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The Evaluation of 16x16 JDFA Pressure Loss Coefficients Using the Fuel Assembly Compatibility Test System

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ABSTRACT

The hydraulic tests for 16x16 JDFA were performed to obtain the pressure loss coefficients using the FACTS. The pressure loss coefficients are calculated by converting the each properties of experimental values for inlet region, mixing vane grid, outlet region and core region by performing a power fit of the pressure loss coefficient values to the corresponding Reynolds number. The test results are compared with the existing calculated values and evaluated by using the CALOPR code in terms of pressure drop. It is turned out that the differences between the test results and the calculated values are about by 3.8% for the pressure loss coefficients and by 8.5% for the pressure drop.

1. INTRODUCTION

The pressure loss coefficient values are convenient means of quantifying the resistance of any particular component to fluid flow. Since the unrecoverable pressure drop in a one-dimensional turbulent flow field is proportional to the square of the velocity, the classical definition of the term loss coefficient is given by:

$$K = \triangle P / \left(\frac{\rho V^2}{2g_c} \right)$$

Most of the pressure loss coefficient values used by thermal-hydraulics designers are based on experimental data and are valid only for the specific fuel assemblies and core plate designs tested. The pressure loss coefficient values are used by thermal-hydraulics for DNB analysis and to calculate pressure drops, lift forces, crossflow velocities and bypass flows across the fuel assembly and its components. Therefore, it is important that the pressure loss coefficient should be used in design from the proper test results.

The pressure loss coefficients of the 16x16 Joint Design Fuel Assembly (JDFA) of KORI Unit 2 are calculated in reference[1]. In general, the hydraulic compatibility between two different fuel assemblies should be based on test results in which both fuel assemblies are subjected to the same conditions including channel geometry, test setup and treatment of data.

The objectives of this paper are to determine the pressure loss coefficients of 16x16 JDFA by the experimental test and to compare with those of the existing values. To obtain the pressure loss coefficients of 16x16 JDFA, the test is performed using Fuel Assembly Compatibility Test System(FACTS) in Westinghouse.

2. THE EXPERIMENTS

2.1 Hydraulic Test Facility and Conditions

The fuel assembly is square in cross-section with 6 inconel mixing vane midgrids and 2 inconel non-mixing vane end-grids of 1.50 inches in height. The fuel assembly has 20 thimble tubes and 1 instrument tube of 0.471 inches in diameter. The fuel assembly is comprised of the skeleton assembly and 235 fuel rods. The rods are composed of depleted uranium pellet encompassed by Zircaloy-4 cladding and plugs. The rod are 151.46 inches in length and 0.374 inches in diameter. The lower end of the rods are positioned 0.83 inches off the bottom nozzle. The existing flow hole thimble bolts used to connect the top nozzle to the thimble tubes were replaced by solid thimble bolts. This eliminated flow through the thimble tubes. In addition, a holddown bolts secured the assembly to the assembly to the lower core plate via instrument tube. This eliminated assembly lift and instrument tube flow.

The FACTS, this isothermal, closed-loop test system was designed to provide single-phase hydraulic data from which the pressure drop characteristics of fuel assemblies could be determined. The flow diagram of the FACTS loop is shown in Figure 1. Loop flow, which is measured by a venturi flow meter, was controlled by pneumatically operated bypass and series proportional control valves. Heat was introduced into the system soley by the work done on the fluid by the main pump. Temperature was controlled by adjusting the flow of cooling water on the secondary side of the heat exchanger. Loop pressure was established by a pneumatically driven hydraulic pump acting against a back pressure regulator. Protection against over-pressurization of the loop was provided by a pressure relief valve with a rupture disc serving as backup protection. The design operating limits of the system are 250 °F and 225 psig. All pressure boundary component were designed in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code and ANSI/ASME Standard B31.1 for boiler external piping. The hydraulic tests were performed by varying the flow rate over a predetermined range at two temperature for each test. At 150°F, the flow rate ranged from approximately 1000 gpm to the maximum loop flow by increments of 100 gpm. At 250°F, the flow rate ranged from approximately 1100 gpm to the maximum loop flow by increments of 75 gpm. Figure 2 describe the elevations and connections of the pressure taps for the hydraulic tests. All the pressure transmission lines attached to pressure taps on the flow housing penetrated the pressure housing through an instrument ring located above the base plate.

2.2 Data Calculations

The measured values of pressure drop and loop flow at the different test temperatures were converted to pressure loss coefficients. Pressure loss coefficients and Reynolds number were based on the flow area and equivalent diameter of the test fuel assembly inside the flow housing. Pressure differentials were measured at location such that pressure loss coefficients were obtained for fuel assembly grids, inlet, outlet, and the overall fuel assembly.

