Design of the Flow Plates for a Dual Cooled Fuel Assembly

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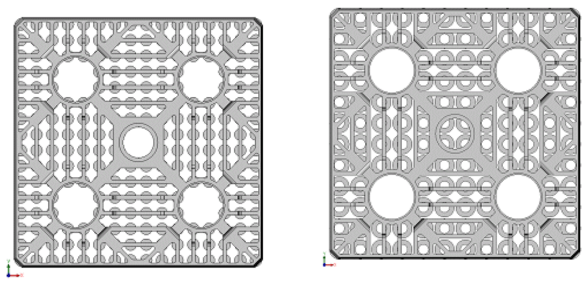
1. Introduction

In a dual cooled fuel assembly, the array and position of fuels are changed from those of a conventional PWR fuel assembly to achieve a power uprating. The flow plate provides flow holes to direct the heated coolant into/out of the fuel assembly and structural intensity to insure that the fuel rod is axially restrained within the spacer grids. So, flow plates of top/bottom end pieces (TEP/BEP) have to be modified into proper shape. Because the flow holes' area of a flow plate affects pressure drop, the flow holes' area must be larger than/equal to that of conventional flow plates. And design criterion of the TEP/BEP says that the flow plate should withstand a 22.241 kN axial load during handling lest a calculated stress intensity should exceed the Condition I allowable stress [1]. In this paper, newly designed flow plates of a TEP/BEP are suggested and stress analysis is conducted to evaluate strength robustness of the flow plates for the dual cooled fuel assembly.

2. Flow plates for dual cooled fuel



(a) with conventional 16x16 array　　(b) with 12x12 array of dual cooled fuels

Fig. 1 The conventional flow plate of a top end piece.

Fig. 1 shows a conventional flow plate of TEP overlapped with the conventional 16x16 and current 12x12 dual cooled fuels. In the case of a dual cooled fuel assembly, diameter of each fuel rod is much larger than the conventional fuel rod and an internal flow passage is formed in the center of a fuel rod. Some flow holes block the flow passage of coolant when the conventional flow plate is just used. Therefore, a flow plate of TEP must be designed for a dual cooled fuel assembly. Fig. 2 is a newly designed flow plate of TEP. The flow holes' area is increased about 0.7 % than the conventional one. Through Fig. 2, inner/outer flow passages of dual cooled fuel rods are exactly aligned with the flow holes of the newly designed flow plate.

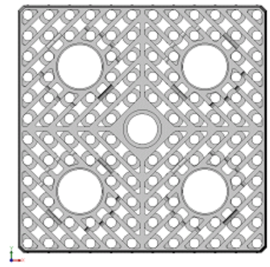
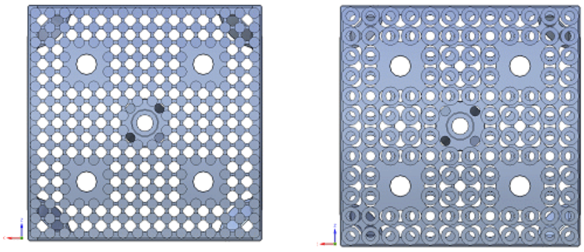


Fig. 2 Newly designed flow plate of a top end piece overlapped with a dual cooled fuel assembly.



(a) with conventional 16x16 array　　(b) with 12x12 array of dual cooled fuels

Fig. 3 The conventional flow plate of a bottom end piece.

Fig. 3 shows a conventional flow plate overlapped with the conventional 16x16 and current 12x12 dual cooled fuels. Some flow holes of the conventional flow plate block the flow passage of coolant as found in the case of TEP. Therefore, the flow plate of BEP should be developed for a dual cooled fuel assembly. Fig. 4 is a newly designed flow plate of BEP. The flow holes' area is increased about 6.5 % than the conventional one.

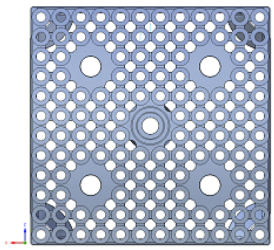
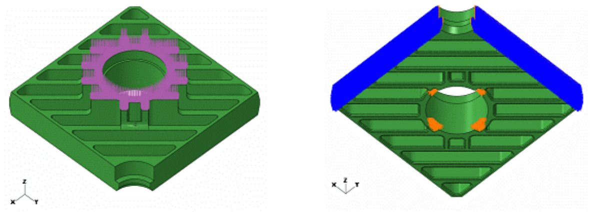


Fig. 4 Newly designed flow plate of a bottom end piece overlapped with a dual cooled fuel assembly.

