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HIGH-FREQUENCY VIBRATION TEST ON PWR GRID STRAPS

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Abstract

Recently some commercial PWR nuclear power plants were experienced fuel rod fretting failure, if fuels are leaked it takes a lot of cost and irradiation exposure to operator for recover it. High frequency vibration is recently arising problem with low frequency fuel assembly vibration and medium frequency of fuel rod vibration. The High Frequency Vibration (HFV) testing was performed in the small-scale hydraulic test loop.

The Various grid assemblies are investigated using this loop test, in this paper discussed about high frequency vibration of various PWR grid straps. The specific three test results are presented in this paper, The reference 1 Model shows relatively high vibration magnitudes compare to Design A and Design B. Design B is recently developed fuel assembly, this Design B shows very low magnitude of vibration near the Nuclear Plant operation range.

New grid straps developed by KAERI team are planned to conduct high frequency vibration test using the small-scale hydraulic test loop by end of April 2004.

1.0 Introduction

Recently some commercial PWR nuclear power plants were experienced fuel rod fretting failure, if fuels are leaked it takes a lot of cost and irradiation exposure to operator for recover it. In this paper discussed about high frequency vibration of various PWR grid straps. High frequency vibration is recently arising problem with low frequency fuel assembly vibration and medium frequency of fuel rod vibration.

The High Frequency Vibration (HFV) testing was performed in the small-scale hydraulic test loop.

2.0 OBJECTIVE & TEST ASSEMBLIES

The objective of the small-scale Hydraulic testing is to investigate HFV and hydraulic characteristics of the various mid grids under flow conditions in the correct rod bundle geometry.

Specific objectives are listed below.

- Vibration frequency and amplitude measurements of grid strap and simulated fuel rods at in reactor flow rate
- Pressure drop measurements of test grids

The loop and test assemblies are designed to have 3 spans(400 mm span) of upstream flow field conditioning before the grid under investigation and 1 span of the appropriate downstream flow boundary conditions. Therefore, there are five mid grids required to be in the appropriate bundle flow field for this testing.

The test assemblies used in the loop are mini-bundles prototypical of the actual fuel assembly geometry. The actual dimensions (rod OD, rod pitch, grid strap details, etc.) are maintained, but the test assembly is of a smaller array size and is shorter than the actual fuel assembly geometry. The array tested are 5x5's. The height of the test assemblies are 2,000mm, with 1,700 mm in the bundle flow region.

The concept of the test assemblies for easy assembly and reuse of all components, including grids. Also, bundle fabrication and breakdown is done by hand with no need for special tooling or fixtures. There is no simulated bottom or top nozzles attached to the test assembly.

Each test assembly is made up of the following:

- 5 test mid grids (only inner straps tested), which are in the bundle flow region
- 1 support grid which is not in the bundle flow region
- hollow test rods, which are sealed with standard end plugs
- Instrumented rod (containing bi-axial accelerometer for HFV testing)

The rods are designed to fit with a minimal clearance between the flow straightener plate and the top plate in the loop. Four of the hollow test rods are designed with threaded end plugs on one end. These end plugs are designed to go through the top plate to hold the bundle from this plate if needed. Typically, no nuts are put on these end plugs, and they are used for alignment of the bundle with the test housing.

The instrumented rods are also designed with a threaded end plug on one end, with the instrument leads going out the other end. The instrumented rods are shorter than the other rods to allow clearance for the instrument leads to be directed through the top plate. The end plug fits through the flow straightener plate and a nut is attached to hold the accelerometer rod axially in the bundle. This prevents the rod from moving downstream during testing and crushing the instrument leads against the top plate. Note that the design of the instrumented rod is consistent with the Westinghouse design of instrumented rods for full-scale assembly loop testing, with modification made to the overall length of the rod and the change to the threaded end plug for the test.

To control the axial position of the grids in the flow conditions, pins perpendicular to the flow are inserted into 3 or 4 hollow corner test rods. These pins are located downstream of the top of the grid to hold the grid from moving downstream (i.e., vertically up the assembly) during the axial flow testing. In addition, on 2 of the corner rods, pins are also located upstream of the grid to aid in bundle fabrication and ensure proper location of the grids prior to testing.

