Heat Transfer Experiment in a Radially Separated Tube Bundle Type DTBSG (II)

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1. Introduction

In a Sodium-cooled Fast Reactor (SFR), the possibility of a water/steam leak into the sodium in a steam generator and a violent sodium-water reaction have been the difficulties in the use of SFR. To resolve this problem, a new concept of a double tube bundle steam generator (DTBSG) system and a thermal-hydraulic performance analysis code was developed [1,2]. To verify the code and to confirm the viability of the concept, the heat transfer experiment in a radially separated tube bundle type DTBSG (Fig. 1) which is one of the three tube bundle configurations was carried out. And numerical investigations were performed.

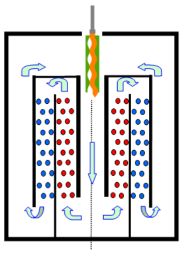

Fig. 1. Heat transfer tube bundle configuration of the radially separated DTBSG (red color: hot fluid tubes, blue color: cold fluid tubes).

2. Experiments

The experimental apparatus of the radially separated DTBSG including a test section is as shown in Fig. 2. The test section is a SG with a 445 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 three fluids which were used in this experiment were hot water, wood metal and cold water as a hot, medium and cold fluid. Hot fluid flows through the inside tubes of the separator and cold fluid flows through the outside tubes of the separator as shown in Fig. 1. The shell is filled with the wood metal as a medium fluid which is circulated by a pump installed inside the shell of the test section.

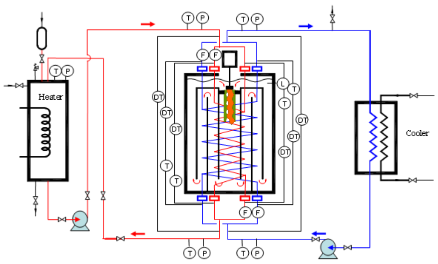

Fig. 2. Flow diagram of the heat transfer experiment in the radially separated tube bundle type DTBSG.

3. Result and Discussion

Figs 3-4 show the measured temperature distributions in the radially separated DTBSG. T1-T6 is the temperature of inside of the separator in the order of bottom to top axially at intervals of 40 mm, and T7-T12 is the temperature of outside of the separator in the same order as the T1-T6. The inlet and outlet temperatures of the hot and cold fluids are about 150℃ and 100℃, respectively.

The Fig. 3(a) and 3(b) show the temperature distributions for the group 4 of the five group experiments. In this experiment, only the flow rate of the hot water is varied 4.00~13.20ℓ/min without a change of the flow rate of the other fluids. The temperature inside of the separator was increased on the increase of the flow contrary to other group experiments, as shown in Fig. 3(a). This phenomenon is due to that the flow rate of the hot water only is varied. The temperature profile outside of the separator is as shown in Fig. 3(b).

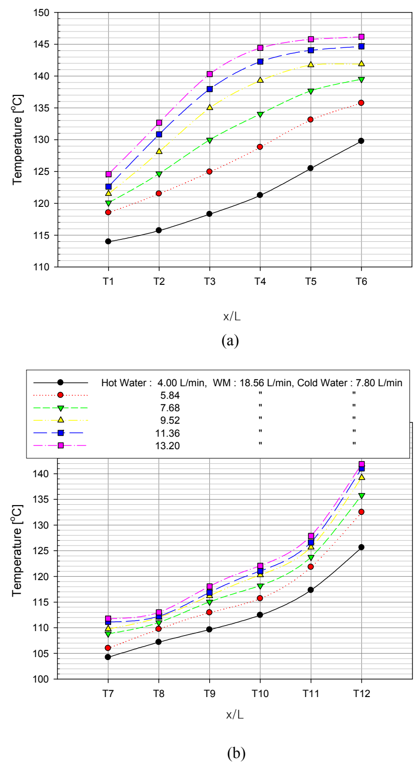

Fig. 3. Axial temperature profile in the test section verifying the flow rate of the hot fluid and keeping the flow rate of the intermediate and cold fluid at a fixed rate: (a) inside of the separator, (b) outside of the separator [Group-4].

