Development of the Graphical User Interface for the Fuel Assembly Bow Analysis

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1. Introduction

KEPCO NF, Westinghouse and ENUSA jointly developed a new fuel assembly growth and bow computer code(SAVAN2D), a new fuel assembly analysis and performance model, and a new GUI(Graphical User Interface) for the prediction of in-core deformation behaviour of the fuel assemblies[1,2]. The SAVAN2D code can analyze fuel assembly growth and bow using fuel assembly design data and core conditions. In this paper, the development results and application areas of the SAVAN2D pre-processing and post-processing program are presented.

2. Fuel Assembly Bow Analysis

The analysis method for the fuel assembly bow consists of 4 simulation steps[3]. The first step is to develop and verify skeleton model. The second step is to develop and verify fuel assembly model including fuel rod bundle model. The third step is to simulate the growth and bow behaviour of a single fuel assembly at a representative in-core condition. And, the last step is to simulate the full core conditions for each row and/or column in the core. The model development stage consists of the first and second simulation steps. The representative skeleton and fuel assembly models can be developed using fuel assembly design data and mechanical test results. The fuel assembly model developed during this stage will be used as a basic model of the core model. The structural performance analysis stage consists of the third and fourth simulation steps. The fuel assembly growth and bow analysis at representative in-core conditions can be performed for a single fuel assembly and/or for the all fuel assemblies in the core during those steps.

3. Graphical User Interface Development

The GUI has been developed as a separate program for the pre-processing and post-processing of the fuel assembly bow evaluation. The pre-processing and post-processing program has been developed using Visual Basic 2005 with Visual Studio 2005 IDE(Integrated Development Environment).

The SAVAN2D_Preprocessor, pre-processing program of the SAVAN2D code, has been developed for the easy preparation of the input files of fuel assembly design data and core conditions and the easy execution of the SAVAN2D code with options. The SAVAN2D_Preprocessor program provides the functions of analysis setup, input data preparation, and SAVAN2D analysis. Fig. 1 shows the Analysis Option window. Fig. 2 and Fig. 3 show the Plant Specific Input window and Cycle Specific Input window, respectively. Fig. 4 shows the SAVAN2D Analysis window.

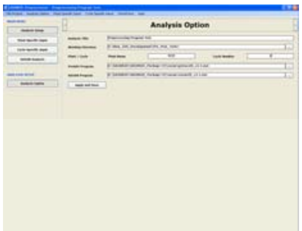

Fig. 1. Analysis Option

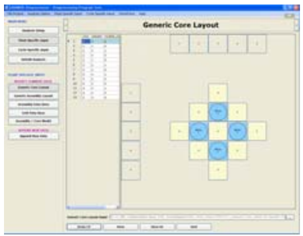

Fig. 2. Plant Specific Input

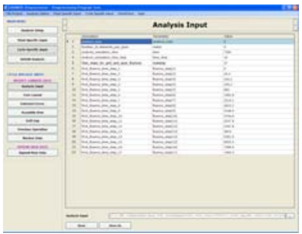

Fig. 3. Cycle Specific Input

Fig. 4. SAVAN2D Analysis

The SAVAN2D_Postprocessor, post-processing program of the SAVAN2D code, has been developed to generate the standard output database based on the SAVAN2D output, present these database in user friendly form in SAVAN2D_Postprocessor environment and keep these standard results in text format files in the assigned directory. The SAVAN2D_Postprocessor program consists of the menus for database manager and database viewer. The menus for database manager provide the functions of database log file generation, test database generation, RCCA(Rod Cluster Control Assemblies) database generation, and SAVAN database generation. The menus for database viewer provide the functions of graphical review of test database, RCCA database, and SAVAN database. Fig. 5 and Fig. 6 show the database manager window and database viewer window, respectively. User can generate the log file and database file, edit the skeleton and assembly test result files, perform the SAVAN2D analysis for RCCA drag force calculation, and generate the database for test simulation, RCCA drag force simulation, and core simulation using the database manager window. User can use the program to select interesting evaluation item, to select interesting row or column, to select one or more assemblies for the generation of graph, to select the time step, to select the axial elevation by grid number, and to select the zoom rate.