3.0 TEST LOOP

The loop is a closed-loop, isothermal, room temperature, hydraulic test loop designed to provide the HFV and the pressure drop data under the vertical flowing condition.

The major features of the loop includes a tank located 300mm off of the floor, a 50 hp single-speed pump, a variable frequency pump drive, a turbine flow meter, and lexan flow housings mounted to a rotatable frame. The tank, which is open to the atmosphere, defines the highest water level for the loop, thus setting the water head on the system. By having a loop open to atmosphere, the pressure in the system is minimized since the only adder to hydraulic pressure losses is the static water head, which is small. This meets a design objective of minimizing the pressure load in the lexan flow housing, which is the weakest member of the entire loop. Note that the rupture disc prevents inadvertent over-pressurization of the system with a maximum limit of 100 psig.

Another design feature to minimize stress on the lexan flow housing is the use of flexible piping pieces, one just prior to the tee and another connected to the outlet tee. This flexible piping takes the misalignment between the piping and the flow housing/frame assembly. These features are effective as the misalignment can be seen in both flexible pieces.

The loop piping is mostly 400mm PVC, including valves and tees. The piping and components (valve, tees) connecting the pump exit to the inlet tee are made of stainless steel. These stainless components, which have shorter axial lengths than corresponding CPVC components, were used due to linear space limitations in this region.

Loop Operation

Loop flow is controlled by the variable frequency pump drive a remote dial located at the loop. Note that loop flow can also be controlled at the variable frequency drive using the control panel. The remote dial is set to give the required flow as indicated by the rate indicator of the flow meter. The rate indicator shows the flowrate in gpm. The bundle velocity is determined from the total loop gpm by a direct calculation using the bundle flow area. Note that the bypass valve must be closed to ensure that the flowrate through the test housing is the known total flowrate from the rate indicator.

Pump heat is the only source of heat addition to the system. To control this heat input and keep the loop temperature in the preferred testing range, a heat exchanger in the tank using plant chilled water at approximately 10 °C is available.

Flow Housing

The flow housings for the loop are all made using the same design concept. The flow housing is a bolted lexan assembly which is designed to provide the appropriate cross-section for the gridded rod bundle, withstand the pressure loads resulting from the required high velocity testing, and provide the appropriate flanges for connection to the loop. A typical housing is made of four 25.4 mm thick walls, bolted together with a gasket running along the length in a groove to provide the appropriate seal. A 230mm circular flange (also 25.4mm thick) is bolted on each end of the wall assembly, with an appropriately cut flat gasket in between the flange and the walls.

Loop Configuration

The loop inlet piping is parallel to the wall behind the loop. The center of the vertical housing (from a top view) is lined up along the centerline axis of this horizontal inlet piping. The housing wall where the pressure taps are located X-axis, Y-axis, and Y-corner for the loop testing.

The lexan flow housing is attached to the loop using tees with 230 mm flanges. The flow housing/tee assembly is connected to a steel frame through these 230mm flanges for structural support. The steel frame is attached to a shaft and can be rotated to a horizontal position for loading and unloading of test assemblies.

4.0 TEST CONDITIONS & DATA ACQUISITION

The primary controlled parameter in the hydraulic testing is the bundle velocity. A bounding range of bundle velocities tested is 3,000mm/sec to 7,600 mm/sec, in increments of 300mm/sec.

Loop pressure is maintained below 60 psig in horizontal piping just upstream of the test section to protect the mechanical integrity of the lexan flow housings joints. Protection against over-pressurization of the loop is provided by the rupture disc, which is currently set to 100 psig. Note that for the loop operation, pressure increases with increasing loop flow. At 3,000 mm/sec, the loop pressure upstream of the test section is on order of 10 psig. The highest expected pressure in this region is 60 psig at 7,600 mm/sec.

Loop temperature is maintained at or near room temperature during testing. A range of 25° C to 30 °C as observed by the temperature gauge upstream of the test section is maintained while taking data. Due to pump heat input, the loop temperature could increase above 25 °C for expected testing. The heat exchanger in the tank is used to remove this added pump heat and maintain the loop temperature within the desired range.

High Frequency Vibration Testing

Various vibration data acquisition metoodes are used accelerometer (2 rod axes, 2 housing accelerometers), vibrometer(grid strap measurements) and acoustic measurements of the high frequency vibration, it will be made for the wide range of bundle flow velocities.