3. RESULTS AND DISCUSSION

3.1 Pressure Loss Coefficients

The pressure loss coefficient correlations are determined by performing a power fit of the pressure loss coefficient values to the corresponding Reynolds numbers. The form of these correlations is

$$K = ARe^{B}$$

where A and B are constants. The pressure loss coefficient correlations were calculated for the inlet region, mixing vane midgrids, outlet region, and the core region. Figure 3 shows that the pressure loss coefficients versus Reynolds number, along with the correlation curve fits, for the respective data sets. The correlations and their value at a Re=500,000 are shown in Table 1 along with the span combinations used to determine the correlations. The inlet region correlation accounts for the lower core plate, bottom nozzle, and adjacent non-mixing vane grid. The correlation was determined by averaging K1 with (K8-K2). The mixing vane grid correlation was determined by averaging K3, K4, K9, and K11. The outlet region accounting for the upper core plate, top nozzle, and adjacent non-mixing vane grid was determined from K10. The core region accounting for the entire fuel assembly and core plates was determined from K12.

3.2 The Comparison of the Calculated Loss Coefficients

The pressure loss coefficients for the 16x16 JDFA were calculated using the single subchannel analysis code, DIWAN[1]. To validate the test results, the comparison of the test results and the calculated data for the 16x16 JDFA were made in terms of Reynolds number in Table 2. Also the Westinghouse 16x16 STD Fuel Assembly[2] were compared. As it is shown in Figure 4, the pressure loss coefficients vary slightly as a function of Reynolds number. It is turned out that the test results are in good agreement with the existing values as much as approximately by 3.8%.

3.3 Pressure Drop Calculation

The evaluation is made by DIWAN for 16x16 JDFA pressure drop. The results and the conditions used for analysis are shown in reference[3]. Based on this data and conditions, the CALOPR computer code[4] was used to calculate the pressure drops across the fuel assembly using the test results and the calculated pressure loss coefficients for 16x16 JDFA and Westinghouse 16x16 STD fuel assembly. Table 3 shows these results. Concludingly, the pressure drop of fuel assembly based on test results is less than that of DIWAN's result about by 8.5% which is within the uncertainty range of experimental results.

4. CONCLUSIONS

In this paper, the tests were performed to evaluate the 16x16 JDFA pressure loss coefficients. The experimental values of each properties were converted to pressure loss coefficients. The pressure loss coefficients were calculated for the inlet region, mixing vane grid, outlet region, and core region by performing a power fit of the pressure loss coefficient values to the corresponding Reynolds numbers. The obtained experimental results were compared with the calculated data and with the Westinghouse 16x16 STD fuel assembly. It was turned out that the existing analyses were not conservatively performed as compared with the test results for the pressure loss coefficients and pressure drops.

REFERENCES

1. Bruch, "Topical Report on Fuel Assembly Pressure Drop Analysis Code DIWAN/ZETBERA", September 1987
2. Westinghouse, "Thermal-Hydraulic Design Procedure Manual, Vol 1." 1990
3. KWU/KAERI, "Fuel Design Report for 16x16 Fuel Assembly" September, 1987
4. Westinghouse, "Thermal-Hydraulic Design Computer Code Manual, CALOPR Code," 1993

Table 1. The pressure loss coefficient correlations of the experimental results

Component	Spans Evaluated	Correlation	Correlation @Re=500,000
Inlet Region	K_1, K_8-K_2	$5.075\ Re^{-0.028}$	3.514
Mixing Vane Grid	K_3, K_4, K_9, K_{11}	$5.452\ Re^{-0.145}$	0.813
Outlet Region	K_{10}	$4.849\ Re^{-0.042}$	2.794
Core Region	K_{12}	$71.047\ Re^{-0.1097}$	16.841

Table 2. The comparison of the pressure loss coefficients in terms of Reynolds Number

Component	Bundle Reynolds No.						
	390,000		430,000		500,000		
	DIWAN	16x16 STD	DIWAN	16x16 STD	DIWAN	16x16 STD	EXP. Values
Fuel Assembly	15.348	15.950	15.236	15.779	15.041	15.520	13.682
Core Assembly	16.525	19.290	16.413	18.991	16.218	18.680	16.841

Table 3. The Results of CALOPR Code using DIWAN values, 16x16 STD, and experimental results.

