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Effect of Top Ligament Blanking on Reducing Flow Induced Vibration of Protective Grid

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1. Introduction

The protective grid is a Inconel 718 spacer grid located just above the bottom nozzle in many kinds of fuel assemblies for PWR. The purpose of using protective grid is to capture debris before they flow up into the fuel assembly and get trapped by the other grids causing fuel rod damages as well as to provide support at the lower end plugs of fuel rods.

Recently, it has been reported that strap failure has occurred in the protective grids and the flow induced vibration of the strap has resulted in the strap fatigue failure [1]. After the root cause of the protective grid failure was found to be the flow induced vibration of the strap, KEPCO NF has made an effort to find the vibration tendencies of grid strap and draw vibration mitigation concepts of the protective grid strap.

The vibration tendency and the effect of the vibration mitigation concept of the protective grid which have been found by the results of the loop tests and simulations in KEPCO NF are presented herein.

2. Flow Induced Vibration of The Protective Grid

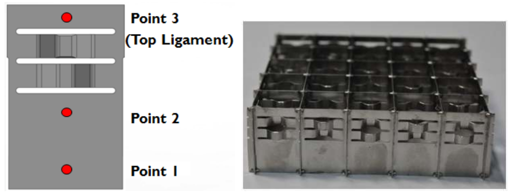
In this section, some of the protective grid flow induced vibration test results and analysis results simulating vortex shedding of protective grid strap are presented.

2.1 Flow Induced Vibration Test Results

The flow induced vibration of spacer grid strap is caused by the vortex shedding off of the strap edges. The vortex shedding frequency of the grid strap is very high when compared to the fuel assembly.

INFINIT loop tests were performed to investigate the tendencies of the protective grid strap high frequency vibration induced by the coolant flow. INFINIT is a flow test loop designed for flow induced vibration and pressure drop testing of a 5x5 small scale fuel assembly bundle under various flow rate conditions

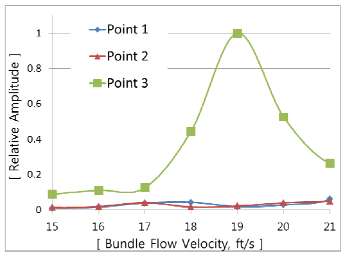
Three different kinds of protective grids were tested in the INFINIT loop at in-core flow velocity [2]. Fig. 1 (a) and (b) show the vibration measurement points of the protective grid strap and a 5x5 protective grid assembly feature which was installed in the test assembly.



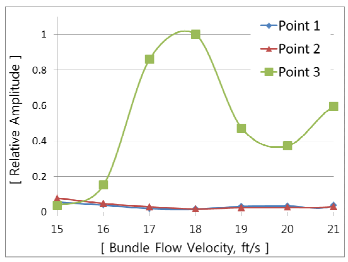
(a) Grid strap (b) 5x5 assembly

Fig. 1. Protective grid.

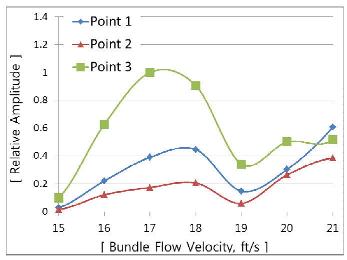
Fig. 2 (a), (b) and (c) show the relative vibration amplitudes of the each type of protective grids classified by the vibration detecting points.



(a) Type A



(b) Type B



(c) Type C

Fig. 2. Vibration amplitudes of protective grids.

From these test results, it was clearly found that the maximum flow induced vibration amplitude of the protective grids strongly tends to occur at the top ligament of the strap.

2.2 Flow Induced Vibration Simulation Results

A flow simulation was performed to investigate the flow field passing the top ligament of protective grid strap at in-core flow velocity using SolidWorks 2012 Flow Simulation program [3]. Fig. 3 shows the streamlines of the flow field around the flat top ligament of a typical protective grid. It is clear that the flow of the flat top ligament shows coincident flow pattern and vortex shedding along the entire trailing edge.

