Design of Steam Generator for SMART ITL

Hwang Bae [a*], Hyun-Sik Park[a], Sung-Jae Yi [a], Sang-Ki Moon[a]
[a]*Korea Atomic Energy Research Institute, Thermal Hydraulics Safety Research Division, 1045 Daedeokdaero, Yuseong, Daejeon 305-304, Republic of Korea*
[*]*Corresponding author: hbae@kaeri.or.kr*

1. Introduction

Integral type reactor has simple structure and large size because main components including pressurizer and steam generator are installed in the reactor vessel without a large pipe. Safety system is also so simple because LBLOCA is fundamentally excluded.

SMART[1] has been designed in KAERI for integral reactor. Steam generator of the once-through modular and helical type[2] is installed in the outer vessel of SMART. Integral test loop (ITL) of SMART has been also designed under the volume scale method. It is important to understand thermal hydraulic flow characteristics of SMART to protect the safety event. ITL is the most effective test for nuclear safety. Height is conserved as 1:1. The area and volume is scaled down 1/49. To simulate the thermal-hydraulic characteristics, the steam generator of ITL has several components not to apply the volume scale method. The inner and outer diameter of the heat transfer tubes, the length of the active heat transfer tube and the vertical pitch among the tube should be designed as to 1:1 whereas the number of tube and the heat transfer area is scaled down 1/49.

As result of volume scaling[3], the annular downcomer of ITL is not enough to contain the SG. Four steam generators of ITL are installed in the outside of the reactor vessel whereas eight ones of SMART are in the annular downcomer of the inside. Each steam generator of ITL is connected to reactor vessel by two pipes in the upper and lower side such as hot legs and cold legs. Fifty tubes are aligned by three layers per one SG. The number of tube yields the number of SG. That is, as the results of volume scaling, the number of tube is 7.65. It is not enough to simulate the thermal-hydraulic characteristics of the inside of SG and it is too small to bend the tube helically. One SG in ITL represents two SGs in SMART. Designed SG is illustrated in Fig.1.

The scaling distortion is caused by the conserved-design parameter such as the diameter and length of the tube as well as the vertical pitch or the tube. Numerical analysis was carried out to evaluate the effect of curvature distortion that occurs out of the scale factor.

2. Design Parameters

Design parameters and the scale ratio for ITL are listed in the Table.1.

<u>SG DESIGN</u>

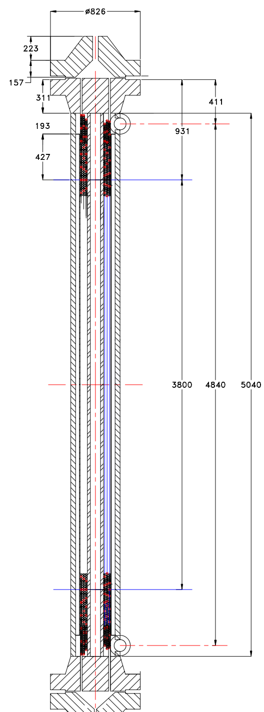
After scaling analysis using the conservation parameters, the minimum helical curvature that yields the other parameter should be determined. Below 5 steps should be iterated until tube length is conserved and the ratio of active heat transfer area is satisfied by 1/49.

1. determination of minimum helical curvature
2. slope of helical tube
3. tube length
4. number of winding
5. active heat transfer area

<u>SLOPE OF HELICAL TUBE</u>

Slope of helical tube is determined by the minimum curvature and vertical pitch of the helical tube.

Target parameter is listed at Table 1 and schematics of SG helical tube is illustrated at Fig. 1.



