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Study on fuel channel behavior following various PT/CT contact angles under late-heatup condition with SBLOCA/LOECC

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1. Introduction

Fuel channel has been studied for applying Wolsong-2,3,4 Nuclear Power Plant in Korea. As a part of the project, the fuel channel integrity is evaluated under Small Break LOCA(Loss of Coolant Accident) with loss of emergency core cooling injection. The loss of coolant from broken loop results in core voiding, and low steam flows in the channel which are caused by ECC water leakage assumed are to add the heat from zircaloy-water reaction. Therefore, fuel channel would experience late-heatup condition under the accident. At the low steam flow rates, fuel and pressure tube heat up and the pressure tube may balloon or sag into contact with its calandria tube. LOCA with loss of emergency core cooling injection occurs in CANDU, moderator takes a role of an ultimate heat sink. Decay heat is removed to moderator through PT/CT contact. Therefore, behavior of PT/CT contact must account for LOCA/LOECC.

In this paper, a sensitivity study according to PT/CT contact angle is presented when pressure tube experience sagging contact.

2. Analysis and Results

In this section some of the assumptions used to model the channel are described. And transient results are compared following PT/CT sagging contact angles.

2.1 Model

A detailed single channel is modeled to analyze fuel channel behavior under the late-heatup condition. Total six representative channels (B10, G05, S10, O6, W10 and O6_mod) are selected according to their horizontal location in the core and channel power. Each fuel channel consists of twelve fuel bundles corresponding to their axial node, and both pressure tube and calandria tube are modeled into 18 sectors along their circumferential direction.

2.2 Assumption

The late-heatup analysis provides the hydrogen source term to containment and the fuel and PT temperature as well as the heat load to moderator from PT/CT contact due to PT deformation. These results provide the input to other licensing and safety assessment. 5g/s steam flow and O6_mod channel showed to be most conservative condition under the late-heatup. [1] when pressure tube sagging contact occurs, the variation of the sag contact angles are set to be 40, 60, 120 degree in this estimation to know the limiting condition on fuel failure and containment integrity.

The assessment of fuel channel behavior is assumed under those three sag contact angles in this study. The number of contact fuel element are 6, 8, 12 element as the contact angles are 40, 60, 120 degree respectively. The analysis is performed with the CATHENA 3.5.4.4. thermal hydraulic computer code.[2]

2.3 Result

The result of fuel channel analysis provides input data for following subsequent relevant analysis, like fuel temperature used for fuel integrity analysis and heat load to moderator estimated for moderator subcooling margin applying to channel analysis, hydrogen produced that analyses for containment

According to this, The sensitivity of fuel temperature, hydrogen produced and heat load to moderator from pressure tube and calandria tube are estimated with PT/CT contact angle in this analysis. Figure 1 shows that, when contact angle is 120 degree, the temperature of center pin increases most quickly among the cases. The narrower the surface area where PT/CT contact, the slower temperature increasing rate of center pin.

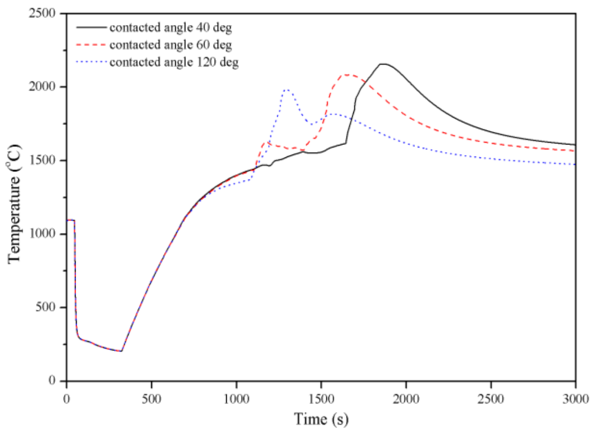

Figure 1. Center Pin Temperature for each PT/CT contact angle for 2.5% RIH Break/LOECC, 5g/s.

