FACAPT – Failure Assessment Program for CANDU Pressure Tube

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1. Introduction

Currently, 3 CANDU reactors (Wolsong 2, 3 and 4 NPPs) have been operating in Korea more than 20 years and some safety issues have been raised regarding pressure tubes.

Pressure tubes, which are made by Zr-2.5%Nb alloy, are the main components of the CANDU reactor and serve as the fuel channel as well as the coolant pressure boundary of the primary heat transport system. Pressure tubes have degraded not only material properties such as fracture toughness, deuterium ingress, mechanical characteristics but also deformation, wear, crack and fracture under the severe operating conditions of a high neutron flux, high temperature and pressure inside the pressure tube.

These degradations of the pressure tube caused some safety issues such as a reduction of the operational margin in terms of the regional over-power trip set point owing to the diametrical expansion of the pressure tube and a probability increase of the pressure tube failure owing to the material property change such as a fracture toughness and deuterium ingress. In order to overcome these issues, KAERI has been carrying out R&D project regarding the development of the assessment technology for pressure tube integrity of the CANDU reactors. The aim of the R&D project is to secure the safe operation of domestic CANDU reactors at least until the design life span. Fig. 1 shows the overall research issues for CANDU pressure tube.

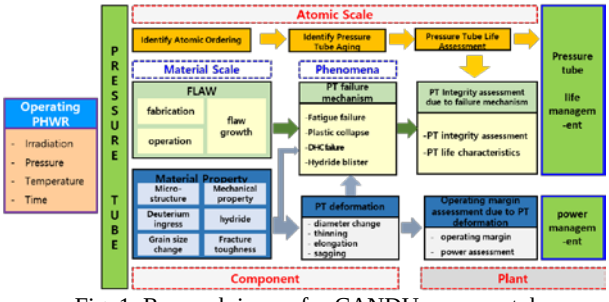

Fig. 1. Research issues for CANDU pressure tube.

In this paper, we are going to introduce the objective of FACAPT (Failure Assessment Program for CANDU Pressure Tube) development, the structure of the program and the application of the program to pressure tube safety issues. The developed FACAPT will be applied to the evaluation of the pressure tube failure assessment for the domestic CANDU reactor in order to verify that the pressure tube can be able to keep its soundness and integrity at least until the 30 years of the licensed operation period.

2. Structure of the FACAPT

2.1 Objectives of the FACAPT development

Since domestic CANDU reactors in Korea have been operated with high capacity factor more than 80%, its life of 210 kEFPH (Effective Full Power Hour), which guarantees the soundness of the pressure tube and is same to 30 years if the reactor operates with 80% capacity, may reach earlier than the licensed operation time of 30 years. In that case, there may be some discrepancy between the pressure tube integrity life time of 210 kEFPH and the licensed operating life of 30 years. In order to solve this problem, we should verify that the pressure tube is able to keep its soundness and integrity beyond the 210 kEFPH, at least until the licensed operation time of 30 years.

Canadian Standard Association (CSA) has issued a guide code [1] to conduct an integrity assessment in order to solve the safety issues regarding the aged pressure tube owing to its degradation. However, we have not had such an experience of pressure tube integrity assessment for the domestic CANDU reactor in Korea.

This study has focused on the development of the evaluation tool for the pressure tube integrity assessment including not only the deterministic assessment module for crack initiation and growth evaluation but also probabilistic assessment module for whole core.

2.2 FACAPT Structure

Fig. 2 shows the whole structure of the developed FACAPT which is the evaluation tool including the crack initiation and growth module, integrity assessment module and probabilistic assessment module.

Deterministic module is consisted of the initial condition and input variable part, evaluation of crack initiation part, evaluation of crack growth part and integrity assessment part as shown in Fig. 3 ~ Fig. 4.

Probabilistic module deals with the whole core of 380 pressure tubes in the reactor based on the deterministic assessment for each pressure tube.

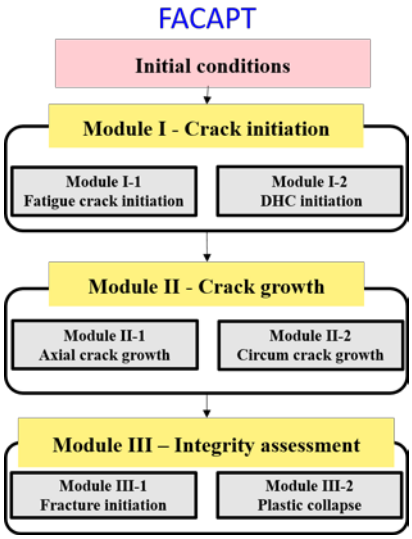

Fig. 2. Whole structure of FACAPT.

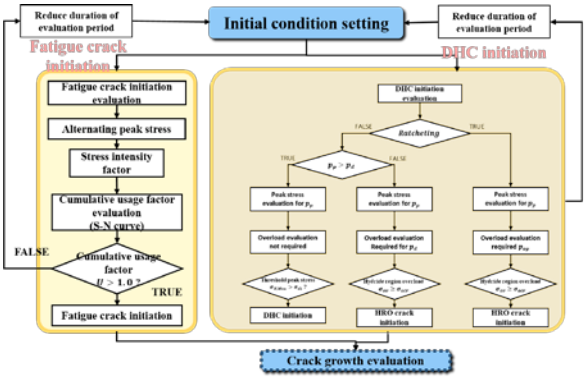

Fig. 3. Evaluation of crack initiation.