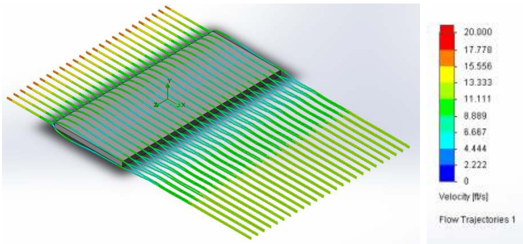


Fig. 3. Streamlines passing the flat top ligament.

Fig. 4 shows that relative peak vibration force occurs at a specific frequency. This accounts for the correlated vortices along the entire length of the strap trailing edge.

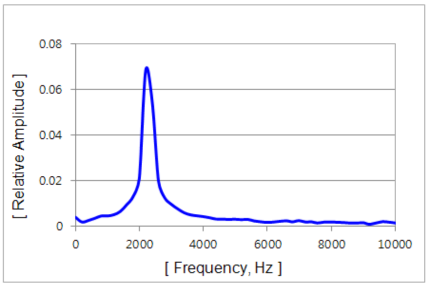


Fig. 4. Power spectral density of the vibration force on the flat top ligament.

3. Vibration Mitigation Concepts

To mitigate the flow induced high frequency vibration of the protective grid top ligament, the concept of blanking W shape slot in the top ligament was suggested.

A flow simulation was performed with the same flow conditions as that of the aforementioned flat top ligament case. Fig. 5 shows the streamlines of the flow field around the W shape blanked top ligament. The flow pattern and vortex shedding do not coincide along the trailing edge of the blanked top ligament.

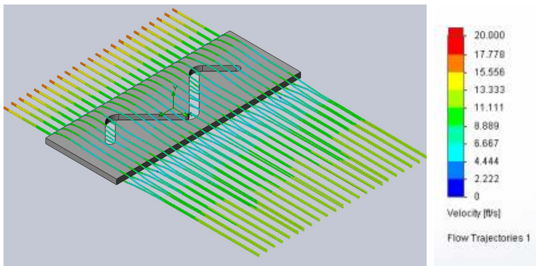


Fig. 5. Streamlines passing the blanked top ligament.

Fig. 6 shows that the relative frequency range is shifted widely, and the amplitude level is reduced to small values. This means that the blanked W shape slot in the top ligament of the strap has the remarkable effect on reducing the flow induced high frequency vibration of the protective grid. Based on these simulation results, several different kinds of blanking shapes have been drawn and will be simulated and tested to investigate the vibration mitigation effects with respect to their configurations.

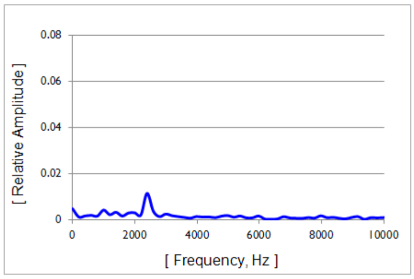


Fig. 6. Power spectral density of the vibration force on the blanked top ligament.

4. Conclusions

The flow induced vibration test and simulation results showed that the maximum vibration amplitude of the protective grid strongly tends to occur at the top ligament of the strap and the coincident vortex shedding along the top ligament trailing edge causes the peak vibration force at a specific frequency. A vibration mitigation concept of blanking W shape slot in the top ligament was suggested and simulated showing reduced vibration forces with widely shifted frequency range.

REFERENCES

[1] Paul M. Evans, Michael E. Conner, Roger Y. Lu, Investigation of Vibration Related Fractures in PWR Grids, 2011 Water Reactor Fuel Performance

[2] J. Y. Ryu, K. B. Eom, N. G. Park, I. K. Kim, Y. H. Kim, S. Y. Jeon and J. M. Suh, Flow Induced Vibration Test Results of the Various Nuclear Fuel Protective Grids in INFINIT Facility, 19th International Congress on Sound and Vibration, Vilnius, Lithuania, July 8-12, 2012.

[3] SolidWorks 2012 User's Manual.