The high frequency vibration data is acquired at the 4th grid. This is the axial position for (1) the location of the bi-axial accelerometer in the instrumented rod, (2) the attachment holes for the housing accelerometers on the outer housing wall, (3) the position at which the microphone is held against the outer housing wall, and (4) the grid at which grid strap motion measurements are taken with the vibrometer.

Hydraulic Testing

Data will be recorded manually from loop instrumentation for the condition defined in former section. The data to be recorded is:

1. Bundle velocity
2. Loop temperature in the inlet piping if different that 25 °C
3. Pressure differential measurements from the pressure transducers

To obtain data, the following procedure is performed to ensure that:

1. The pressure transducers are ready to take data
2. The appropriate measurements are meet.

5.0 TEST RESULTS and CONCLUSIONS

The Various grid assemblies are investigated using High Frequency Vibration test loop, the specific three test results are presented in Figure. From this results reference 1 Model shows relatively high vibration magnitudes compare to Design A and Design B.
Design B is recently developed fuel assembly, this Design shows very low magnitude of vibration near the Nuclear Plant operation range.
New grid straps developed by KAERI team are planned to conduct high frequency vibration test at the test loop by end of April 2004.

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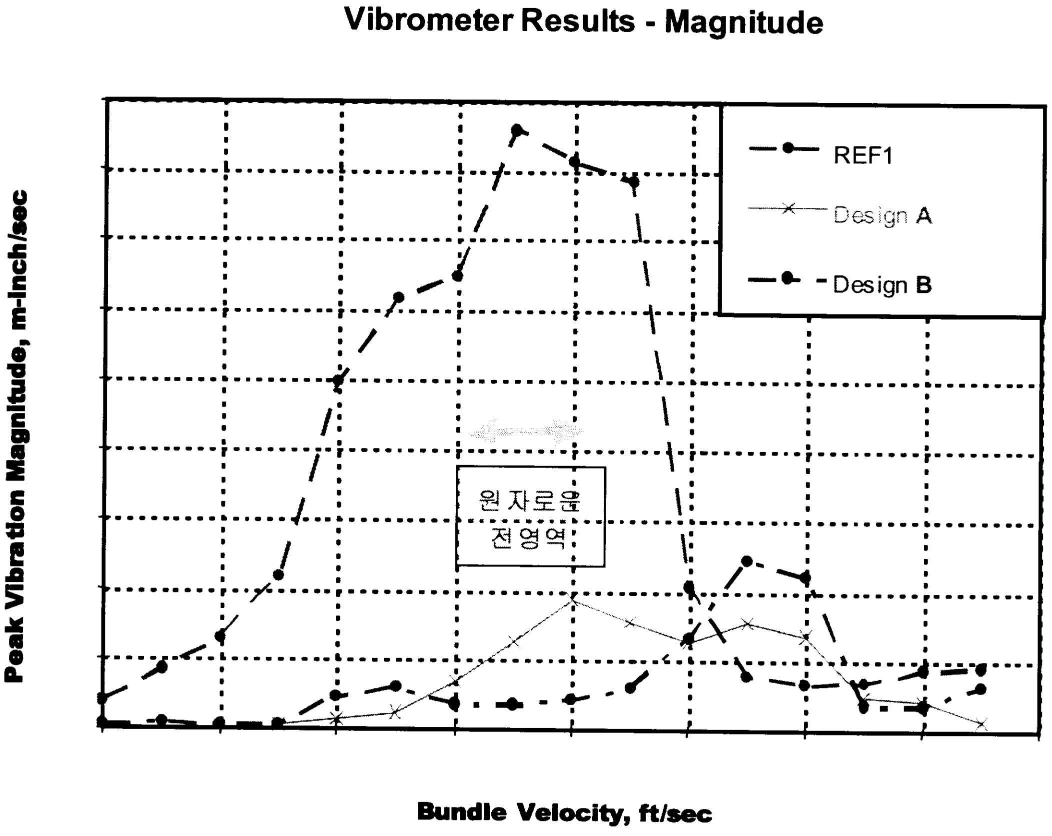

GRID STRAP HIGH FREQUENCY VIBRATION TEST RESULTS