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Design Concept of a 1/5-Scale Core Simulator

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1. Introduction

A 1/5-scale core simulator for a Separate Effect Test (SET) of the SMART330 was designed. To simulate the pressure drop of a fuel assembly, three orifices are installed at the upper side of the core simulator. The axial flow rate of the fuel assembly is measured using a venturi flow meter at the lower part of the core simulator corresponding to an inlet of core flow path. A core bypass flow is ignored because it is a quite few amount when compared with the total core coolant water and it is not a required factor for core flow distribution test.

2. Design of core simulator

The reactor geometry and internals are designed by the 1/5-scale linear scaling methodology. The core flow ratio is 1/125. The scaling ratios and design parameters are listed in Table 1 and 2.

Table.1 Linear scaling ratio

Parameter	Symbol	Ratio	Remark
Length	l_R	1/5	
Height, H	l_R	1/5	
Gap	l_R	1/5	
Diameter, D	l_R	1/5	
Volume	$(l_R)^3$	1/125	
Flow area	$(l_R)^2$	1/25	
Velocity	V_R	1	Re control

Table.2 Design parameters for 1/5-Scale model

Condition	Value
Temperature, °C	60
Pressure, MPa	0.2
Core velocity, m/s	2.01
Velocity ratio,	1.0
Core flow rate, kg/s	108.7
Flow rate ratio -	1/18.5
Density, kg/m^3	983.3
Density ratio	1.35
Viscosity, Ns/m^2	4.66e-4
Viscosity ratio, -	5.3
core Re, -	4.69e+4
core Re ratio, -	1/1.39
FMHA Re, -	3.68e+5
FMHA Re ratio, -	1/19.5
Total pressure drop, kPa	188.0
Ratio of total pressure drop, -	1.35

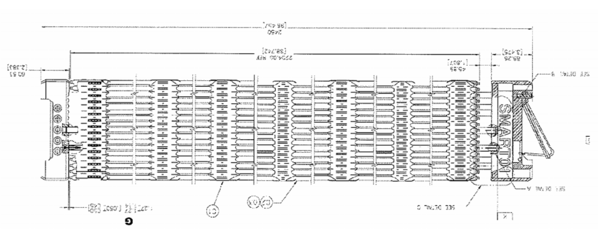
The working condition for the core flow distribution test facility is 100°C and 0.1MPa whereas the operating condition of SMART330 is 323°C and 15MPa. The different temperature causes a different density ratio which is 960m^3/kg at 100°C and 670m^3 /kg at 323°C. The density of coolant water in this test is 1.4 times greater than that of SMART330. Therefore, the actual flow rate ratio and the pressure drop are increased to 1.4 times rather than that of the linear scaling method. The design value of pressure drop in SMART330 is about 20 KPa. To compensate the scaling distortion, the pressure drop is set to about 35.1KPa.

Linear Scale

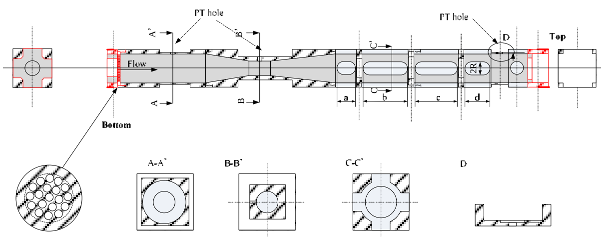
The Euler number is an important design parameter which should be considered basically to conserve hydraulic characteristics.

$$Eu_R = \Delta P / (\rho v^2) = 1 \qquad (1)$$

The Euler number ratio, Eu_R, should be equal to 1 for conservation of the hydraulic characteristics between SMART330 and the core flow test facility under the turbulent flow condition. To simulate the turbulent flow characteristics, the Reynolds number is set to be over 10^4. The Reynolds number ratio of the 1/5-scale core simulator, Re_R, is about 1/20 ~ 1/40.



