe, the flow extraction was conducted with the iso-kinetic condition by controlling the pressure difference between the inlet and outlet of the sampling probe. Two different types of sampling probes (i.e., interior and edge type sampling probes) were developed with the original design of KAERI [3]. Because the corner flow rates have been known to be relatively smaller than other subchannels [1-2], the corner subchannel flow rates were not measured for the present study.

A total of 36 subchannel flow rates were obtained by the developed iso-kinetic sampling method (Fig. 3). Our iso-kinetic sampling method was differentiated from the previous iso-kinetic sampling method [1-2]. This makes a flow through the measuring subchannel maintain a similar flow stream condition, and it needs a minimum number of pressure gauges for making an iso-kinetic condition. In addition, it is free for the syphon effect issue in low *Re* conditions, because the FIFFA loop is available to control the inlet pressure of the sampling tube.

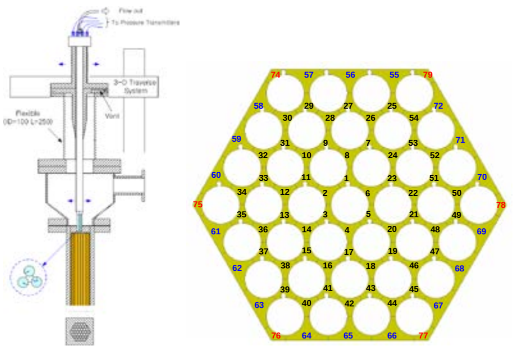

Fig. 3. Schematic of the sampling probe and numbering of subchannels.

3. Results and discussion

3.1 Subchannel flow rate

The subchannel flow rate results by the iso-kinetic sampling method are shown in Fig. 4 with the results of CFD analysis. All measured values of the flow rates in the interior subchannels are in good agreement with those of CFD analysis. The interior subchannel can be free from arguing of the swirl effect by wrapped wires, so it has smaller deviation than those of the edge subchannels. Since a CFD analysis has uncertainties depending on the selection of turbulent models, it does not mean that they are real physical values.

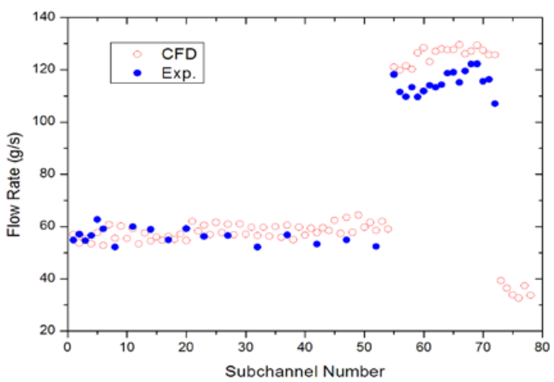

Fig. 4. Subchannel flow rates in experiments and CFD analysis (*Re* = 37,110).

3.2 Mass balance error

The physical issue is the mass conservation in the present experiments. The total flow rate and summation of each subchannel flow rate should be the same in principle. Table 1 shows the calculated results of the mass balance in both experiments and CFD analysis. About 3.1% errors exist in the present experiments, which is a quite good result compared with previous experimental results.

Table I: Mass conservation of experiments and CFD

	Experiments	CFD
Interior subchannel flow rate (g/s)	56.21	58.02
Edge subchannel flow rate (g/s)	115.06	125.64
Mass conservation (%)	96.9	102.2

3. Conclusions

To verify and validate computer codes for the SFR core thermal design, a hexagonally arrayed 37-pin wire-wrapped fuel rod bundle test section was fabricated. The measurement experiments were conducted using a well-designed test loop and iso-kinetic sampling probe. The developed iso-kinetic sampling method in the present study has its own merits, and flow rate results by sampling showed in good agreement with the preliminary CFD analysis results. In addition, the estimated mass balance error was only about 3% in the experiments. Therefore, the present methodology and results can be used in future experiments for design code verification and validation.

ACKNOWLEDGMENTS

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