<질의 사항 답변>

1. 기본적인 에너지 보존 개념에 따라 feedwater 유량이 증가함에 따라 입축구의 온도차가 작아지는 결론을 얻었다. 다만 결과 부분에 대해 계산 결과가 그래프나 코드결과를 보여주지 않아 정량적으로 확인이 어려워 논문의 설득력이 떨어진다고 판단된다.

(답변) 본 논문은 증기발생기에 유입되는 feedwater 유량을 변경하는 것이 아니라 동일한 상태에서 downcomer측과 economizer측 유량 비율을 변경함에 따른 열수력적 변화를 해석적으로 확인하였다. 증기발생기 내부는 구조적으로 매우 복잡하여 열수력적 해석을 수행하였다. 증기발생기 내부에 대한 상세한 유동해석결과와 증기발생기 형상은 운영회사의 보안사항에 해당하기 때문에 논문에 수록할 수 없어 변수에 대한 경향성만 본 논문에 추가하였다. 해석 결과에 대한 보다 상세한 내용은 포스터로 제시할 예정이며, 게시기간 종료이후 수거할 예정이다.

2. 본 연구의 결과를 통해 새로운 finding이나 contribution에 명확하지 않아 논문의 목적이 불분명해보인다.

(답변) 본 논문의 목적은 동일한 feedwater에서 downcomer측과 economizer 측으로 유입되는 유량 비율 변화가 증기발생기 열수력에 미치는 영향을 확인하는 것이 목적이다. 전체적인 유량을 변화에 따른 증기압이나 입출구 온도차는 에너지 보존 개념에 따라 예측할 수 있지만, 비율 변화에 따른 영향은 복잡한 구조형상에 따라 쉽게 예측할 수 없다. 이에 본 연구에서는 ATHOS3 코드를 이용한 증기발생기 열수력 해석을 수행하여 열수력 특성변화를 관찰하였다. 본 논문의 목적을 명확히 하기 위하여 1.Introduction에 아래와 같은 설명을 추가하였다.

“However, due to structural complexibility of steam generator, the flow rate effect on the steam generator thermal-hydraulic characteristic is difficult to analyze.”

Thermal-Hydraulics Characteristics Change of OPR1000 Steam Generator Depending on Inlet Feedwater Flow Rate Ratio

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1. Introduction

Steam generator cools primary water of nuclear reactor core while generating steam using secondary water. The steam generator tube of domestic OPR1000 nuclear plant is made of Alloy690TT and the primary water flows inside the tube. The secondary water flows into the steam generator through the downcomer feedwater nozzle and economizer feedwater nozzle as shown in Fig. 1.

The figure shows the water flow in OPR1000 steam generator. The secondary water supplied through the downcomer nozzle mixes with droplets from separator and forms the downward flow path between the shell and shroud. This secondary water flows into the bundle of tubes at the lower stage cold-leg tube support plate region. The secondary water supplied through the economizer nozzle flows into the top of tubesheet at cold-leg region and forms an upward flow. These two flows mix in the evaporation region.

The feedwater flow rate of downcomer and economizer feedwater nozzle under normal operating condition is presented in the design report[1]. The feedwater is mainly designed to be supplied through the economizer feedwater nozzle.

The changes of the feedwater flow rate can affect the thermal-hydraulic characteristics of the steam generator and the output of nuclear reactor core. However, due to structural complexibility of steam generator, the flow rate effect on the steam generator thermal-hydraulic characteristic is difficult to analyze.

In this study, thermal-hydraulic characteristic analysis of OPR1000 steam generator is performed using ATHOS3 code which is developed by Electric Power Research Institute(EPRI)[2,3,4]. Case study is conducted in case of different feedwater flow rate ratio. The steam dome pressure, primary outlet temperature and saturation temperature are calculated in each case.

2. Thermal-hydraulic analysis

2.1 Thermal-hydraulic analysis model

ATHOS3 1/2 symmetric model of OPR100 steam generator model is determined from the design report

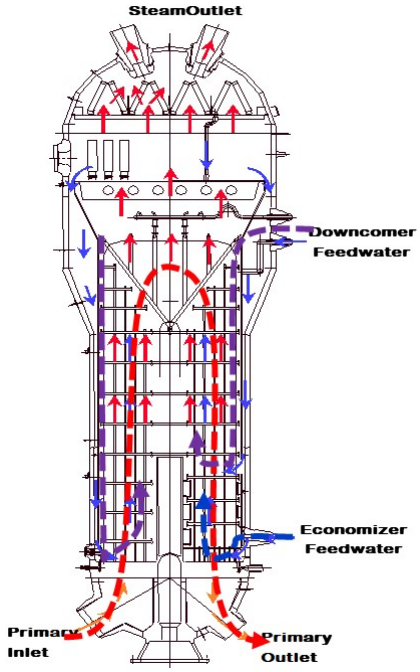

Fig. 1. Primary and secondary water flows in OPR1000 steam generator

of domestic OPR1000 steam generator. The model includes the tube bundle, shroud, tube support plate, flow distribution plate and separator as a geometric input data. The model is conducted using cylindrical coordinates with 20 circumferential grids, 20 radial grids and 45 axial grids

2.2 Boundary condition

Normal operating condition is considered in this study. Thermal-hydraulic design data presented in the design report and primary inlet temperature from operating data are considered. The blowdown flow is neglected in this analysis. Material properties of steam, primary water, secondary water and tube under normal operating condition are considered in the analysis.

