Dynamic Characteristics of a Modified Fuel Channel

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1. Introduction

The dynamic characteristics of a modified fuel channel have been analyzed by using a finite element method and the possibility of a resonance between the fuel channel and the pressure fluctuation of a coolant which originates from the coolant pump has also been assessed.

In ref. [1], the dynamic characteristics of the originally designed fuel channel were presented. There was a need to modify the fuel channel to fit with the change of the inner structures of the reactor. Accordingly, two types of modified fuel channels were newly designed. One considered the slot on the hanger shroud tube in order to guide the control element assembly (CEA) rod through the slot. The other implemented the HJTC instead of the shielding plug to measure the water level in the reactor. Considering these design changes, it was necessary to analyze the dynamic characteristics of the modified fuel channels to see whether the resonance occurs or not.

The analysis for the slotted fuel channel has been performed for three kinds of fuel channels (Type A, Type B and Type C), and for the HJTC fuel channel it has been done for only 'Type A' under the in-water surrounding condition (temp.=310^0C).

2. FE modeling of fuel channels

A fuel channel (FC) can be modeled as a beam structure because the length of the FC is much greater than its cross-sectional diameter. Therefore, the FC was modeled by using the beam3 element of the ANSYS code and the mass of a FC was calibrated by using the mass21 element. In order to analyze the dynamic characteristics of the FC using the beam3 element, the modified FCs were divided by 24 regions for the slotted FC and 20 regions for the HJTC FC according to their geometric shape. Then, the geometric data of each region such as the cross-sectional area, second moment of the inertia were calculated and the material properties and added mass were also determined.

3. Modal analysis of modified fuel channels

The modal analyses of the modified FC were carried out for three kinds of fuel channels 'Type A', 'Type B', and 'Type C' in the case of the slotted FC and for the 'Type A' only in the case of the HJTC FC. Here, FC type was classified according to their fuel assemblies which comprised of different fuel configuration. Six different boundary conditions were applied to each case; 'clamp-clamp', 'clamp-simple', 'clamp-free', 'simple-clamp', 'simple-simple', and 'simple-free' at both ends of the FC.

Tables 1 and 2 show the modal analysis results of the slotted FC 'Type A' and HJTC FC 'Type A'. Two modified FC have the similar dynamic characteristics and the first four modes take more than 90 % of the cumulative mass fraction.

The peak frequency of the pressure fluctuation of the flow originating from coolant pump was expected to have 3 peak values. Figures 1 and 2 show the natural frequencies of the slotted FC 'Type A' and 'Type B', respectively, with the 3 peak frequencies of the pressure fluctuation. The first mode frequencies, which are the most dominant modes, are much lower than that of the pressure flow so a resonance between the modified FC and the pressure flow is not expected.

Fig. 3 summarizes the results of the slotted FC for the boundary conditions of 'clamp-simple' and 'simple-simple' because they are more similar to the real FC situation from among the six kinds of the boundary conditions. As can be seen in Fig. 3, it is expected that there would be no resonance between the slotted FC and the pressure flow.

Fig. 4 shows similar results for the HJTC FC. Fig. 5 compares the modal analysis results with the originally designed FC and the HJTC FC. The natural frequencies for the HJTC FC are higher than those for the original FC because the mass reduction effect of the HJTC FC is much greater than the stiffness reduction effect.

Table 1 Modal Analysis Results of the slotted FC 'Type A' - Mode participation factor, and Cumulative mass fraction.

Mode	clamp -clamp	clamp -simple	clamp -free	simple -clamp	simple -simple	simple -free
1	1.000 0.701	1.000 0.794	1.000 0.752	1.000 0.741	1.000 0.847	1.000 0.455
2	0.024 0.701	0.016 0.795	0.377 0.859	0.017 0.749	0.004 0.847	0.747 0.708
3	0.459 0.849	0.375 0.906	0.262 0.911	0.420 0.880	0.333 0.941	0.413 0.786
4	0.008 0.849	0.024 0.907	0.186 0.937	0.054 0.882	0.004 0.941	0.421 0.867
5	0.322 0.921	0.000 0.907	0.161 0.956	0.278 0.939	0.198 0.974	0.280 0.902

Table 2 Modal Analysis Results of HJTC FC 'Type A' - Mode participation factor, and Cumulative mass fraction.

