Design Development of SCOP facilities for Core Flow and Pressure Distribution of SMART Reactor

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1. Introduction

A design of SMART reactor has been being developed, which is composed of 4 internal circulation pumps, 57 fuel assemblies, 8 cassettes of steam generators, flow mixing head assemblies and other internal structures. Since primary design features are far from the conventional reactors, the characteristics of flow and pressure distribution are expected to be different accordingly. In order to analyze the thermal margin and hydraulic characteristics of SMART reactor, quantification tests for flow and pressure distribution with a conservation of flow geometry are necessary. In the present study, the design feature of the facilities in order to investigate flow and pressure distribution, named "SCOP" would be described. The design was based on the conservation of Euler number which is a ratio of pressure drop to dynamic pressure with a sufficiently turbulent region having high Reynolds number. The SMART design is linearly reduced to 1/5 ratio with a conservation of the velocity scale, which yields a 1/20 of Reynolds number scaling ratio.

2. Design Features of SCOP

2.1 Scaling Ratio

In order to preserve the flow characteristics, the SMART design is linearly reduced with a scaling ratio of 1/5 and the flow geometry was design to be conserved. Table 1 shows a summary of the scaling relations adapted in the SCOP facilities with respect to the SMART reactor.

Table I: Summary of Scaling of SCOP

	SMART	Scaling Ratio	SCOP
Temperature, °C	**310**	**-**	**60**
Pressure, MPa	**15**	**-**	**0.2**
Length Ratio, -	**1**	l_R	**1/5**
Height Ratio, -	**1**	l_R	**1/5**
Diameter or Width Ratio, -	**1**	l_R	**1/5**
Area Ratio, -	**1**	l_R^2	**1/25**
Volume Ratio, -	**1**	l_R^3	**1/125**
Aspect Ratio, -	**1**	**-**	**1.0**
Velocity Ratio, -	**1**	V_R	**1.0**
Mass Flow Rate, kg/s	2090	$\rho_R V_R l_R^2$	117.04
Mass Flow Ratio, -	1	$\rho_R V_R l_R^2$	1/17.9
Density, kg/m^3	704	ρ_R	983.2
Density Ratio	1	ρ_R	1.40
Viscosity, Ns/m^2	8.43e-5	μ_R	4.66e-04
Viscosity Ratio, -	1	μ_R	5.53
Core Re, -	1.83e5	$\frac{\rho_R V_{CR} D_{CR}}{\mu_R}$	1.86e+05
Core Re Ratio, -	1	$\frac{\rho_R V_{CR} D_{CR}}{\mu_R}$	1/0.98
FMHA Re, -	7.18e6	$\frac{\rho_R V_R D_R}{\mu_R}$	3.64e+05
FMHA Re Ratio, -	1	$\frac{\rho_R V_R D_R}{\mu_R}$	1/19.8
Total DP, kPa	138.74	$\rho_R V_R^2$	194.2
DP Ratio, -	1	$\rho_R V_R^2$	1.4

2.2 System Design

In order to preserve the flow characteristics, the SMART design is linearly reduced with a scaling ratio of 1/5. An overall assembling of the test facilities are demonstrated in Fig. 1. Although the reactor circulation pumps are working inside the reactor, the SCOP adapts external type of pumps with a preservation of flow geometry through the diffuser. The each of the four external loops has a pump, heater, heat exchanger and flow meter. The loop temperature is controlled at each loop by controlling the heater power or heat exchanger secondary flow rate. At discharge part of the flow meter, the pressure and temperature would be measured by PT transmitter and RTD respectively. The system pressure is controlled by makeup tank which is installed at above the reactor simulator.

Core inlet flow distribution and outlet pressure distribution in order to supply boundary condition to estimate thermal margin of reactor will be simulated by

57 simulators which conserve the pressure drop of the fuel assemblies. The steam generator which is supposed to be inside of the reactor is exposed to the outside of the pressure boundary in order to draw the instrumentation line efficiently. The shell type of the SG primary side was simplified to the cylindrical shaped simulator with a pressure drop adjustment with an orifice inside. The tube inside SG secondary part was neglected in the SCOP facilities since SG secondary is not interested region. The simulators for 57 fuel assemblies and 8 steam generators are calibrated accurately in the separated facilities named "CALIP". A brief design concept of the simulators is shown in Fig. 2.

