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Materials Reliability Program: Evaluation of Controlling Transient Ramp Times Using Piping Methodologies When Considering Environmental Fatigue (F_{en}) Effects (MRP-218)

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REPORT SUMMARY

It has become necessary to develop a solution that establishes the most severe transient for design purposes when environmental fatigue rules are considered. This report details qualifying fatigue analyses that have been performed using piping methodologies to define controlling transient ramp times for a variety of piping geometry and material configurations. The intent of these analyses is to provide the component designer with a set of parametric tools that can be used to easily design components without the need for iterative fatigue analyses to determine the bounding conditions when environmental fatigue multiplier (F_{en}) rules are considered. The tool developed to perform the parametric analyses contained and described in this report is available for future designer use if more specific analyses are required.

Background

Previous MRP research supporting non-zero ramp times presents difficulties in both specifying values ahead of time and qualifying a component for appropriate ramp times. At the same time, it is important to avoid creating a situation whereby plant operations must proceed at a specified pace to remain design compliant. Qualifying fatigue analyses should cover all conceivable ramp times, such that the operator neither has to be limited to a minimum pace nor confirm through observations that the pace is at least as fast as assumed in the design. This MRP study evaluates controlling transient ramp times using piping methodologies, taking F_{en} into consideration.

Objective

To define bounding ramp times for a range of piping geometry and material configurations by performing qualifying fatigue analyses using piping methodologies.

Approach

Investigators developed and qualified a program (*RampRate.exe)* for performing the qualifying fatigue analyses to define bounding ramp times for a variety of geometry and material configurations. They then performed a parametric evaluation that varied all inputs to the final *RampRate.exe* program over a range of values expected to occur in plant design. They ran the program iteratively, varying all inputs to cover most expected plant conditions and configurations. A total of 2592 cases of *RampRate.exe* were run for each of two configurations: 1) a piping tee and 2) a piping girth weld. Finally, investigators plotted and tabulated the results of the parametric study for the piping tee and piping girth weld.

Results

This study concludes that

- The peak ramp times obtained for all solutions demonstrate that the slowest controlling transients are still in the range of 1°F/sec, or 3600°F/hour. Thus, there should be no concern about cooling reactor vessels too slowly.
- Although the results of the parametric evaluation are for a specific temperature range, 50-600°F, the results are expected to be similar for other temperature ranges within the range evaluated.
- Although the results of the parametric evaluation are based on piping methods, the results are expected to be similar for design by analysis, such as application of NB-3200 methods.

EPRI Perspective

The PWR Materials Reliability Program conducts research to improve fundamental understanding of materials performance in pressurized water reactors, and to develop technologies for early detection and mitigation of emerging issues. The analyses described in this report are particularly relevant to designing new plants with consideration of environmental effects on materials. The intent of these analyses is to provide the component designer with a set of parametric tools that can be used to easily design components without the need for iterative fatigue analyses to determine the bounding conditions when F_{en} rules are considered. It should be noted that this work was not completed under the EPRI Nuclear Quality Assurance Program.

Keywords

Materials Reliability Program
Transient Ramp Times
Piping Methodologies
Environmental Fatigue
Thermal Fatigue

6 CONCLUSIONS

This report describes qualifying fatigue analyses that have been performed to define bounding ramp times for a variety of geometry and material configurations. The intent of these analyses is to provide the component designer with a set of parametric tools that can be used to easily design components without the need for iterative fatigue analyses to determine the bounding conditions when F_{en} rules are considered.

The following conclusions are made with respect to the work documented in this report:

- A parametric evaluation was performed that varied all inputs to the final *RampRate.exe* program over a range of values expected to occur in plant design. The intent of this study was to obtain limiting ramp time results that designers could use to "look up" the limiting ramp time for the configuration and conditions under consideration. The program was iteratively run varying all inputs to cover most expected plant conditions and configurations. The results of the parametric study are shown in Appendices A and B, and can be used by designers to "look up" the limiting ramp time for the configuration and conditions under consideration.
- The peak ramp times obtained for all solutions demonstrate that the slowest transients that control are still in the range of 1°F/sec, or 3600°F/hour; thus there should be no concern about cooling reactor vessels too slowly.
- Although the results of the parametric evaluation are for a specific temperature range (i.e., 600°F to 50°F), the results are expected to be similar for other temperature ranges within the range evaluated.
- Although the results of the parametric evaluation are for piping methods, the results are expected to be similar for design by analysis (i.e., NB-3200) methods.
- For all cases of ferritic material (i.e., carbon and low alloy steel) on Side B of the joint with low DO levels, the traditional expectation of a step (i.e., zero ramp time) being limiting was obtained. This resulted in 864 cases (out of 2,592) being eliminated from the results for each of the two components evaluated (these cases are not included in Appendices A and B).

The tool developed to perform the parametric analyses, as well as all results associated with this report, are available from the author for future use by the designer should more specific analyses be required. See Appendix C for source code listing of *RampRate.for* and all associated input files.

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