RULES AND DIRECTIVES
BRANCH
USNRC

As of: June 03, 2014	
Received: May 30, 2014	
Status: Pending_Post	
Tracking No. 1jy-8cds-m5mm	
Comments Due: June 02, 2014	
Submission Type: Web	

PUBLIC SUBMISSION

2014 JUN -3 AM 9: 52

RECEIVED

Docket: NRC-2014-0023
Effect of LWR Coolant Environments on the Fatigue Life of Reactor Materials

Comment On: NRC-2014-0023-0001
Draft Guidance for Industry and Staff: Effect of LWR Coolant Environments on the Fatigue Life of Reactor Materials

Document: NRC-2014-0023-DRAFT-0003
Comment on FR Doc # 2014-08792

4/17/2014
79FR21811

Submitter Information

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Organization: Westinghouse Electric Company

(4)

General Comment

Please see attached file.

Attachments

LTR-NRC-14-26-WEC-NUREGCR6909

SUNSI Review Complete
Template = ADM – 013
E-RIDS= ADM -03
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LTR-NRC-14-26

May 29, 2014

Subject: Transmittal of Westinghouse Electric Company Comments on Draft NUREG/CR-6909, Revision 1, "Effect of LWR Coolant Environments on the Fatigue Life of Reactor Materials," Docket ID NRC-2014-0023

Dear Ms. Bladey,

Thank you for the opportunity to provide comments on draft NUREG/CR-6909, Revision 1, "Effect of LWR Coolant Environments on the Fatigue Life of Reactor Materials."

Please find enclosed the Westinghouse Electric Company (Westinghouse) comments on the draft NUREG/CR-6909, Revision 1. The comments are arranged by sections of the document, with page number references or figure numbers where deemed necessary.

For technical questions regarding the enclosed comments, please contact Mark Gray at 412-374-4602.

Very truly yours,

James A. Gresham, Manager
Regulatory Compliance

Attachment

bcc: James A. Gresham
Mark Gray
Cheryl Robinson
Anne M. Stegman
David Roarty
Thomas Meikle

Effect of LWR Coolant Environments on the Fatigue Life of Reactor Materials

Introductory Comment
There remains much industry discussion about the applications of factors on fatigue data to determine fatigue curves, the applicability of compounding factors, appropriate curves for the availability of data, etc. We support further investigation and development of these issues with respect to the material presented in this draft report, and encourage acceptance of alternatives as they are developed in industry programs. In light of this, we do not offer further comments on the metallurgical science presented in the report. The comments below are focused on the areas in the draft report that pertain to application of the Fen factors to the fatigue analysis.

Section 4.1.14 Modified Rate Approach

- This section seems to be out of place as a subsection of the Carbon and Low-alloy steel fatigue life behavior, as if it only applied to these materials. It would be better placed as Section 4.4 or in Appendix A.
- The section does not address the situation where the strain rate history is not continuously positive between the valley and the peak, as depicted in the ideal examples in the figures, and the impact of such situations on the denominator of Equation 49 for consistent calculation of Fen.
- The context of the introduction of equation 50 could lead the casual reader to conclude that a threshold can be used (i.e., the equation is appropriate), whereas the discussion that follows concludes the opposite (i.e., that only equation 49 should be used). Introductory wording that makes it clear that equation 50 is only hypothetical may be beneficial.
- Application of a strain amplitude threshold in the context of equation 50 should be distinguished from application of the threshold in general for a fatigue pair – i.e., the analyst should be able to apply Fen of 1.0 to pairs whose Salt corresponds to a strain amplitude within the threshold, precluding consideration of a strain rate method needed for the pair. (This comment may be more applicable to the notes in Appendix A that disclaim the use of threshold with modified rate.)
- Points (b) and (c) in this subsection seem to only be talking about application of the average strain rate approach, and not the modified rate approach application, and could be confusing to the reader with respect to their points. Perhaps the subsection should be re-titled and both approaches explicitly described, then addressed with the applicable points about the temperature recommendations for each approach.
- Point (b) concludes that "appropriate temperatures" should be selected for average strain rate calculations, after stating that maximum temperature is most conservative. Is this just a lead-in to point (c), or is the conclusion to use maximum temperature with average strain rate method? Please clarify what is discussion vs. recommendation.
- It is not clear if the conclusion of point (c) is intended for the average strain rate method or the modified rate method. It seems to be the former, since modified rate applications use an integration step that results in insignificant difference from using the average or maximum temperature in each step, as stated in its last sentence. Suggest separating what is recommended for temperature input to the average approach, and then for the modified rate approach.

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- Figure 81: Please check that the legend entries appropriately describe the quantities being represented by the lines on the graph, especially "Average Strain Rate", which would be expected to be one value over the interval.
- The single bullet occurring after Figure 81 seems to get lost. It appears, based on the comments above, that a number of recommendations about strain rate calculation using either average or modified rate should be made in conclusion of this subsection.

Appendix A, Section A2

- The final paragraph states that the maximum temperature limit of 325°C (617°F) is "adequate for all expected operating LWR conditions considering the use of average temperature." In the case of applying the modified rate approach, the integration over the strain history may include time steps for which the temperature over the interval is above 325°C (617°F). Is the statement intended to justify the use of the equation using the upper limit in the situation where the integration interval temperature is higher? Please clarify the intended application of this statement.