The test will be performed on the reference flow rate scaled corresponding to the SMART nominal flow conditions and abnormal conditions assumed single pump failure at the lower pressure and temperature conditions.

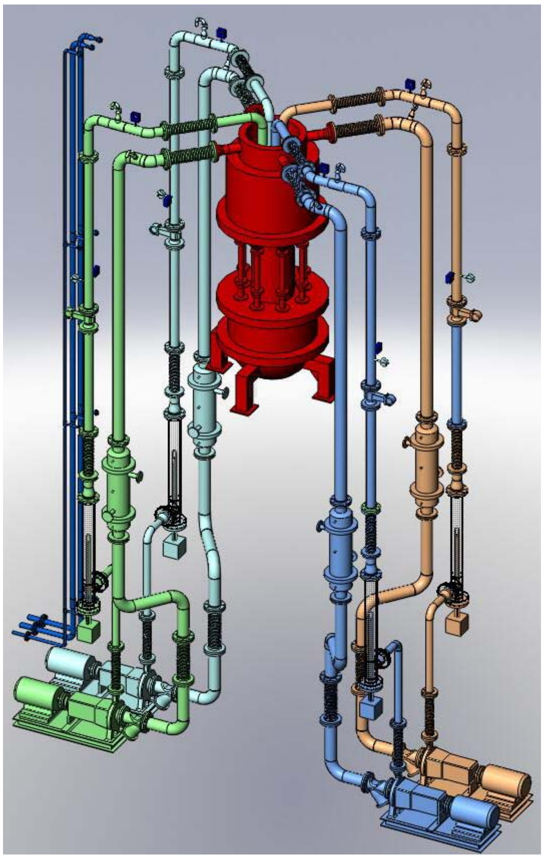

Fig. 1. Bird-eye View of SCOP Test Facilities.

2.3 Instrumentation

The loop flow, pressure, and temperature would be measured by using vortex flow meters and smart type pressure transmitters and RTDs. The major measured parameters inside the reactor simulators are pressures or differential pressures. Total 210 points of pressure would be measured with a limited number of differential pressure transmitters by using sequentially operated solenoid valves. The core inlet flow distribution is measured by measuring differential pressures of the venturi type of core simulators. The system is operated under a lower constant temperature which is measured at two points inside the reactor vessel and 4 points at downstream of 4 flowmeters.

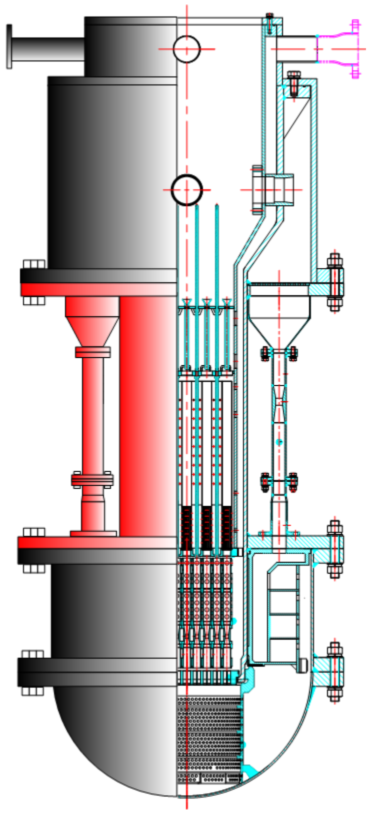

Fig. 2. Schematics of SMART Reactor Simulator

3. Conclusions

In order to identify the flow and pressure distribution of the SMART reactor, 1/5 linearly reduced scale of test facilities, named "SCOP" are being designed. This paper describes the overall design feature including scaling, assembling, component design and instrumentation.

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