Fig. 4(a) and 4(b) show the temperature distributions for the group 5 experiment. In group 5, only the flow rate of the cold water is varied 4.00~13.20ℓ/min without a change of the flow rate of the other fluids. In this case, the temperature inside of the separator was increased on the increase of the flow, as shown in Fig. 4(a). The temperature change effects on the flow rate inside of the separator were small at the top (T6) and large at the bottom (T1) with values of 4.3℃ and 12.2℃, respectively. This phenomenon is estimated due to the thermal effect of the cold water. The temperature outside of the separator was decreased on the increase of the flow contrary to other group experiments, as shown in Fig. 4(b). This phenomenon is due to that the flow rate of the cold water only is varied.

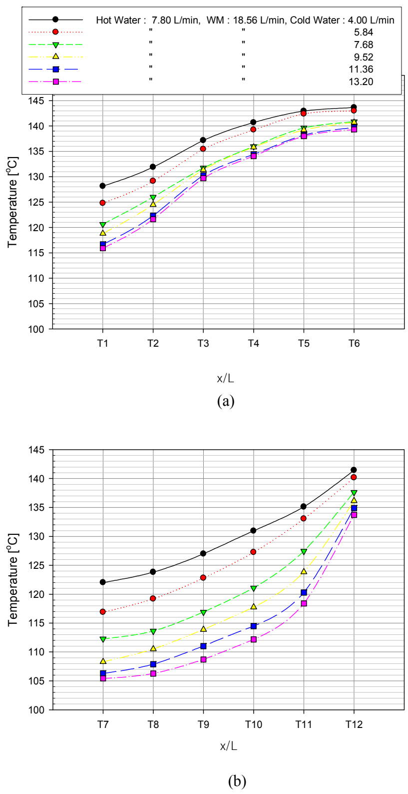

Fig. 4. Axial temperature profile in the test section verifying the flow rate of the cold fluid and keeping the flow rate of the hot and intermediate fluid at a fixed rate: (a) inside of the separator, (b) outside of the separator [Group-5]

Numerical analysis code overestimates the heat transfer in comparison with the experiment owing to a simplification of the modeling [3]. On average, the temperature difference for the experiment and numerical analysis has an 11% error. In the heat transfer modeling of the tube bundle in the shell side, the application of a length averaged Nusselt number does not simulate this effect. In most cases, the heat transfer rate difference is very low as shown in Fig. 5. But difficulties in the measurements of the flow rate resulted in the errors in the heat rate for a low heat transfer rate. From this result, the numerical analysis code used in this analysis is good for an analysis of DTBSG.

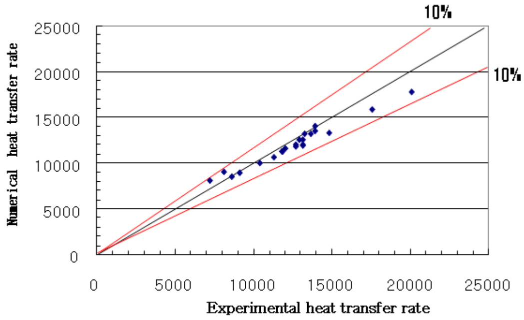

Fig. 5. Comparison of the heat transfer rate.

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3. Conclusions

Experiments for the heat transfer phenomena in a radially separated tube bundle type DTBSG have been performed. The shell temperature distributions in the radially separated tube bundle type DTBSG were compared with the analysis code ISGA. This analysis code predicts the temperature distribution and the heat transfer rate with an error of 11%. So this code will be applicable for the design of a radially separated DTBSG. A comprehensive analysis will be performed to verify the design code and to confirm the viability of the concept in near future.

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