Section A3

- The text of the continued sentence after Table A.2 needs to follow equation A.19; it should not be separated by the figures and tables.
- Wording at the bottom of page A-5: "tensile stress producing portion of the stress cycle" is not consistent with the intent previously described as "increasing strain or stress". A compressive stress producing portion of the stress cycle may still exhibit increasing strain or stress, and vice-versa.
- Page A-6, item (2): What is the purpose of requiring a "linear temperature response" for this case? Is this the only case where an average strain rate and average temperature can be used?
- Page A-6, item (2): "the "average" temperature used ... **should produce results** that are consistent with ... modified rate approach" (emphasis added) – is this a statement of support for using average temperature as described, or is this a requirement that must be demonstrated for each evaluation? It seems to be the former, but this should be clarified considering the statements in Section 4.1.14 regarding the use of average temperature.

Appendix C, Section C2

- Page C-2: "The transients were linked in sequential order" – There is no sequence to transients in an ASME design analysis, or to those evaluated in this sample problem, as implied by this wording. The order may have been chosen based on anticipated transient pairings and methods of linking to obtain strain rate, but the subject of transient linking with respect to application of the modified rate approach is not addressed in this report. It is suggested that this be clarified and/or expanded.

Section C3

- Page C-8, point A and sub-point a. – "Table C.2" is not stress history; is the intended reference Table C.5 instead of C.2?

- Page C-8, point A and sub-point b: "maximum total stress" – expanded in step h to also include membrane plus bending stress.
- Page C-8, point A and sub-point h: suggest a reference back to step b to define "which case" to use for the extreme time to provide clarity.
- Page C-9: "Strain rates were calculated based on the total S'_{31} history which was the limiting CUF case." – Please consider clarifying with respect to the following :
    - If the principal stresses were ordered classically, S1>S2>S3, then S'31 is expected to control the CUF. It would also be expected to provide the maximum strain range over an interval.
    - If the principal stresses were not ordered classically, then this result and method may be unique for this example.
    - If there are any NRC expectations with respect to the principal stress difference history to be used for strain rate calculation, these should be clarified for general applications.
    - Until this sentence in Appendix C, a "case" has been associated with one of the stress quantity extremes described in step h. This sentence suggests that there were also principal stress difference "sub-cases" for each of the step h cases evaluated to determine the limiting CUF. If this is correct, please clarify how the principal stress difference sub-cases were used to determine the limiting CUF value and associated strain rate conditions. If this is not correct, please revise this sentence appropriately.
- Page C-9, A. Average Strain Rate Approach, sub-point ii:
    - The stress intensity range between the peak and the valley in the general case should be based on the stress component ranges as in NB-3216.2.
    - The basis for using E at the maximum temperature should be clarified, as well as any NRC expectation in this regard.
- Page C-9, A. Average Strain Rate Approach, sub-point iii: For the average strain rate approach, linking from valley to peak in each fatigue pair, it is not expected that strain rate should be less than zero. Please clarify this point.
- Page C-10, Average Strain Rate Approach, sub-point v: Assignment of Fen to "both the peak and the valley" is not clear, since Fen is determined for the whole stress range in the pair. Please clarify this point.
- Page C-10, A. Average Strain Rate Approach, point vi: Please see comment above on page C-2 "transient linking issue" with respect to the implied "stress intensity history". The history to be considered for each Fen should be between the valleys and peaks determined from the fatigue pairs formed in step f on page C-8, which is not necessarily the history implied by Figure C-5 in the general case. Therefore, this statement as presented in the context of this example could be misleading.
- Page C-10, B. Modified Strain Rate Approach, point ii: The stress intensity range between the time points in the general case should be based on the stress component ranges as in NB-3216.2.
- Page C-10, B. Modified Strain Rate Approach, point iii: It is not clear how setting Fen to 1.0 for intervals of negative strain rate provides a consistent integration over the complete strain range, with the denominator of the Fen integration equation being $e_{max} - e_{min}$. It would be helpful to provide the explanation for this.

- Page C-10, B. Modified Strain Rate Approach, point v: The numerator of the Fen-n equation does not agree with Equation 49, which uses delta-strain.
- Page C-10, B. Modified Strain Rate Approach, point vi: Assignment of Fen to "both the peak and the valley" is not clear, since Fen is determined for the whole stress range in the pair. Please clarify.
- Page C-11, B. Modified Strain Rate Approach, point vii: Please see comment above on Average Strain Rate Approach, point vi.

Section C4

- First paragraph: It could be inferred from the wording here that only the membrane plus bending stress was used in the fatigue evaluation. Suggest clarification that both membrane plus bending and total stresses were used.
- It would be helpful to address how the strain rate integration period was determined using Total Stress when the valley and/or peak time of the Total Stress did not correspond to the times selected based on the Membrane plus Bending stress difference.
- Table C.4: It would be beneficial to provide the time intervals corresponding to Fen-nA and Fen-nB calculations