(a) Fuel assembly of SMART330



(b) Cross section of the 1/5-scale core simulator

Fig. 1 Schematics of the 1/5-scale core simulator

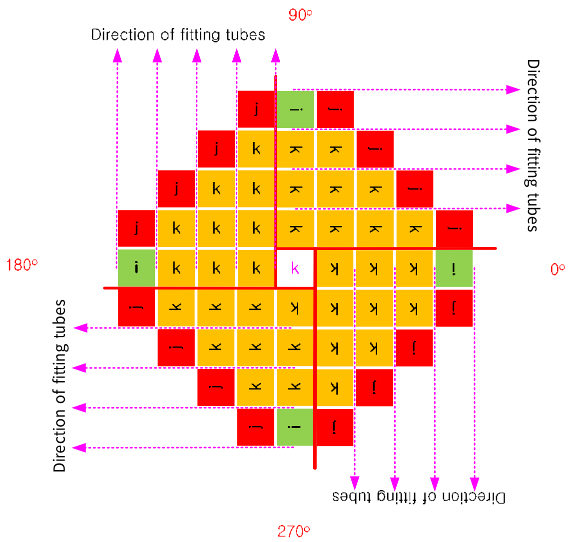


Fig. 2 Alignment of the 1/5-Scale core simulators

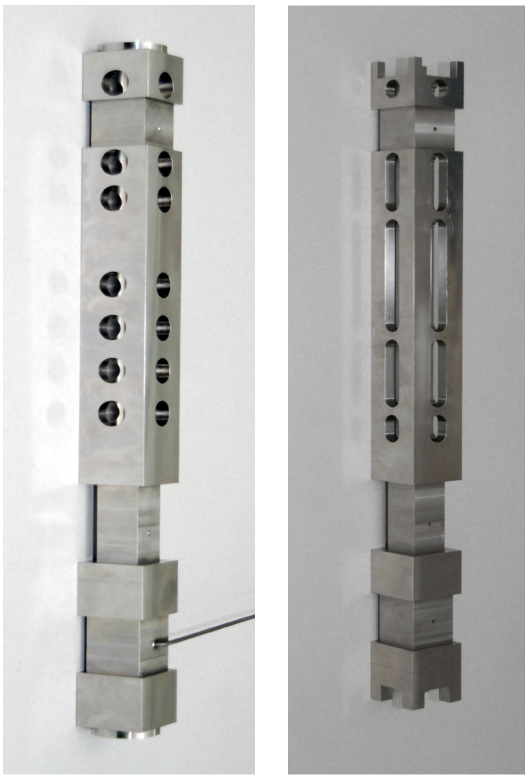


Fig.3 Hole shape; (a) circular, (b) rounded

The dynamic flow characteristics are conserved by the Euler Number (ratio) for the conservation of pressure drop. Unfortunately, the internal structures of the fuel assembly are too complicate to build an exact fuel assembly. The simplified core simulator was designed and its axial pressure drop was conserved including the density compensation ratio of 1.4.

Cross Flow Hole

Two kinds of cross flow shown in Fig.3 are considered in the beginning of design. One is a circular type and the other is a rounded rectangular type. In this study the rounded rectangular type is discussed only. The cross flow area per one side of fuel assembly for SMART is 0.10361m^2. The cross flow area, in the 1/5-linear scaling method, is 4.146e-3 m^2 exactly. The radius, R in Fig.1, is about 14.2mm for five side holes.

The three orifices, to simulate the pressure drop of the 1/5-scale core simulator, are embedded between side holes. The hole diameter of 25mm is determined by the result of analytical simulation.

The fifty seven core simulators are assembled in the core region between the fuel alignment plate and the core support plate. There is a gap of 3.2mm between the top of the simulator and the bottom of FAP. The outside wall between the core simulator and the core baffle is isolated whereas the others have side holes for all outer walls.

3. Conclusions

The 1/5-scale core simulator of the core flow test facility is designed by the linear scaling method under the conservation of the Reynolds number and the Euler number. The test condition could be a normal temperature and atmosphere pressure whereas an operating condition of SMART is the high temperature and pressure. The flow condition is compensated by density ratio for different operating condition between SMART and SET. The final orifice diameter will be determined by a flow calibration test of the 1/5-scale core simulator.

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