

Integrity of a Fuel Channel during a SSE Horizontal Event

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1. Introduction

Fuel Channels(FC) should maintain its integrity during an operation in a reactor core in the design base accidents such as a safe shutdown earthquake (SSE). In order to show its integrity during a SSE horizontal motion, a fuel channel was modeled as a spring-mass-beam with a gap element of the ANSYS[1] code. The displacement, stress and moments at each node and element of the model were calculated using the displacement input of the upper core support plate(UCSP), the mid core support plate(MCSP) and the lower core support plate(LCSP). Since there exists a gap between the center of the FC and the mid core support plate(MCSP), the FC horizontal motion would be restricted by the MCSP. If a gap closure occurs, the dynamic impact of the FC will produce a severe stress at this position.

The displacement, stress and moment of each node and element were examined whether the FC contacted with the mid core support plate or not. The nodal maximum stresses of the elements were compared with the design stress limit.

2. Methods and Results

In this section, some of the model and the model input are described.

2.1 Calculation Model

In order to obtain the dynamic responses of a fuel channel, the FC can be modeled as a Spring-mass-Beam model as in Figure 1. The gap between the FC and the mid core support plate was modeled using the COMBIN40 element of ANSYS. The stiffness of the gap element at the MCSP was obtained by the thickness, contact area and young's Modulus of the MCSP.

The FC was divided into several sections where they had different section properties, i.e. sectional area, material properties and second area moments etc. The model had 84 nodes in the axial direction. The gap between the lower and the upper CEDM guide tube support plates was considered to be large enough not to contact with the FC, thus they were excluded in the modeling.

2.2 Displacement Input

The excitation input of the FC was the displacement history[2] of the UCSP and LCSP as in Figure 2 from

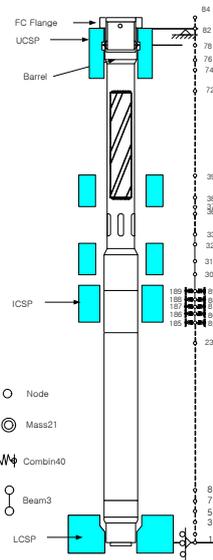


Figure 1 FC Horizontal Model

the results of a core structure analysis (performed from NSSS). The MCSP displacement time history was interpolated from the displacement of the UCSP and LCSP. The maximum displacement of the input was about 1 mm in the horizontal direction as shown in Figure 2 and 3

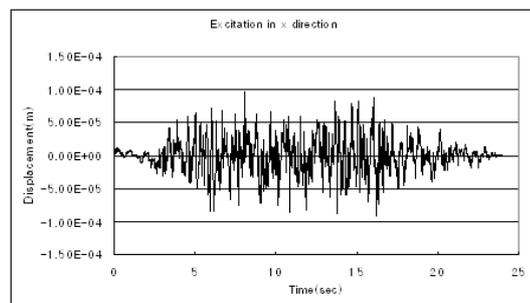


Figure 2 Displacement input at the UCSP

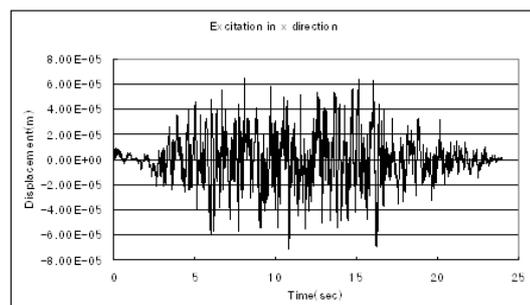


Figure 3 Displacement input at the LCSP

2.3 Calculation Results

The α , β damping values calculated from the first and 5th natural frequencies of the FC using a critical damping ratio of 1%(conservatively used 1 % instead of 2%[3]) were 2.1094 and 9.88764E-06, respectively.

ANSYS transient analysis was used for the calculation. Direct integration of the displacement inputs was used with a auto time step option.

The maximum displacement position to be expected was at the center of the fuel location or the center of the FC. Figure 4 and Figure 5 show the horizontal displacement of the two positions of the FC. It showed that the maximum displacement of the FC at the gap position(nearly center of the FC) was 0.079 mm which did not exceed the amount of the gap size 0.3 mm. Thus FC would not contact with the MCSP during a SSE.

