Application of ADINA Code for Control Rod Drop Analysis

K. H. Yoon,[a] J. Y. Kim, [a] K. H. Lee, [a] Y. H. Lee [a] and H. K. Kim [a]
a Innovative Water Reactor Fuel Center, KAERI, 150 Dukjin, Yuseong, Daejeon, khyoon@kaeri.re.kr

1. Introduction

Guide tubes serve as the main lateral and axial load carrying members of a fuel assembly. And they provide a guide path for the control element assembly (CEA), neutron sources and in-core instrumentation.

The outer guide tubes comprise four units that are fabricated from Zircaloy-4 tube material. The guide tubes form the basic structural member of a fuel assembly by supporting the spacer grids and by their direct attachment to the lower and upper end fittings. Figure 1 is a schematic representation showing the expanded region of the guide tube and its corresponding interfaces.

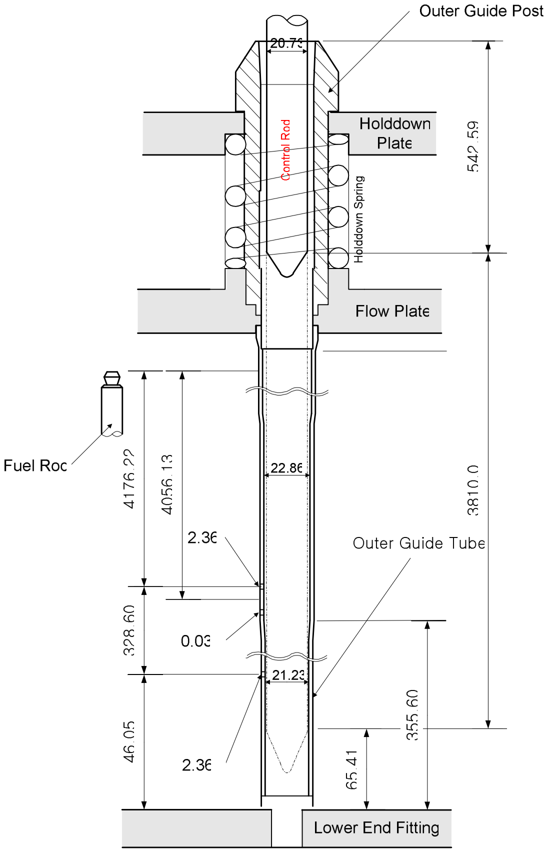

Figure 1. Schematic drawing of the FA guide tube and CEA model

Guide tube flow holes and clearances between a guide tube and a control rod must be designed for the CEA scram time. During a normal operation with a fully inserted CEA, the coolant flow rate in the annulus between the guide tube and control rod must be sufficient enough to prevent excessive CEA temperatures.

The design of the outer guide tubes should be compatible with the CEAs. Specifically, the CEA scram time should meet the requirements as shown in Figure 2 [1&2].

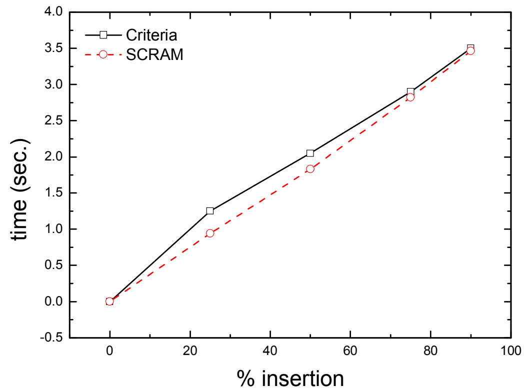

Figure 2. Safety curve limits for a scram without a delay time

2. FEM model

An FE model for a scram simulation was created using the ADINA commercial code [3]. The geometrical data was assumed to be axisymmetric. Therefore, the whole model was produced in 2-D. And the coolant was supposed to be an incompressible and ideal fluid. All the design parameters followed the data of a solid fuel. For the scram analysis, the simple model as shown in Figure 3 was used.

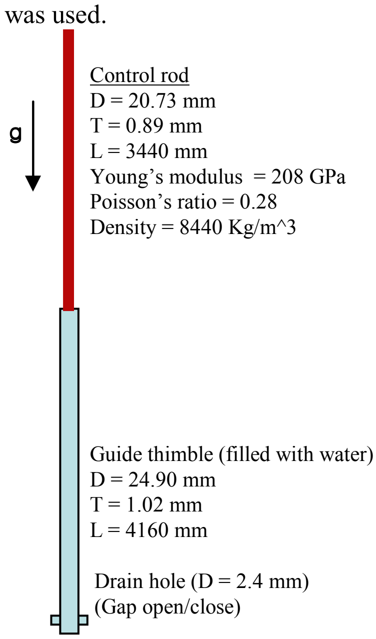

Figure 3. Simple model description for a scram analysis

The contact surface between the control rod and coolant (fluid) was modeled with a fluid-structure interface boundary condition. The fluid within the guide tube was assumed to be an incompressible flow, so the density of the coolant was constant. And the drain holes at 46 mm and 374 mm from the top surface of the bottom end fitting were modeled with gap elements. Therefore, the gap elements were closed when the control rod past the drain holes. The simple model and the applied boundary conditions are represented in Figure 4.