The case study is conducted changing the feedwater flow ratio of downcomer and economizer feedwater nozzle flows while the total feedwater flow rate is constant. The changes in the steam dome pressure, primary outlet temperature and saturation temperature are analyzed.

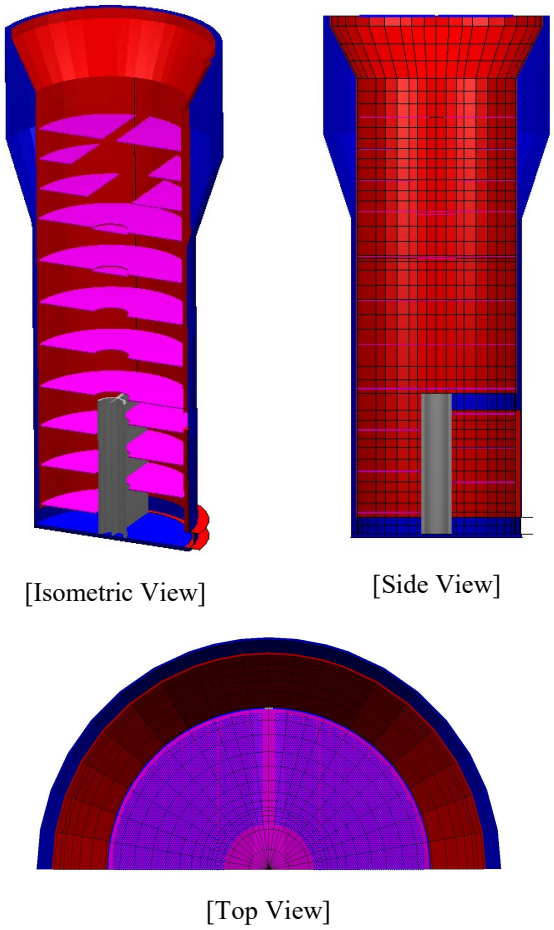

Fig. 2. ATHOS3 Thermal-hydraulics model of OPR1000 steam generator

3. Results

3.1 Thermal-hydraulics characteristics

Fig. 3 and 4 shows the Steam dome pressure and temperature tendencies depend on downcomer flow rate ratio from thermal-hydraulic analysis. As the downcomer feedwater flow rate is increased, primary outlet temperature, saturation temperature and steam dome pressure are decreased. When the downcomer feedwater flow rate is increased by 1.5 times, the steam dome pressure is decreased by 0.022 MPa(0.3%), and the primary outlet temperature is decreased by 0.005°C. The saturation temperature is decreased by 0.2 °C.

4. Conclusions

Thermal-hydraulic characteristics of OPR1000 steam generator depending on feedwater flow rate ratio is studied. For analysis, ATHOS3 code is used. Under normal operating condition, when the downcomer feedwater flow rate is increased, both steam dome pressure, primary outlet temperature and saturation temperature is decreased.

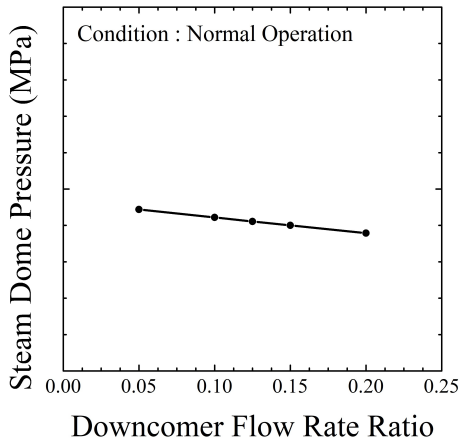

Fig. 3. Steam dome pressure tendency depend on downcomer flow rate ratio

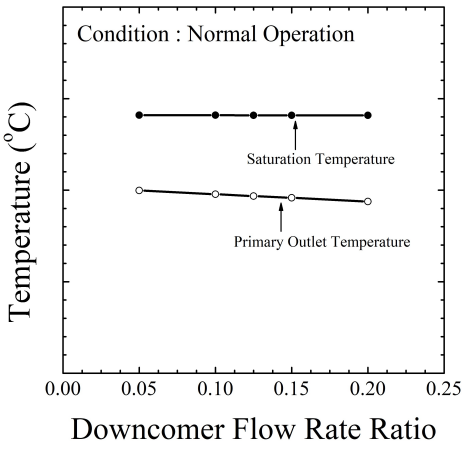

Fig. 4. Saturation and Primary Outlet Temperature tendency depend on downcomer flow rate ratio

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