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Thermo-mechanical Analysis for the Ductless Assemblies

Byoung Oon LEE, Tae Young SONG
Korea Atomic Energy Research Institute, Yusung, Daejeon 305-600, Korea

1. Introduction

The objective of the thermo-mechanical analysis of the assemblies is to ensure that the distortions, loads and reactivity changes which occur when a core heats up and/or is irradiated are within design limits.

The CRAMP code is designed to solve the problem of mutually interacting and distorting sub-assemblies in a fast reactor. The CRAMP code is developed for the assemblies with a duct. So it is not possible to directly analyze the thermo-mechanical behavior for the ductless assemblies.

The stiffness model for an application of the ductless assemblies to an HYPER core were developed in order to evaluate the preliminary thermo-mechanical behavior of the ductless core. The preliminary bowing analyses were performed by CRAMP.

2. Methods and Results

In this section, the stiffness model for the ductless assembly, the stiffness for the CRMAP input, the thermo-mechanical analysis for HYPER are described.

2.1 Stiffness Model for the Ductless Assembly

The ductless assemblies are being considered for the HYPER fuel assembly, so the establishment of the stiffness model is required for the thermo-mechanical analysis[1].

Stiffness model on an application of the ductless assemblies to an HYPER core were developed. The stiffness of the ductless assembly and the grid spacers were calculated by ANSYS.

It is assumed that the contacts between assemblies occurred at the gird spacers. The staggered wave beam grid was selected because of the characteristics of a low pressure drop. Figure 1 shows the array of the fuel rods within the staggered wave beam grid.

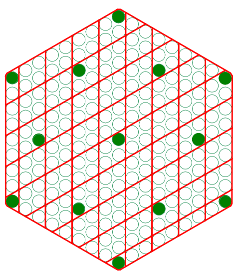
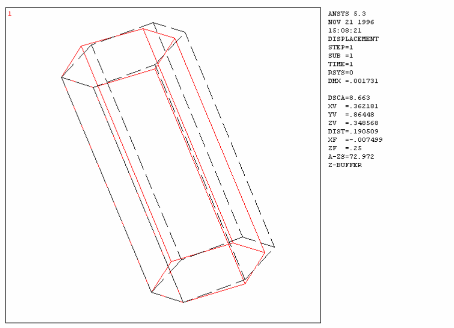
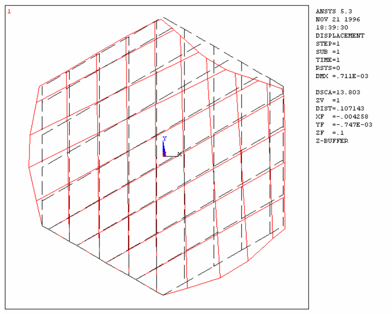


Figure 1. Array of the fuel rods within the assemblies

The three kinds of the stiffness of the grid spacer were derived, because the stiffness of the grid spacer were different according to the direction. The stiffness of the tie rod were derived according to the length of a tie rod. Figure 2 shows the results of the calculated stiffness of the ductless assembly.



(a) stiffness of the ductless assembly



(b) stiffness of the gird spacers

Figure 2. Calculated stiffness by ANSYS

2.2 Stiffness for the CRMAP Input

The CRAMP code is developed for the assemblies with a duct[2]. So it is not possible to directly analyze the thermo-mechanical behavior for the ductless assemblies.

The stiffness of the duct type assembly was evaluated by ANSYS, so the thicknesses of the duct equivalent to the stiffness of the ductless assemblies were derived.

Figure 3 shows the calculated stiffness of the duct type assembly by ANSYS.

It was estimated that the bowing stiffness of the ductless assembly was around 1/5 to 1/10 of that of the duct type assembly. The stiffness of the grid spacers was around 3 times larger than that of the load pad of the duct type.

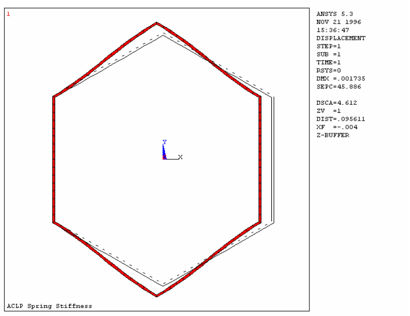


Figure 3. Stiffness of the duct type assembly

Table 1 shows the input thickness for CRAMP according to the conditions of the ductless assemblies.

Table 1. Input thickness for CRAMP

Conditions of ductless assembly	Thickness for the input of CRAMP
Axial length of the tie rod - 30cm - 50cm	 1.73 mm 1.40 mm
Grid spacer	3 mm

2.3 Thermo-mechanical analysis for HYPER

The high neutron fluxes and operating temperatures associated with a fast reactor are inducing the important radiation damage phenomena, which can cause significant dimensional changes in the core components of the reactor. These dimensional changes challenge the integrity of the assembly and the safety of the core. The thermo-mechanical analysis of the assembly are mainly performed to evaluate (1) change of reactivity, (2) force at pads on core assemblies, (3) withdrawal force at refueling, (4) loading and refueling deviation of assembly, and (5) bowing modes for control assembly[3].

In this paper, the bowing and the contact loads were analyzed by the updated CRAMP inputs with the characteristics of the ductless assembly.

Figure 4 shows the bowing modes of the HYPER core in case of 1mm of the grid spacer gap. The bowing of the assemblies contributes to the overall reactor thermal reactivity coefficient and the contact loads.

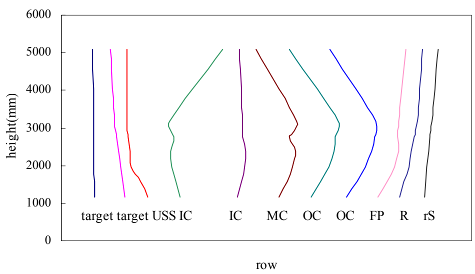


Figure 4. Bowing modes of the HYPER core.

In case of 1mm of the grid spacer gap, it was estimated that the maximum displacement was about 3mm, and the maximum contact load was about 0.7 kN at the above core grid spacer.

The contact loads between assemblies by the bowing effects were small through core cycles.

In case of 0.2 mm of the grid spacer gap, the maximum displacement was about 2mm, but the maximum contact load was about 2.1 kN at the above core grid spacer. The reverse bowing at the middle region also occurred by the large contact loads. It was expected that 0.2mm of the grid spacer gap was not conservative for satisfying the integrity of the assemblies by the thermo-mechanical behavior.

It is expected that the concept of the ductless assemblies can be applicable to HYPER core in case of 1mm of the grid spacer gap.

3. Conclusion

The stiffness model for the ductless assemblies were developed. The stiffness for the CRAMP input was derived by ANSYS. The bowing stiffness of the ductless assembly was lower than that of the duct type assembly. The stiffness of the grid spacers was larger than that of the load pad of the duct type.

Thermo-mechanical analysis for HYPER core was performed by the CRAMP code. The grid spacer gap between the assemblies was preliminary driven for keeping the lower contact loads. It was expected that 1.0mm of the grid spacer gap was conservative for satisfying the integrity of the assemblies by the thermo-mechanical behavior.

There are lots of the challenge on the thermo-mechanical analysis such as the change of the reactivity, so more sensitivity analyses are needed for clarifying the thermo-mechanical behavior.

Acknowledgements

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