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Test Specifications and the Design of the Wire Wrapped 37-Pin Fuel Assembly for Hydrodynamic Experiments

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1. Introduction

According to the plans of Atomic energy committee to construct the 4th generation SFR by 2028, KAERI is performing the conceptual R&D under the program of mid and long term project of the Korean government. It is important to understand the flow characteristics in sub-channels through the experimental investigations and to estimate the calculation uncertainties for insuring the confidence of the CFD calculation results. [1] Most influencing parameters on uncertainties and sensitivities of the CFD analyses are the friction coefficient and the mixing coefficient. The friction coefficient is related to the flow distribution in reactor sub-channels. The mixing coefficient is defined with the cross flow between neighboring sub-channels. The eventual purpose of the thermal hydraulic design considering these parameters is to guarantee the fuel cladding integrity as the design limit parameter.

At the moment, the experimental program is being undertaken to quantify these friction and mixing parameters which characterize the flow distribution in sub-channels, and the wire wrapped 37-pin rod assembly and its hexagonal test rig have been designed and fabricated. The quantified thermal hydraulic experimental data from this program are utilized primarily to estimate the accuracy of the safety analysis codes and their thermal hydraulic model.

2. Test Specifications

Experiments for the verification of thermal hydraulic analysis codes should consider the essential design parameters of the real prototype reactor. Fig. 1 shows the configuration of the prototype reactor core and its single fuel assembly.

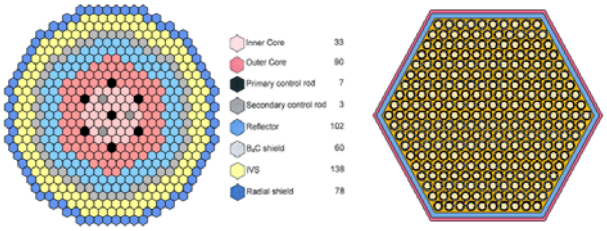


Fig. 1. Configuration of the 150MWe prototype reactor and schematic of the fuel assembly

150 MWe reactor core consists of two core regions, inner and outer, where the core enrichments are different. [1] Reactor core has a total of 123 fuel assemblies and each fuel assembly has its isolated hexagonal flow passage. Each fuel assembly has 271 fuel rods which are arranged with triangular sub-channels.

Generally, hydrodynamic experimental facility should be designed considering the geometric similarity and the flow dynamic similarity to conserve the hydraulic characteristics of the prototype reactor. [2] In this hydrodynamic experiment, four dimensionless parameters were derived as follows from the principal physical parameters in the flow system such as P, V, ρ, v, L, D_H, ε.

- L/D_H Aspect ratio
- ε/D_H Relative surface roughness
- Re Reynolds number (VD_H/v)
- Eu Euler number ($\Delta P/\rho V^2$)

First two parameters, i.e., the aspect ratio and relative surface roughness belong to the geometric parameters, and the similarities have been satisfied by maintaining the configurations and geometric sizes of the flow sub-channels. Other two dimensionless parameters which indicate the dynamic similarities have been conserved by establishing the experimental loop flow conditions with the same Reynolds number. The number of rods in a test fuel assembly has been determined as 37, not 271 of a complete fuel assembly. Operating conditions in a test fuel assembly are 5.49 kg/s at 60℃ which is equivalent to Re ~ 37,100. Table 1 presents the geometrical specifications and the hydraulic conditions which have been determined by considering the conservation of the geometric and flow dynamic similarities between the test and prototype fuel assembly.

Table 1. Geometric and hydraulic specifications

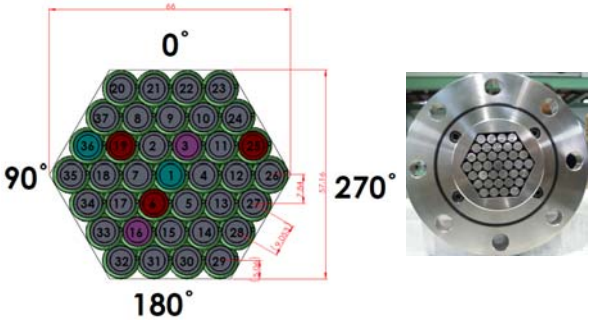
Parameters	SFR, 271 Pin	Water, 37 Pin	Remarks
Rod diameter (mm)	7.4	8.0	
Rod length (mm)	3,400	1,500	
Wire diameter (mm)	0.93	1.0	
Lead length (mm)	204.9	221.5	
P/D	1.125		1/1
H/D	27.69		1/1
System pressure (MPa)	0.1	0.4	
Temperature (℃)	467.5	60.0	
Fluid density (kg/m^3)	840.2	983.4	
Dynamic viscosity (Ns/m^2)	2.49 x 10^{-4}	4.67 x 10^{-4}	
Pressure drop	0.25		1/1
Re number	3.71 x 10^4		1/1

