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Parametric Analysis of Protective Grid Flow-induced Vibration

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1. Introduction

Protective grid (P-grid) flow-induced vibration in a nuclear power reactor is one of the critical factors for the mechanical integrity of a nuclear fuel. The P-grid is located at the lower most position above the bottom nozzle of the nuclear fuel as shown in Fig. 1, and it is required for not only filtering debris, but also supporting fuel rods.

On the other hand, P-grid working conditions installed in a nuclear fuel in a reactor are severe in terms of flow speed, temperature and pressure. Considering such a severe condition of P-grid's functional performance in working environment, excessive vibration could be developed. Furthermore, if the P-grid is exposed to high levels of excessive vibration over a long period of time, fatigue failure could be unavoidable [1].

Therefore, it is important to reduce excessive vibration while maintaining P-grid's own functional performance. KEPCO Nuclear Fuel has developed a test facility - Investigation Flow-induced Vibration (INFINIT) - to study flow-induced vibration caused by flowing coolant at various flow rates [2].

To investigate specific relationships between configuration of P-grid and flow-induced vibration characteristics, several types of the P-grids were tested in INFINIT facility. And, based on the test results through parametric studies, the flow-induced vibration characteristics could be analyzed, and critical design parameters were found.

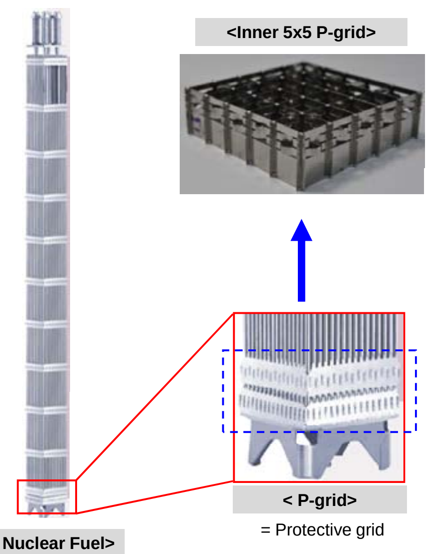


Fig. 1. General Position of P-grid in a Nuclear Fuel

2. Configurations of the Test Models

Fig. 2 shows configurations of the one strap cell of the test models. These specimens were developed for improving P-grid functional performance, and designed for KSNP, WH 16 and WH 17 fuel types, separately. Since these existent several kinds of P-grid, the sizes of the specimen and test configurations are little different. The specimens were manufactured into 5x5 grid structure for inserting test housing in INFINIT facility, and these were carried out at a range of flow velocity between from 10 ft/s to 25 ft/s including in-core velocity. The measurement points were three for each strap; such as upper, middle and lower location in the strap.

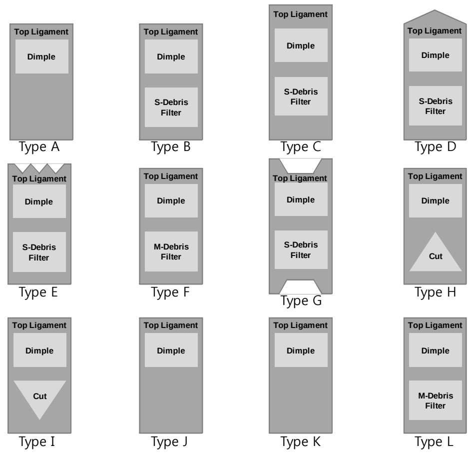


Fig. 2. Test Models

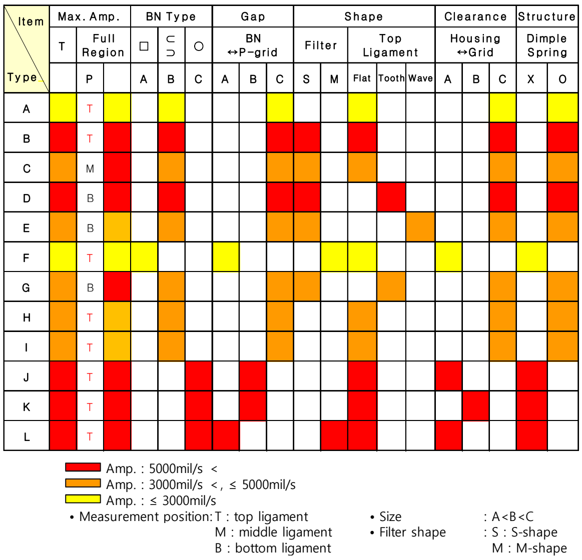
3. Parametric Analysis

To investigate characteristics of the excessive amplitude caused by flow-induced vibration, 12 model's results were tabulated in Table I. The data of Table I was sorted by top ligament base because it has dominant appearance of the flow-induced vibration in the P-grid entire region. And, each item on the Table I was categorized based on the type of the P-grid strap and its assembled structure configurations.

The data was roughly classified with 3 colors in accordance with magnitude of strap vibration.

- Yellow : $A \leq 3000$mil/s
- Orange: $3000\text{mil/s} < A \leq 5000$mil/s
- Red : $5000\text{mil/s} < A$

Table 1. Parametric Studies for Flow-induced Vibration in INFINIT



Base on the test results, it is analyzed that three main factors are related to excessive vibration of P-grid.

The first factor is related to maximum vibrated position on the strap. From the tests, tendencies of maximum amplitude are commonly seen to appear at the top ligament region (Point 3) such as in Fig. 3. The reason is analyzed that vortex shedding effect are mostly affected to excessive vibration at the edge of the strap. Since, it could lead to resonance at high frequency ranges. So, the excessive vibration could be occurred.

Fig. 3. Measurement Position of P-grid

The second factor is related to shape of top ligament edge. Also, it can be thought of a continuation of the first design factor. The results of Table I explain that the models have certain inclined angle of the top ligament edge region show lower levels of vibration amplitude than that of flat edge. It is analyzed that inclined edge region of the top ligament could potentially disperse and widen the vortex-shedding frequency range. So, the coincident vortex shedding and natural frequency that causes excessive vibration could be disturbed.

The third factor is related to bottom nozzle configurations. Especially, hole size and position in bottom nozzle have mainly influence on vibration amplitude. The coolant passes through a small hole in the bottom nozzle as shown in Fig. 4, the coolant flow might become a jet stream. If this jet is emitted with high speed into the center of P-grid ligament, flow-induced vibration with excessive amplitude could be generated. So, it could be expected for design aspects that when the hole size is larger and center position of ligament is avoided from the centerline of the hole, the vibration level of amplitude might be smaller.

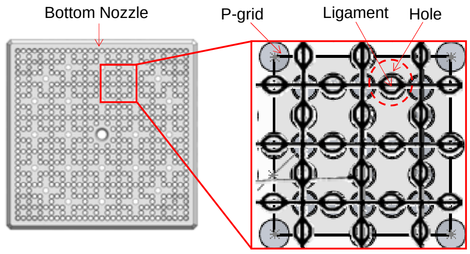


Fig. 4. Position of P-grid Ligament and Small Hole in Bottom Nozzle

4. Conclusions

Through the parametric analysis, the models were compared and analyzed in terms of structural design and its performance. In consequence of these studies, three factors causing excessive vibration of the P-grid are discussed. To reduce excessive vibration, the designs related with three factors should be considered. In the future work, it is required to study additional tests about these design factors, and investigate P-grid flow-induced vibration.

ACKNOWLEDGEMENTS

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