Evaluations of RPV stress intensity factor during PTS events

*Xiaoyong Ruan[1], Toshiki Nakasuji[1], Kazunori Morishita[2]
[1]Graduate School of Energy Science, Kyoto University, [2]Institute of Advanced Energy, Kyoto University.

The cracks of the inner surface in the RPV is evaluated by Fracture Mechanics (FM) analysis during PTS loading, which is important in assessing the safety of nuclear power plants. In the present study, the three-dimensional Computational Fluid Dynamics (CFD) simulations and Fracture Mechanics analysis is performed. And it revealed the dependence of Stress Intensity Factor (SIF) on the positon of RPV.

Keywords: Reactor Pressure Vessel, Pressurized Thermal Shocks, 3D-CFD, Fracture Mechanics

1. Introduction

The Reactor Pressure Vessel (RPV) is exposed to neutron irradiation, which causes embrittlement of the ferritic steels and makes the material susceptible to brittle fracture[1]. In Pressurized Thermal Shock (PTS) situation, the cold plume will flow into the downcomer and cool down inner surface in the RPV, which lead to high tensile circumferential stresses in the RPV walls. With the neutron irradiation, these circumferential stresses may lead the PRV to brittle fracture.

In the present study, the three-dimensional Computational Fluid Dynamics (CFD) simulations and Fracture Mechanics (FM) analysis is performed to simulate a PTS loading in the RPV. And it revealed the dependence of SIF as a function of location of RPV.

2. Analysis process

For the CFD simulations, the injection Emergency Core Cooling (ECC) water is injected in each cold leg. The ECC reaches a value of 20 kg/s, 40 kg/s and 80 kg/s, three cases in this CFD simulations.

The FM analysis is used to obtain the SIF. The acquired results for the three-dimensional temperature distributions are obtained from CFD. Analysis of the most dangerous region such as the regions are the inlet, the location of maximum von Mises stresses, inside, outside and border of the cooling plume in core region. Because of the high irradiation, Cracks inside the plume in the core region was considered to be the most dangerous positon of RPV.

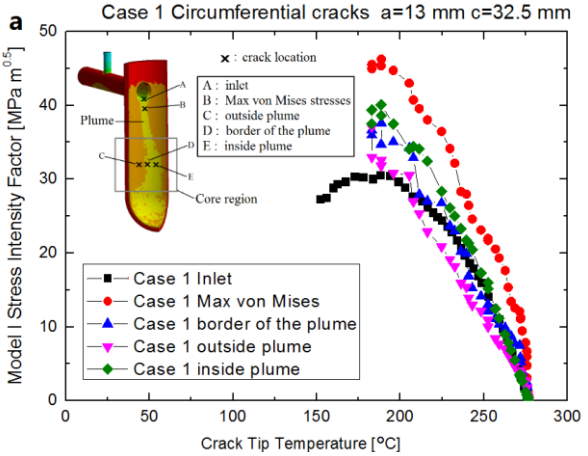

Fig.1 SIF comparison at each crack location in Case 1 (20kg/s)

3. Conclusion

We performed 3D-CFD simulations and fracture mechanics analysis of the RPV subjected to PTS loading. It analyzed the most dangerous region. And it compared with SIF at the deepest crack point for each locations when the Safety Injection Pumps (SIP) flow changes. It revealed the dependence of cooling conditions for SIF occurred to the cracks.

References

[1] Odette, G.R., Lucas, G.E., ASTM STP 909, ASTM International, West Conshohocken, PA, USA , 1986, pp. 206-241.

[2] Sharabi, M., Freixa, J., Nucl. Eng. Technol., 44 (7), 2012, pp. 709-718.

[3] González-Albuixech V.F., Qian G., Nuclear Engineering and Design, Vol.297, 2016, pp.111-122.