3. Hydrodynamic Experiments in a 37-Pin Wire Wrapped Rod Bundle

A 37-pin wire wrapped test fuel assembly was designed and fabricated for the experiments. The flow rates in each sub-channel, sub-channel pressure drops and the mixing experiments are going to be performed to obtain the flow split parameters, the friction factors and the mixing parameters for this geometry. An iso-kinetic extraction method, pitot-tube static pressure measurement method and salt tracer injection method were adopted for these experiments. [3]

3.1 Test Section

The design and fabrication of the 37-pin bundle test section have been completed based on the above test specification. Fig. 2 shows the cross section of the test assembly. The wire wrapped 37-pins are tightly packed with 0.7% assembling tolerances of rod pitch and wall pitch in the hexagonal housing. There are seven instrument rods deployed among 37 rods for the measurements of pressure and the salt tracer injection as illustrated at the left in Fig. 7. The right photo shows the top view of the fabricated 37-pin test assembly.



Bare Rod	30 ea
Delta-P for friction	3 ea (6, 19, 25)
Exit Pressure	2 ea (3, 16)
Salt injection	2 ea (1, 36)

Fig. 2. Configuration of the wire wrapped 37-pin test assembly

3.2 Test Loop

Hydrodynamic experiments in a 37-pin wire wrapped rod bundle are going to be performed at the CTL-II (Cold Test Loop-II) test facility in KAERI. CTL-II basically consists of a water storage tank, a circulation pump and the test rig, and it has been modified for this test program. Fig. 3 illustrates the schematic of this test loop, which includes the supplementary inventories such as the salt injection line into the rod bundle and the flow sampling line from the sub-channel exit. The test rig consists of a hexagonal duct housing, which includes a 37-pin rod bundle, the upper plenum and the lower plenum. The lower plenum has four branches for the inflow from the main loop symmetrically and includes the flow straightener at the inside. A total of twelve 1/16″ tubes penetrate the bottom of the lower plenum, where eight tubes are for the measurements of the pressure and four tubes are for the salt tracer injection. The upper plenum also has four branches for symmetrical outflow to the main loop. The top of the upper plenum has flexibility to adopt the probes for the iso-kinetic flow sampling and the probe package for conductivity sensing at the exit of the sub-channels.

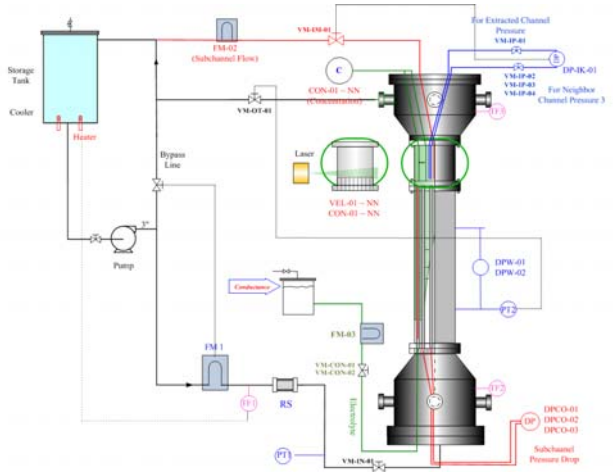


Fig. 3. Schematic of the test loop

3. Conclusions

A wire wrapped 37 pin fuel assembly has been designed for the measurements of the flow distribution, where the measurements are utilized to quantify the friction coefficient and the mixing coefficient. The test rig of the wire wrapped 37 pin fuel assembly has been fabricated considering the geometric and flow dynamic similarities. It comprises four components i.e., the upper plenum, the fuel housing, the lower plenum, and the wire wrapped 37 pin fuel assembly. At further works, the quantified friction and mixing coefficients through the experiments are going to be utilized for insuring the reliability of the CFD analysis results.

ACKNOWLEDGMENTS

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