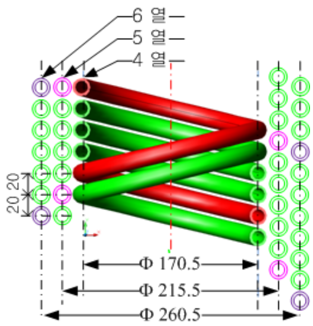


Fig. 1 Schematics of SG and helical tubes in the ITL

Table.1 Designed parameter of SMART ITL SG
D : diameter[m], C : circumferential length[m], No : wounding number, angle : slope of helical tube [deg]
H : height[m], L : length[m], A : area[m^2]

	D	C	No	angle	H	L	A
1	0.17	0.54	4	8.49	3.8	25.3	5.4
2	0.22	0.68	5	8.40	3.8	25.6	6.8
3	0.26	0.82	6	8.34	3.8	25.8	8.3
Tot.			15				20.5
Avg				8.41	3.8	25.6	

3. Numerical Results

CONSISTENCY OF FLOW DISTRIBUTION

Consistency of flow distribution is estimated by numerical analysis using commercial code, Fluent for the helical tube with the different helical curvature and the same diameter. Inlet velocity is 5 m/s and pressure outlet condition are set. The k-e model to calculate the turbulent flow is solved. Mesh for the solution is illustrated in Fig. 3. Flow distribution in the arbitrary cross-section of the symmetric helical tube shows almost same pattern due to the balance between centripetal and centrifugal force. Flow velocity of outer wall is faster than the other by increasing curvature because centrifugal force is greater than centripetal force. Fig. 3 and 4 show these flow characteristics.

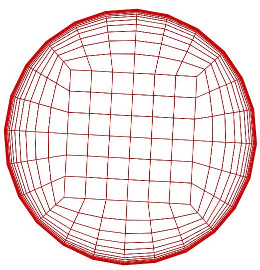
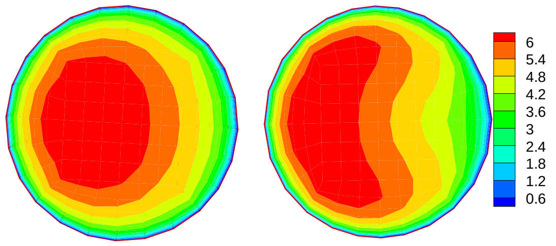
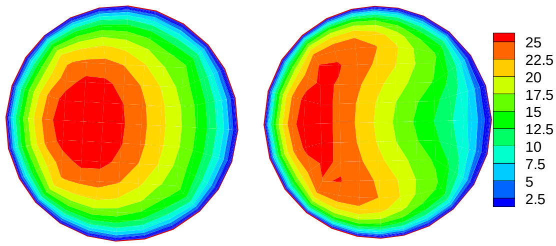


Fig. 2 Mesh of the tube inside



SMART ITL

Fig. 3 Velocity distribution for SMART vs. ITL



SMART ITL

Fig.4 Dynamic pressure distribution for SMART vs. ITL

4. Conclusions

Steam generator of SMART ITL is designed by the volume scale method considering the conservation parameter and scaled parameter. Tube length, tube diameter and vertical pitch among the tubes are conserved. Active heat transfer area and flow path area is scaled down 1/49. Cross-sectional flow of the tube is compared with SMART 330 and ITL. Those two flow patterns are reasonable as showing the flow velocity of ITL is more skewed to outer wall than that of SMART 330.

REFERENCE

[1] Y. Kim, D. Lee, and M. Chang, Design Characteristics of Integral Reactor as Next Generation of Nuclear Reactor, Journal of the Korean Nuclear Society, Vol.27, P269, 1995

[2] Y. Kim, J. Kim, J. Yoon, J. P. Kim, and J. I. Kim, Design Concept of Steam Generator of Integral Reactor, Transactions of the Korean Nuclear Society Spring Meeting, p.735, 1995

[3] S.K. Moon, C.H. Song, C.K. Park, T.S. Kwon, B.J. Yoon, M.K. Jung, A State-of-the Art Report on the Study of the Nuclear Reactor Thermal Hydraulic Using Integral Test Facilities, KAERI/AR-509/98, 1998.