Figure 6 and Figure 7 show the maximum stress (axial membrane plus bending) at the center of the fuel location and the FC. It shows that the maximum stress at the fuel location and the center of the FC were 3 MPa(3 N/mm²), far below the design stress limit(205N/mm² for Zr material and 349.2 N/mm² for stainless steel) which means the FC will maintain its integrity during a SSE.

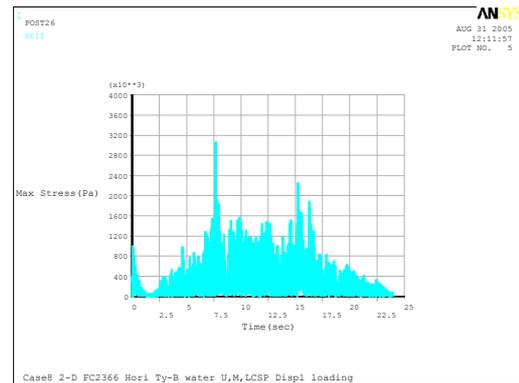


Figure 6 Stress at Node 15

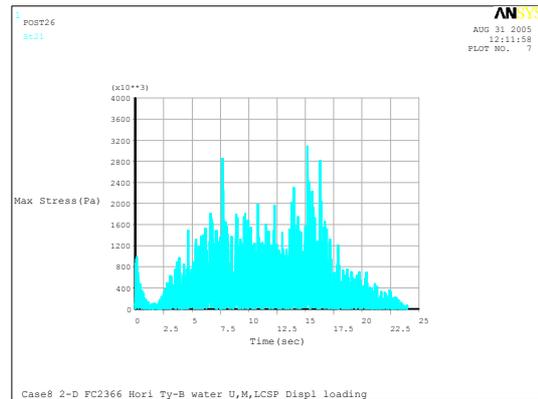


Figure 7 Stress at Node 21

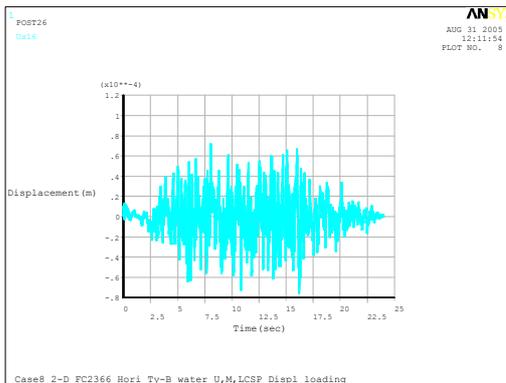


Figure 4 Displacement at node 16

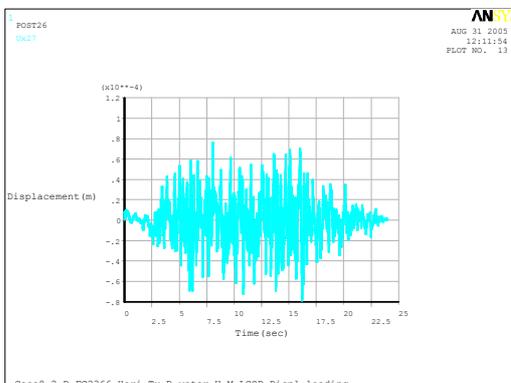


Figure 5 Displacement at node 27

3. Conclusion

A fuel channel was modeled as a spring-mass-beam with the CONBIN40 element of ANSYS to calculate the displacement, stress and moment at each node and element. Calculation results using the FE Model showed that the maximum displacements of the FC were small enough not to contact with the gap of the MCSP. The maximum stress occurred at the center of the FC and it was far below the stress limit, thus the FC can maintain its integrity during a SSE without any impact to the MCSP.

Acknowledgements

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REFERENCES

- [1] SWANSON analysis Inc., ANSYS ver.9.0, 2005.
- [2] Regulation guide 1.61, Damping values for seismic design of nuclear power plants