Verification of the thermal-hydraulic performance analysis code for the integrated steam generators in SFR (II)

Seyun Kim*, Bo Young Choi, Seung-Hwan Seong, Eui Kwang Kim, Jong-Hyun Choi, Seong-O Kim
Fluid Sys. Eng. Div., KAERI, 150 Deokjin-Dong, Yuseong-Gu, Deajeon, Korea, 305-353, seyunkim@kaeri.re.kr

1. Introduction

The concept of a double tube bundle steam generator (DTBSG) was proposed to eliminate of SWR possibility in sodium-cooled fast reactor fundamentally [1]. The thermal-hydraulic performance analysis code, ISGA (Integrated Steam Generator Analyzer) was developed for three candidate types of DTBSGs, those are integrated double region, integrated single region and radially separated bundle types [2]. To verify ISGA code and to confirm the viability of the concept, an experimental research has been carried out. In the three types of bundle configurations, the numerical and experimental investigations of heat transfer characteristics are accomplished.

2. Numerical analysis code

ISGA computer code was developed to analyze the thermal-hydraulic performance DTBSG concepts. For a helical double tube bundle, schematic of node configuration is depicted as shown in Fig. 1. The shell side medium fluid exchanges the heat with hot tube and cold tube simultaneously in integrated type DTBSG. Wood Metal (Pb-Sn-Cd-Bi) is used as a medium liquid metal and the properties are measured.

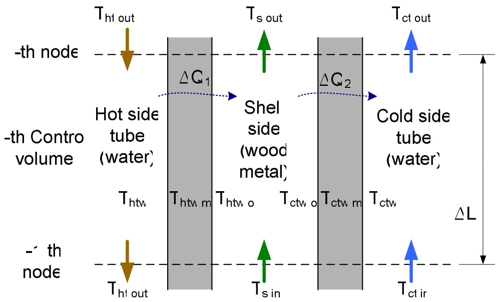

Fig. 1 Schematics of node configuration in ISGA

3. Verification of code

3.1 Experimental conditions

The experimental conditions are established to confirm the feasibility and heat transfer characteristics of DTBSG concepts [3]. The inlet temperatures of hot and cold fluids are about 150°C and 100°C respectively. The heat capacity rates are 0.1~1 [kJ/s-K] for hot and cold flows and 0.01~0.1 [kJ/s-K] for medium flow.

3.2 Temperature distributions

For the separated type DTBSG, the calculated temperature profiles in axial direction were compared to the measured temperature profiles. In separated type DTBSG, temperatures are presented in two different bundle regions, i.e. inner and outer regions as depicted in sub-frame of Fig. 2. The average error of calculated temperature which is normalized with the difference of hot and cold inlet temperature is -9.1% and 12.1% at inner region and outer region of reference condition respectively. General tendency of temperature profiles seems to be reasonable in inner region of DTBSG. However, the disagreement in the temperature is remarkable in outer region in which heat is transferred from shell side to cold tube side. The main reason of discrepancy is supposed to be the multidimensional effects of helical bundle which include the entrance effect.

