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Heat Transfer Experiment in an Integrated Double-Region Type HX for an IHTS Simplification in a LMR

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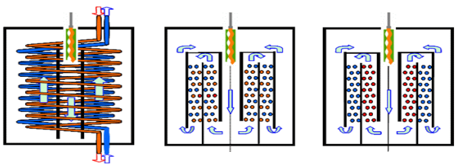
1. Introduction

The Sodium-cooled Fast Reactor (SFR) is a very promising candidate for the development of fast neutron reactors. Sodium is a very attractive coolant due to its high heat transfer properties, on the other hand, if a water/steam leaks into the sodium, a severe problem can occur on account of a violent sodium-water reaction (SWR). To resolve the difficulties in deploying a SRF for a power generation, an elimination of the IHTS by using a new steam generator (SG) was suggested by Kim et al. [1]. The concept of a double tube bundle steam generator (DTBSG) is to eliminate a SWR possibility in a sodium-cooled fast reactor, fundamentally [2], and a thermal-hydraulic performance analysis code, Integrated Steam Generator Analyzer (ISGA) was developed for three candidate types of DTBSGs that are the integrated single-region, integrated double-region and radially separated bundle types as shown in Figure 1 [3].



(a) (b) (c)

Figure 1. Heat transfer tube bundle configuration of the DTBSG: (a) integrated single-region; (b) integrated double-region; (c) radially separated.

In this paper, a heat transfer experiment in an integrated double-region type DTBSG, one of the three tube bundle types as shown in Figure (b), was addressed.

2. Experiment

The experimental apparatus of the integrated single-region type DTBSG consists of a test section, a heater, a cooler and three pumps. The test section is a SG with a 460 mm length, Φ298 mm inside diameter. Inside the shell, there is a cylindrical separator for a two-pass flow of the hot and cold fluids. The hot and cold tubes of a Φ6 mm helical coil are installed alternatively with 22 and 23 tubes for the hot and cold fluid, respectively, and radially as four rows inside and three rows outside.

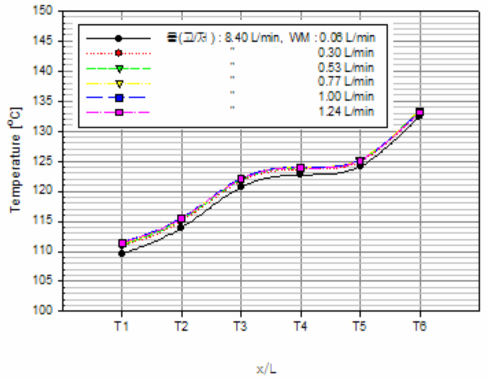
The three fluids which were used in this experiment were hot water, wood metal and cold water as a hot, medium and cold fluid. The wood metal which was used as a intermediate medium, is an eutectic alloy of bismuth, lead, tin and cadmium with the following percentages by weight: 50% Bi, 26.7% Pb, 13.3% Sn, 10% Cd and its properties were measured.

Experiments were carried out for twenty five cases to confirm the feasibility and heat transfer characteristics in the integrated double-region type DTBSG. These conditions were classified into three categories and five groups by the inlet mass flow condition. The mass flow rate of the water and wood metal was varied from 0.067 to 0.267 kg/s and from 0.01 to 0.2 kg/s, respectively. Thirty six thermocouples were located in the shell side to measure the temperature of the wood metal. T1-T6 is the temperature at a radially inner location of the tube bundle between the second and third rows of the coil in the order of bottom to top axially at intervals of 40 mm, and T7-T12 is the temperature at a radially outer location of the tube bundle between the fifth and sixth rows of the coil in the same order as the T1-T6. These are the temperatures in the 'A' direction of three circumferential directions, representatively. The inlet temperature of the hot and cold fluid was 150℃ and 100℃, respectively.