Mode	clamp -clamp	clamp -simple	clamp -free	simple -clamp	simple -simple	simple -free
1	1.000 0.709	1.000 0.766	1.000 0.671	1.000 0.770	1.000 0.840	1.000 0.452
2	0.066	0.120	0.460	0.037	0.065	0.764

	0.712	0.777	0.812	0.771	0.844	0.715
3	0.457 0.860	0.400 0.900	0.345 0.892	0.401 0.896	0.338 0.940	0.436 0.801
4	0.041 0.861	0.078 0.904	0.218 0.924	0.026 0.896	0.041 0.941	0.418 0.880
5	0.309 0.929	0.250 0.952	0.203 0.952	0.262 0.949	0.199 0.974	0.277 0.914

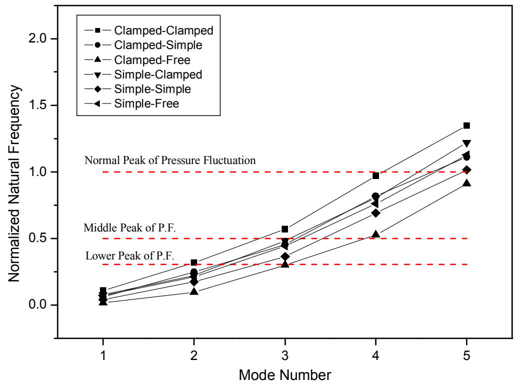

Figure 1 Natural frequencies of the slotted FC 'Type A' fuel channel in water with peak frequencies of the pressure flow.

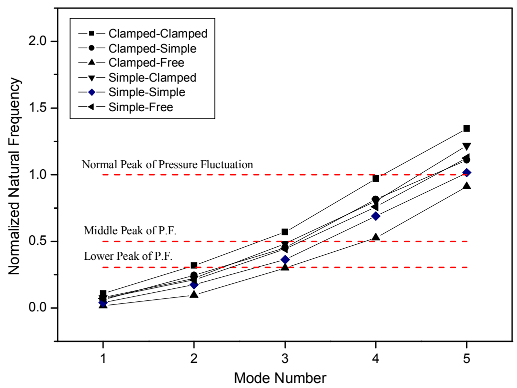

Figure 2 Natural frequencies of the slotted FC 'Type B' fuel channel in water with peak frequencies of the pressure flow.

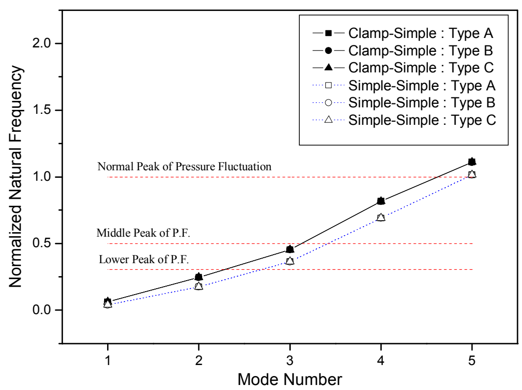

Figure 3 Natural frequencies of the slotted FC with the "Clamp-Simple" and "Simple-Simple" boundary condition.

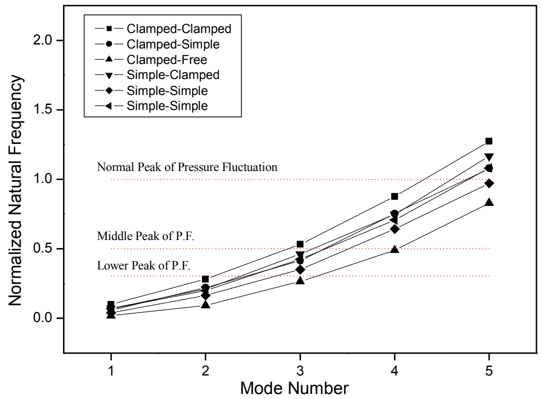

Figure 4 Natural frequencies of the HJTC FC 'Type A' fuel channel in water with peak frequencies of the pressure flow.

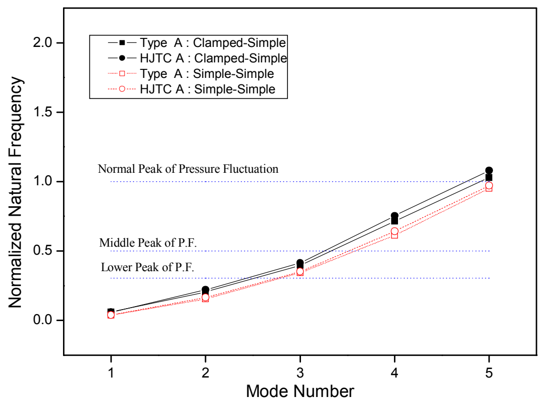

Figure 5 Comparison of the natural frequency results of the original FC and HJTC FC.

4. Conclusion

The dynamic characteristics of modified fuel channels have been analyzed by using the finite element method and the possibility of a resonance between the modified FC and pressure fluctuation has been evaluated.

From the analysis results, it was found that there would be no problem from the resonance point of view between the modified FC and the pressure fluctuation.

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REFERENCES

[1] J.Y. Jung, J.S. Yim and D.S. Shon, "Analysis of the Dynamic Characteristics of a Fuel Channel", 2005 KNS Fall Meeting, Pusan, 2005, 10.