The amount of hydrogen produced is indicated in Figure 2 with PT/CT contact angle. The result with 40 degree PT/CT contact angle has got the highest hydrogen generation.

Figure 3 shows total heat load to moderator with PT/CT contact angles. Heat is well transferred to moderator at the early stage of transient as contact angle is wider. But as transient simulation becomes longer, the amount of transferred heat to moderator from 40 degree contact angle is getting higher. Transient simulation ends at 7000 seconds, and total heat load to moderator indicated in Table 1.

Wider PT/CT contact area causes quicker heat transfer to moderator and it leads faster cooldown of fuel. Therefore, it results in less hydrogen formation.

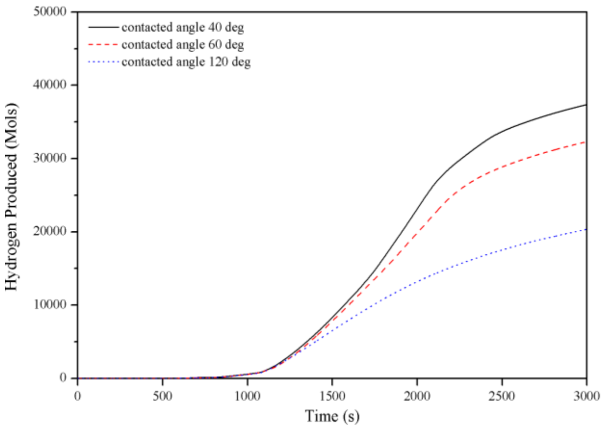

Figure 2. Hydrogen produced for each PT/CT contact angle for 2.5% RIH Break/LOECC, 5g/s.

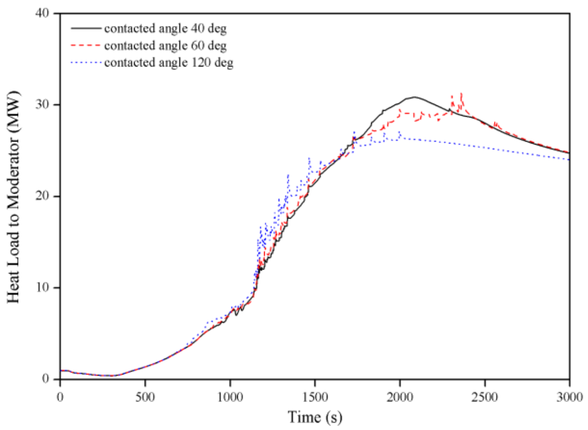

Figure 3. Heat Load to moderator for each PT/CT contact angle for 2.5% RIH Break/LOECC, 5g/s.

Table 1: Total Heat Load to Moderator Following a 2.5% RIH Break /LOECC in Broken Loop with Various contact PT/CT angle

Contact angle (°)	Total Heat Load to Moderator (MJ)
40	129,600
60	129,476
120	127,549

3. Conclusions

The sensitivity of PT/CT sagging contact angle has been studied. The results of sagging contact angle could explain in different ways.

In the case of wide sagging contact angle, the result is quite conservative in the aspect of containment as the heat is well-transferred to moderator. it causes the moderator to heat up.

On the other hand, the narrow sagging contact angle results fuel heatup and give limiting condition for fuel integrity.

As a result of estimation, a proper application of sagging contact angle is required to provide limiting condition for subsequent analysis.

REFERENCES

[1] B.J Moon,E.K.Jang,S.R.Kim, Study on Start Time of Parametric Study for Channel Analysis under SBLOCA/LOECI.35th Annual Conference of the Canadian Nuclear Society, May 31-June 3, 2015.

[2] T.G .Beuthe and B.H.Hanna, Editor, "CATHENA 3.5.4.4 INPUT REFERENCE",153-112020-UM-006,Rev.0,October 2013.