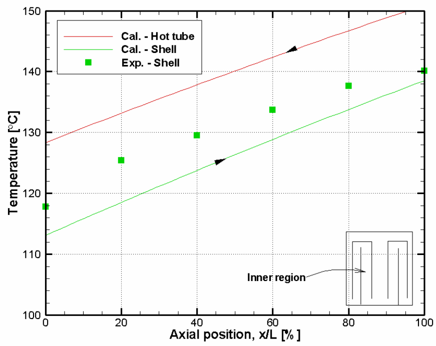

Fig. 2 Axial temperature profile of inner region of separated type DTBSG

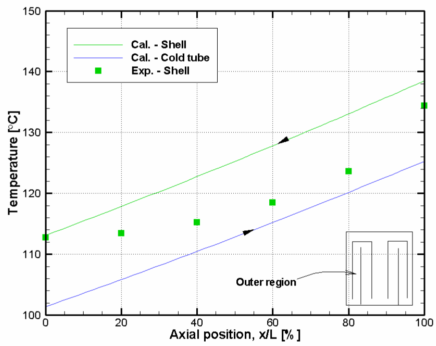

Fig. 3 Axial temperature profile of outer region of separated type DTBSG

3.3 Heat transfer characteristics

The heat transfer rate of 3 fluids are calculated and compared to the experimental data for the integrated double region (IDR), the integrated single-region (ISR) and radially separated (IS) bundle configurations. The heat balances of experiments have 1.6%, 7.5% and 4.1% of error for IDR, ISR and RS respectively. The mass flow rate of medium fluid is significant factor in the performance of DTBSG, especially for separated type. The heat transfer rate vs. heat capacity rate for three candidate configurations are presented in Fig. 4-6. For each case, the heat capacity rate of medium fluid and hot and tube fluid are varied independently. The calculated performance curve shows good agreement with experimental data in three types of DTBSGs. In the integrated type DTBSG, the convection heat transfer is less dominant in heat transfer mechanism of medium flow than in the radially separated type DTBSG [1].

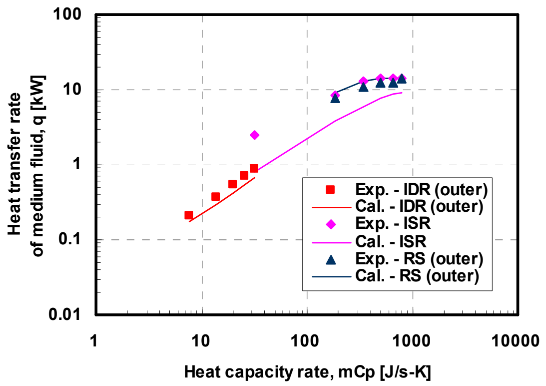

Fig. 4 Heat transfer rate of medium fluid

The heat transfer rate for hot and cold fluids is very close to linear. The average numerical error of IDR, ISR and RS are calculated as 4.5%, 34% and 12% respectively. In the integrated single region, the radial temperature distribution, which is up to 2% of maximum temperature differences, due to the wider flow area than integrated double region result in the discrepancies.

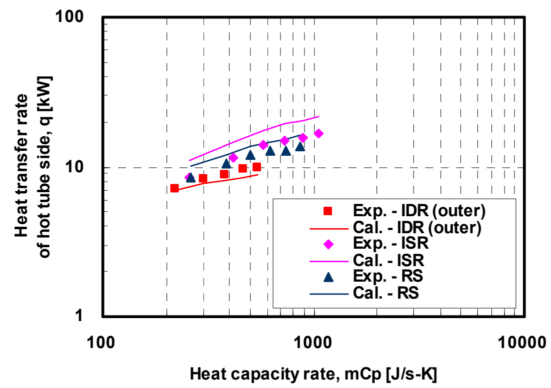

Fig. 5 Heat transfer rate of hot tube side

In the hot side of DTBSG, the analyzed heat transfer rates are overestimated slightly in the integrated single region type and radially separated type. For the integrated double region type DTBSG, the calculated heat capacity rate is smaller than the other type DTBSG, and the heat transfer rate is underestimated.

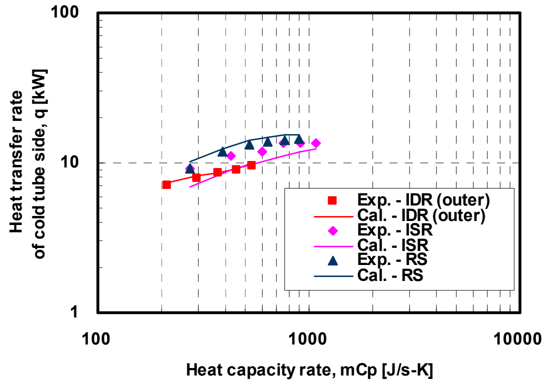

Fig. 6 Heat transfer rate of cold tube side

In similar operation condition, the integrated single region type DTBSG has larger heat transfer rate than the other types for the most part.

4. Conclusion

The 1-dimensional analysis code ISGA was verified with experiments in three kinds of bundle configurations. In the comparisons, ISGA code predicted well the general axial temperature distributions of DTBSG shell side. The heat transfer rate of hot, cold and medium fluid also calculated in various heat capacity rate conditions and compared with experiment. From the investigations, the feasibility of three candidate DTBSG concepts was shown and validity of the 1-dimensional thermal-hydraulic analysis code ISGA was demonstrated with experimental data. The multidimensional effect of double helical tube bundle and refinement of the heat transfer models for shell side should be researched in the future.

Acknowledgment

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