Fuel Type / Pressure Drop	16x16 JDFA	16x16 STD	EXP. Values
$\triangle P_{FA}$ (psi)	21.942	22.375	20.219
$\triangle P_{core}$ (psi)	23.548	27.194	25.039

* based on Reynolds Number=500,000

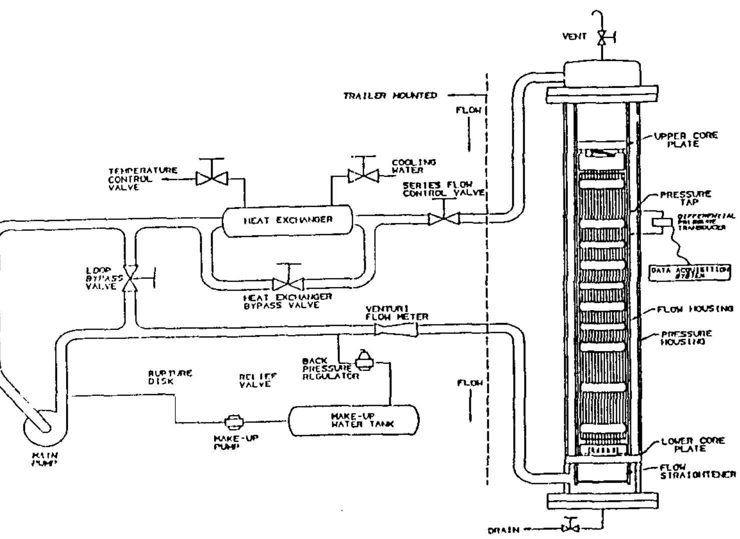

Figure 1. The Flow Diagram of FACTS

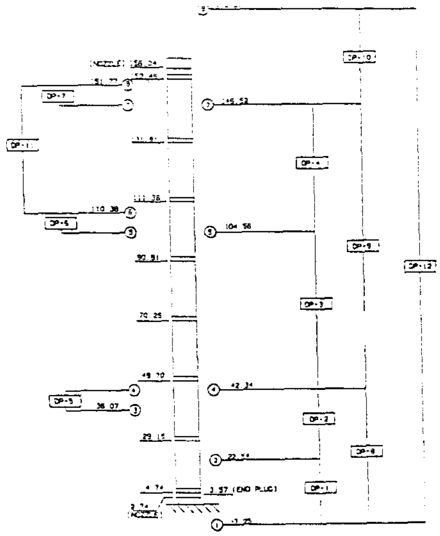

Figure 2. The FACTS Pressure Tap Locations

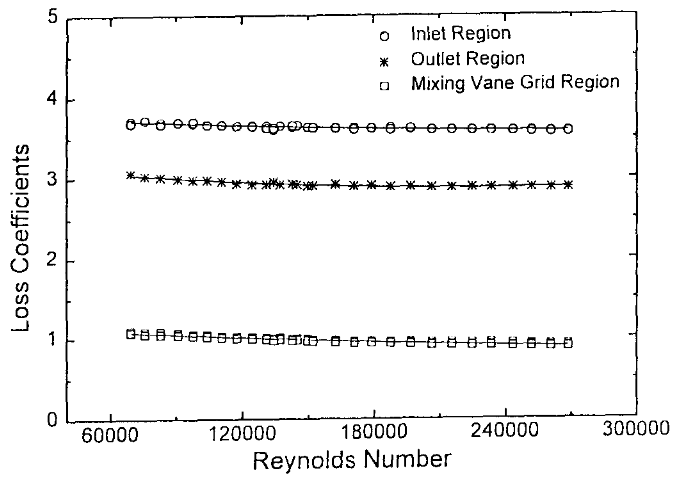

Figure 3. The Loss Coefficients versus Reynolds Numbers

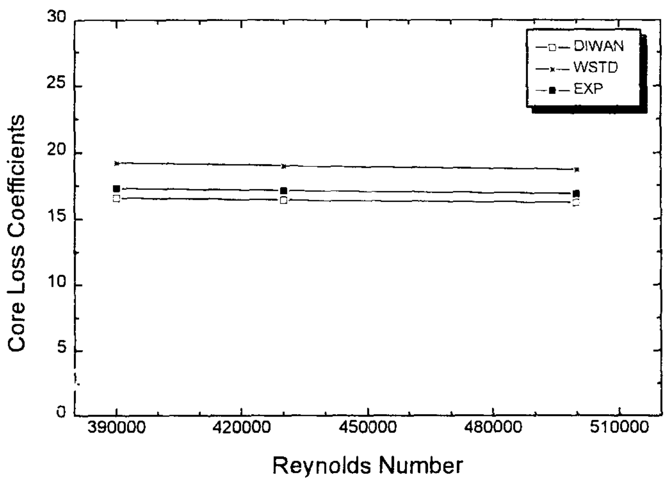

Figure 4. The Comparison of the Core Loss Coefficients