Transactions of the Korean Nuclear Society Spring Meeting
Gwangju, Korea, May 30-31, 2013

The Accident Analysis for Loss of Emergency Core Cooling System in Wolsong Unit 1 Using MARS-KS/CANDU

Jin-Hyuck Kim*, Byung-Gil Huh, Chae-Yong Yang
Korea Institute of Nuclear Safety
*Corresponding author: jhkim@kins.re.kr

1. Introduction

If a large break loss of coolant accident(LBLOCA) of the primary coolant system with loss of the emergency core cooling system (LOECC) once occurs in a heavy water type nuclear power plant, the prolonged cooling by the vapor flow was generated following loss of the coolant. Heat removal will not be almost done due to the vaporization of the fuel channels, and there is a sharp rise in temperature of the pressure tube and the fuel sheath. The deformation in the direction of the diameter of the pressure tube with the high-pressure and high-temperature can be done, and it is in direct contact with the calandria tube if deformation persisted. Once the contact occurs, the heat flux spike phenomenon occurs through the moderator of the low-temperature, which heat is rapidly removed. For the safety analysis of the accident without the emergency core cooling system, the development of modeling for a pressure tube and calandria tube contact and of heat removal load evaluation methodology of the moderator must be required. In this study, the purpose is to evaluate the heat removal load of the moderator with the pressure tube deformation model of MARS-KS-CANDU, which the emergency core cooling system damaged with a large break of the primary coolant system occurs.

2. Pressure tube Deformation Model

Pressure tube deformation model is considered as a part of the heat structure of MARS-KS-CANDU, in which there are three different layers. First, the configuration is that of the innermost of the pressure tube, of the middle of CO_2 gas layer, and of the outer calandria tube. Actually, the center CO_2 gas layer should be modeled as one of the hydraulic dynamic volume, but here the pressure tube, CO_2 gas layer, and the calandria tube were simply modeled as single heat structure because of the difficulty in modeling the phenomena which the pressure tube deformation is in direct contact with the calandria tube. If a pressure tube deformation occurs, the wall thickness of a pressure tube keep thinning and expanding while maintaining the volume of pressure tube. When the deformation continues to happen, there is direct contact between the pressure tube and the calandria tube. On the other hand, the heat transfer between the pressure tube and the calandria tube is composed by the radiation heat transfer between pressure tube and calandria tube and the convection by the CO_2 gas layer. Convection and radiation which is the actual mechanism of heat transfer, cannot be simulated because the pressure tube, CO_2 gas layer, and the calandria tubes consist of one heat structure here. Therefore, the heat transfer by convection is to be calculated to the heat transfer by conduction by using the thermal conductivity of CO_2 gas here. There is typically no big difference even if the gas convection is simulated by the conduction using the values of the gas thermal conductivity. In order to take into account the heat transfer by radiation, it is calculated to conduction in addition to the value of the thermal conductivity of the additional radiative gap conductivity values due to radiation.

3. Calculation Modeling

It was used for modeling of the primary coolant system in Wolsong unit 1 as shown in Figure 1, in order to simulate an accident with a LBLOCA in the primary coolant system with the loss of Emergency core coolant injection. In this case, the condition of the calculation was 35% in size of the break in the fourth core path. Modeling of the fuel channels was modified for prohibiting the coolant injection even if the emergency core coolant injection requirements was needed by changing open condition of 904-906 valve which the emergency core coolant to connect with each header. The analysis calculations were performed by using the previously described pressure tube deformation model. For this, the pressure tube, CO_2 gas layer and the calandria tube were modeled by using one heat structure. Also, in the case that the pressure tube deformation model was not be used, it was set to separate heat structure between pressure tube and the calandria tube, and in the case of the CO_2 gas layer by modeling as a separate volume.

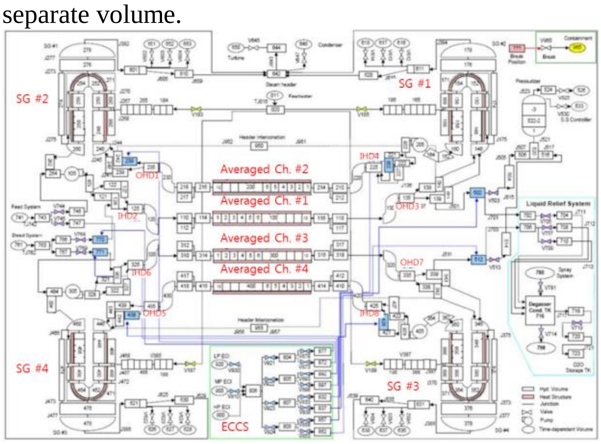

Figure 1 Nodalization diagram for Wolsong unit 1

4. Calculation Results

Early stage of a LOCA+LOECC shows the same thermal-hydraulic behavior in the case of safety system available, and the differences appear after 30 seconds are visible. Unlike the case of the safety system is available; pressure drop is faster in LOECC due to the continuous loss of coolant. From the results of amount of coolant, the coolant was nearly exhausted about around 100 sec. The emergency core cooling system available accident shows other tendency from around 50 sec due to the safety injections. And the flow rate in the fuel channel is almost close to zero. These thermal-hydraulic behaviors in the case that the pressure tube deformation model was not used show same tendency.