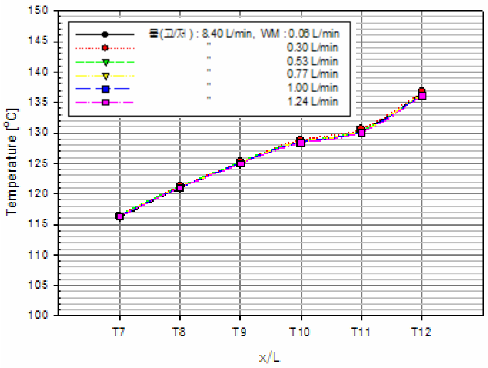
3. Result and Discussion

Figures 2 and 3 show the measured temperature distributions representatively for the group 3 and 4 experiments of five experiments in the integrated double-region bundle type DTBSG.

Figures 2(a) and 2(b) show the temperature distributions for the group 3 experiment. In group 3, the flow rate of the hot water, cold water and wood metal of a medium fluid are varied at the same time 0.14, 0.14 and 0.01~0.2 kg/s, respectively. The temperature of the wood metal increased closer to the top of the shell where the hot water flows in. In the case of the group 3 experiment when only the flow rate of the wood metal is varied 0.01~0.2 kg/s without a change of the flow rate of the other fluids, there was no temperature change on the flow rate at an axial measuring point, although the temperature of the wood metal increased closer to the top of the shell. This phenomenon is due to the very low rate of heat transfer of the wood metal compared to that of the hot and cold water.



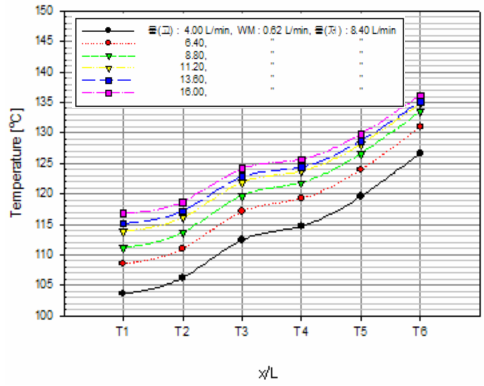
(a)



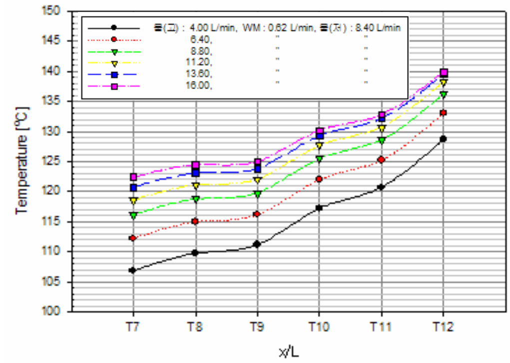
(b)

Figure 2. Temperature distribution profile for; (a) inside axial direction(T1-T6) and (b) outside axial direction(T7-T12) of the separator in group 3 experiment.

Figures 3(a) and 3(b) show the temperature distributions for the group 4 experiment. In group 4, only the flow rate of the hot water is varied 0.067~0.267 kg/s without a change of the flow rate of the other fluids. These figures show a similar trend for the curve inside(a) and outside(b) temperatures of the tube bundle separator. There were temperature change effects for the flow rate variation of the hot water at an axial measuring point from T1 to T6 and from T7 to T12. The temperature difference at the top is a little smaller than at the bottom with values of 9.5℃ and 13.2℃ inside the separator, and 11.3℃ and 15.6℃ outside it, respectively. This phenomenon is presumed to be due to the thermal effect of the hot water.



(a)



(b)

Figure 3. Temperature distribution profile for; (a) inside axial direction(T1-T6) and (b) outside axial direction(T7-T12) of the separator in group 4 experiment.

4. Conclusion

Experiments for the heat transfer phenomena in an integrated double-region type DTBSG have been performed. The shell temperature distributions in the integrated double-region type DTBSG were compared with the analysis code ISGA, and the overall temperature behaviors of the DTBSG were predicted well. A comprehensive analysis will be performed later to verify the design code and to confirm the viability of the concept.

Acknowledgement

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