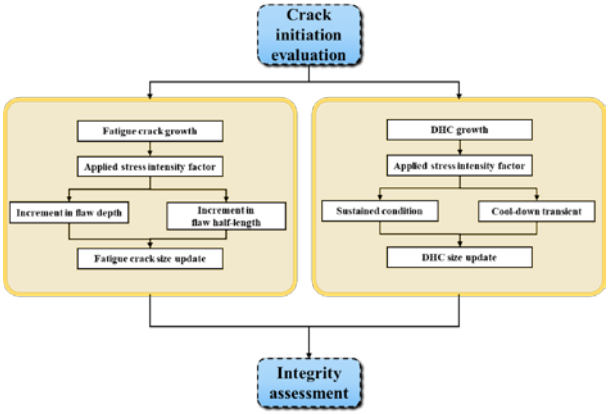

Fig. 4. Evaluation of crack growth.

3. Application of the FACAPT

3.1 Crack initiation by fatigue and DHC

Developed FACAPT was applied to evaluate the crack initiation owing to the fatigue and delayed hydride cracking, respectively and results are shown in Fig. 5 and 6, respectively. Operation conditions were referred from References 2 ~ 6.

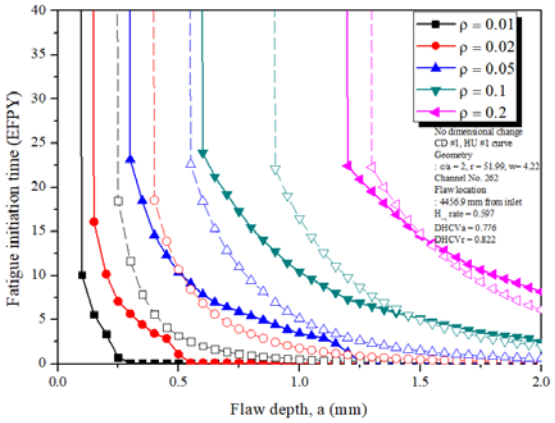

Fig. 5. Crack initiation time by fatigue.

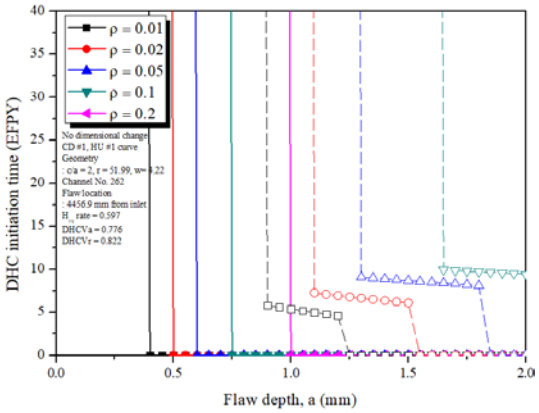

Fig. 6. Crack initiation time by DHC.

3.2 Crack growth evaluation by fatigue and DHC

Crack growth by DHC was evaluated based on the 05 version and 15 version of CSA N285.8. Fig. 7 shows the crack growth results for both case.

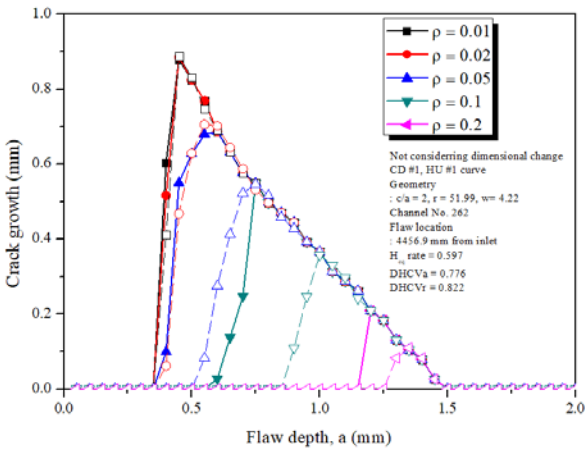

Fig. 7. Crack growth evaluation by DHC.

4. Conclusions

In this study, FACAPT (Failure Assessment Program for CANDU Pressure Tube) was developed in order to overcome the current safety issues regarding aged pressure tubes by evaluating the pressure tube integrity in terms of the failure aspect. Developed FACAPT was applied to the crack initiation of the pressure tube by the fatigue and delayed hydride cracking and also to the crack growth and integrity assessment. From the evaluation results, developed FACAPT works well in evaluating the pressure tube integrity and will be applied to the pressure tube failure assessment for the domestic CANDU reactor in order to verify that the pressure tube can be able to keep its soundness and integrity at least until the 30 years of the licensed operation period.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (Ministry of Science and ICT). (NRF-2017M2A8A4017282).

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