The SAVAN2D analysis results can be evaluated using the SAVAN2D_Postprocessor program for the skeleton and fuel assembly lateral stiffness test simulation, RCCA drag force simulation, and fuel assembly in-core behaviour simulation.

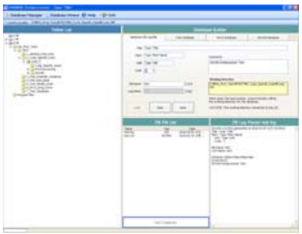
Fig. 5. Database Manager

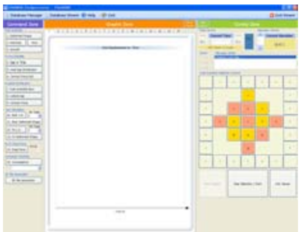
Fig. 6. Database Viewer

The comparison graph between SAVAN2D analysis results and test results for the load-deflection characteristics and deformed shape of the skeleton and fuel assembly can be generated as shown in Fig. 7 and Fig. 8, respectively.


Fig. 7. Load-Deflection

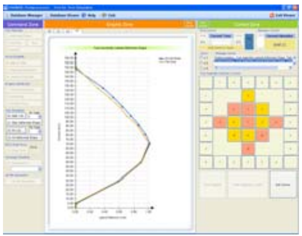
Fig. 8. FA Deformed Shape

The RCCA drag force distribution for the RCCA location in the core and RCCA deformed shape for each RCCA can be generated as shown in Fig. 9 and Fig. 10, respectively.


Fig. 9. RCCA Drag Force


Fig. 10. RCCA Deformed Shape

The fuel assembly deformed shape and growth can be displayed for each fuel assembly or for each row or column. The grid displacement vs. time graph can be generated for each fuel assembly. The assembly-to-assembly and assembly-to-baffle gap vs. time graph can be generated for each row or column. The axial gap and contact force distribution can be displayed for each row or column. The graphs for the in-plane distribution of fuel assembly bow, fuel assembly gap, and contact force can be generated for each grid elevation of the core.

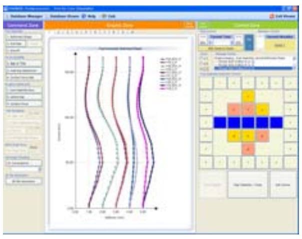
Fig. 11. Axial Bow


Fig. 12. In-Plane Bow

Fig. 11 and Fig. 12 show the axial distribution and in-plane distribution of the fuel assembly bow for the selected row, selected grid elevation, and selected time.

4. Applications

The SAVAN2D pre-processing and post-processing program can be utilized for the fuel assembly dimensional stability assessment in the early stage of new fuel assembly design development. The fuel assembly design modifications including holddown spring force optimization, stiffening the guide thimble dashpot region, implementing a new structural material, and increased skeleton stiffness can be potential corrective actions based on the fuel assembly bow analysis results using SAVAN2D code. The skeleton and fuel assembly design modification can be done based on the skeleton and assembly stiffness simulation and in-core simulation results. The potential for the IRI can be assessed based on the fuel assembly bow analysis results. The program can be used to assess the design change efficiency to control the fuel assembly bow and reduce the potential for IRI events. The fuel assembly bow and RCCA drag force distribution in the core need to be evaluated based on the SAVAN2D analysis results. A core loading pattern analysis can be done from a mechanical point of view to reduce the potential for IRI. Based on the mechanical evaluations of different loading patterns, core loading pattern optimization can be performed. The fuel assembly bow analysis results also can be used for the fuel loading and unloading sequence optimization to reduce the plant overhaul time.

5. Conclusion

The SAVAN2D pre-processing and post-processing program development results and its application areas are presented. The program can be utilized for the fuel assembly dimensional stability assessment, fuel assembly design modification, RCCA drag force evaluation, and core loading pattern optimization.

Acknowledgement

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