3. Robustness evaluation of flow plates

Newly designed flow plates of TEP and BEP should sustain the axial handling load of 22.241 kN. Finite element analysis was performed to investigate whether the new design satisfies this criterion or not. A commercial finite element code ABAQUS/Standard

V6.8-1 [2] was used. Static analysis is conducted. Because the flow plates of TEP/BEP are made of 304 stainless steel, Young's modulus and poison's ratio are 193E+03 MPa and 0.29, respectively. And yield stress is 215 MPa. Figs. 5 and 7 show finite element models, loading and boundary conditions in the case of TEP/BEP, respectively.



(a) Loading conditions (-z dir.)   (b) Boundary conditions

Fig. 5 Analysis model for a flow plate of a top end piece.

Because the flow plate of TEP is a symmetry model about the x and y axis, a 1/4 model is used. Load is applied along the – z direction as a pressure.

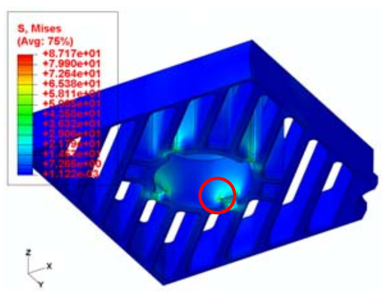
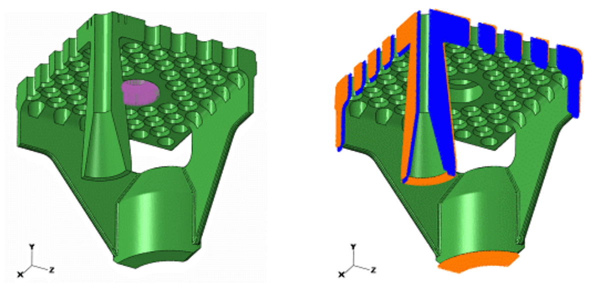


Fig. 6 Analysis results for a flow plate of a top end piece (unit: MPa).

Fig. 6 shows the Von-Mises stress in the case of a TEP's flow plate. Circular mark indicates the position of maximum Von-Mises stress. This stress is less than yield stress. Safety factor is about 2.5.



(a) Loading conditions (-y dir.)   (b) Boundary conditions

Fig. 7 Analysis model for a flow plate of a bottom end piece.

Because the flow plate of BEP is a symmetry model about the x and z axis, a 1/4 model is used as well. Load is applied along the – y direction as a pressure.

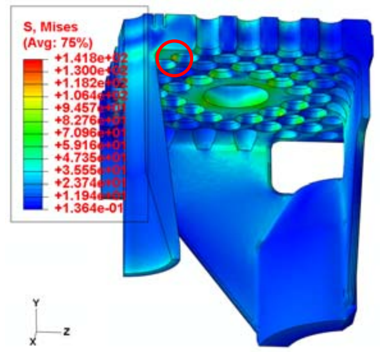


Fig. 8 Analysis results for a flow plate of a top end piece (unit: MPa).

Fig. 8 shows the Von-Mises stress in the case of BEP's flow plate. Circular mark indicates the position of maximum Von-Mises stress. This stress is less than yield stress. Safety factor is about 1.5.

4. Conclusion

Proper shapes of the flow plates of TEP/BEP for a dual cooled fuel assembly were designed to minimize a flow blocking. Since the flow holes of the newly designed flow plates are exactly aligned with the inner/outer flow passages of a dual cooled fuel assembly. Also, the flow holes' area is increased so that these shapes could guarantee a less pressure drop. And the fact that the new designs satisfy the stress limit criteria is confirmed by a FE static analysis. Finally, these designed flow plates have enough strength under the conditions of axial handling loads.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Hyung-Kyu Kim, Kyung-Ho Yoon, Young-Ho Lee, Jae-Yong Kim and Kang-Hee Lee, Conceptual Design of Structural Components of a Dual Cooled Fuel, KAERI/TR-3522/2008, 2008.
[2] H.D. Hibbit, G.I. Karlsson and E.P. Sorensen, ABAQUS Analysis User's Manual(version 6.8-1), 2008.