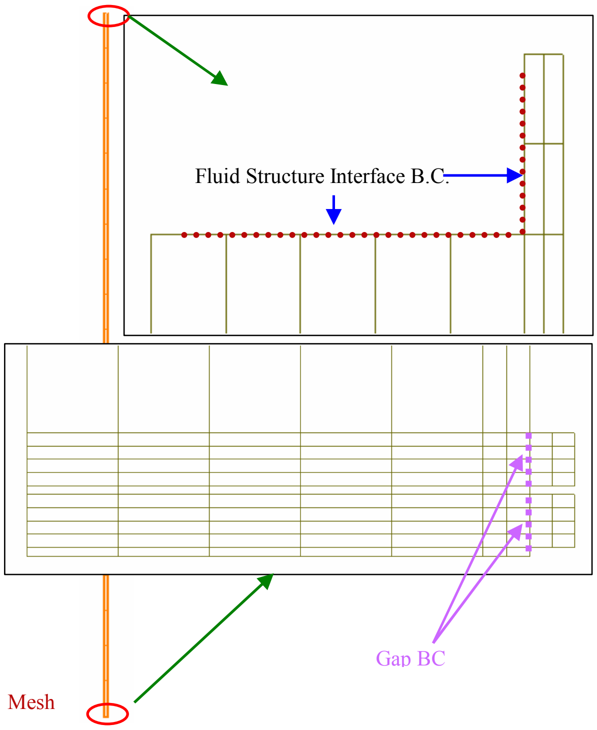

Figure 4. FE model and the applied BC's for the scram analysis

The design variables for the analysis are summarized in the Table 1 [2].

Table 1. Design variables for the scram analysis

Design variable	Value (mm)
Inside diameter of guide tube	22.86
Inside dia. of a GT in buffer region	21.23
Outside diameter of a guide tube	24.90
Outside dia. of GT in buffer region	23.26
Outside diameter of a control rod	20.73
Drop weight of a control rod	13.04
Length of a guide tube	4160.0

For the scram simulation, a fully coupled fluid-structure interaction is needed. So, the ADINA-CFD, ADINA-FSI, and the ADINA-Structure modules were used under the Windows platform machine. Fluid solver controls the time step, solution time and the convergence parameters of the coupled system. Of course, a re-mesh for the fluid is possible, but it wasn't used in this work.

3. The results of analysis

The analysis results were compared with those of the SCRAM, in-house code. These results were for the best estimate (BE) case of the four finger part strength (PS) summarized in the Table 2. The difference between the SCRAM and the present results is within 10 %.

Table 2. Analysis results of the BE case of the 4 finger part strength

	CEA insertion (%)			
Time (sec.)	25	50	75	90
Safety limits [1]	1.25	2.05	2.90	3.50
SCRAM	0.719	1.269	1.817	2.152
Present	0.685	1.185	1.704	1.926

The scram time vs. the Z-displacement of the control rod graph is shown in Figure 5. In this Figure, a variation point took place due to a gap closure.

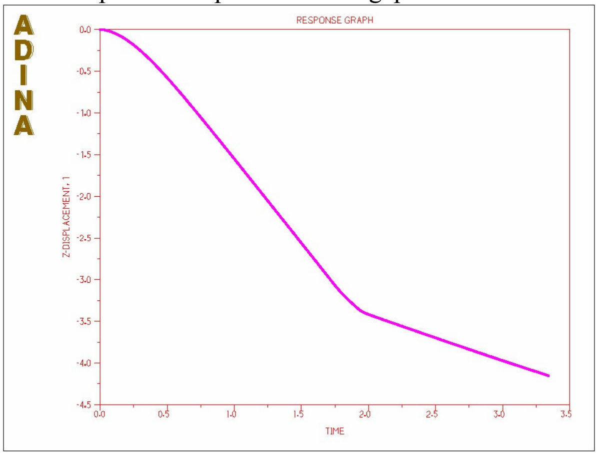

Figure 5. Z-displacement vs. the scram time from the FE analysis

4. Conclusion

A control rod drop analysis was executed with the commercial code, ADINA. This FE model and the procedure are applied by using a fluid-structure coupled algorithm. The results showed a good agreement with those of the licensed in-house code, SCRAM.

ACKNOWLEDGEMENTS

This project has been carried out under the nuclear R&D program by MOST(Ministry Of Science and Technology in Republic of Korea).

REFERENCES

[1] D.S. Chang, UCN34-FMD-CR003, Control Element Assemblies Mechanical Design Bases, Criteria and Verification, 1993.
[2] K.H. Yoon, SCRAM Analysis for UCN 3&4 Control Element Assembly, KAERI Calculation Report, 1996.
[3] ADINA R&D, Inc., ADINA User's Manual, Ver. 8.4, 2007.