A clear difference caused by the pressure tube deformation model is found in the temperature of the fuel channels. Figure 2 represents the temperatures of the pressure tube, the nuclear fuel sheath, and the calandria tube in the case that the pressure tube deformation model is used. And Figure 3 shows of the temperatures when the pressure deformation model is not used. The temperature variations until 500 sec from the two figures were almost the same after the accident. However, after 500 sec, the two calculated results clearly show a different tendency. Using a pressure tube deformation model, increase in the temperature rise of the nuclear fuel cladding was clearly limited due to the heat removal from the moderator. The differences between these temperature changes show more clearly than the cladding appears in the pressure tube. In case of the calandria tube using the pressure tube deformation model, it can see that a temperature slightly increased over time due to the increase of the heat transfer between the pressure tube and the calandria tube. Figure 4 shows a comparison of the heat removal load of the moderator. Compared to the case of not using pressure tube deformation model, a higher temperature at the initial accident allows some variation of pressure tube, and increasing of heat removal load in the moderator in case of using pressure tube deformation model. Since over 300 seconds, it showed an obvious difference. From the results, it is considered that heat transfer through the moderator is simulated more adequately by using a pressure tube deformation model.

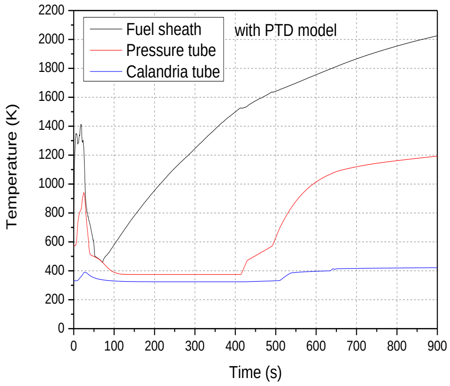

Figure 2 Temperatures variation with PTD model.

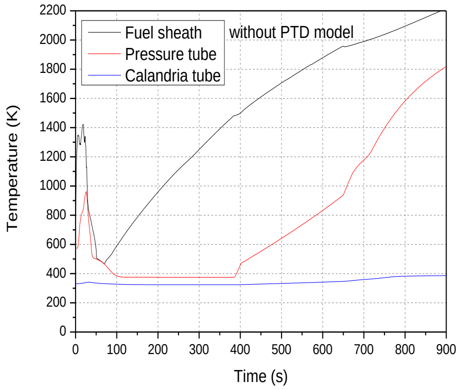

Figure 3 Temperatures variation without PTD model.

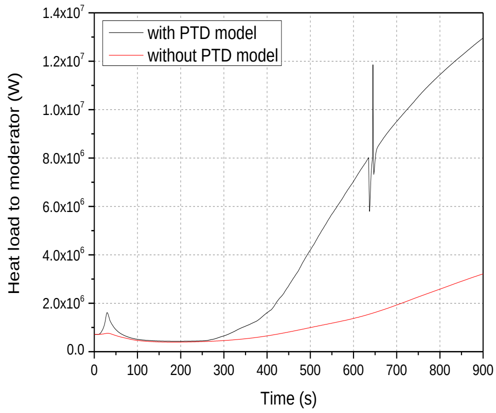

Figure 4 Comparison of heat load to moderature.

5. Conclusion

To analyze the LBLOCA with LOECC in CANDU type reactor, it is imperative to adequately predict the pressure tube deformation and subsequent heat removal load to the moderator. Therefore, in this study, we evaluate whether the pressure deformation model of MARS-KS-CANDU code is properly work through calculation of Wolsong Unit 1. It is estimated that pressure tube deformation model work properly and reliably predict the moderator`s heat load in LOECC accident. However, these assessments should be limited for the qualitative part due to the difficulty of acquiring the experimental data for the CANDU type reactors. In future studies, the appropriate experimental data acquisition and the validation of the MARS-KS-CANDU with those data should be required.

REFERENCES

[1] B.D. Chung, et al., Development and Assessment of Multi-Dimensional Flow Models in the Thermal-Hydraulic System Analysis Code MARS, KAERI/TR-3011/2005.
[2] Atomic Energy of CANADA Limited, "CATHENA Mod-3.5d/Rev 2, Input Reference", 2005.
[3] Final Safety Analysis Report of Wolsong unit 1