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IMPACT OF SEISMIC EVENT ON RUPTURE PROBABILITY OF CIRCUMFERENTIALLY CRACKED LARGE-DIAMETER PIPING

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Abstract: *Historically, the safety of nuclear power plants (NPPs) is based on the ability to eliminate the large loss-of-coolant accident (large LOCA) which is represented by the double ended guillotine break of the primary circuit piping. As a matter of experience with operation of many nuclear units, US NRC prepared the so- called redefinition of large LOCA which is based on the theory of transition break size (TBS). For the PWR (Pressurized Water Reactor) the TBS is characterized by the piping with diameter of 360 mm. The regulatory body has to prove that the postulated circumferential crack satisfies the requirements of ASME Code, Section XI. In the paper a numerical example will be presented.*

Keywords: ***Large LOCA, redefinition, transition break size, circumferential break.***

1. Introduction

When solving the problem of safety of nuclear power plants' (NPP's), a lot of various extreme effects and influences have to be involved. Even if these events are exceptional and highly improbable, they can induce unexpected impacts and vibrations and consecutively environmental, health and biological hazard and naturally a heavy economic loss.

The occurrence of these extreme effects on NPP's equipment and structures is expected with the probability less than 10^{-1}/year and more than 10^{-6} to 10^{-7}/year, i.e. the combination of unexpected events that do not eliminate each other, and decrease of NPP's system function, if the probability of appearance of such a combination is more than 10^{-6} to 10^{-7}/year. Selected combinations or separate extreme events determine the extreme cases essentials for NPP's projects.

Historically, the safety of NPPs is based on the ability to eliminate the large loss-of-coolant accident (large LOCA) which is represented by the double ended guillotine break of the primary circuit piping. The loss of coolant accident is one of the most limiting design-basis accidents that cause the loss of ability of the coolant to remove heat from the fuel. Even small losses of fluid (or loss of coolant flow) may have important consequences (US NRC, 2008).

2. Determining Seismic Risk Contributions

The goal of the analysis is to determine whether the risk associated with the direct, seismically induced failure of the primary reactor cooling piping (PLP) is significantly less than the failure risk caused by the expected loading histories considered in NUREG-1829. For any of the following three criteria satisfied at each analyzed location, the seismic risk of direct failure of PLP is considered negligible:

1. The critical flaw depths are greater than 30% of the through-wall thickness.
2. The critical flaw depths are greater than the ASME Code, Section IX, flaw acceptance criteria.
3. The ISI programs are sufficient for detecting flaws before reaching critical flaw depths calculated according to US NRC (2009), Section 2.2.2.4.2.

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3. Example Calculation

This example will be used to demonstrate the principle of numerical procedure. The individual steps are enumerated in the following text.

3.1. Determine seismic hazard curve coefficients

At the very beginning of the calculation we need to find the seismic hazard of the locality, which will be labeled as Step 1.

1. The seismic hazard curve is determined by the Weibull equation fit for peak ground acceleration (PGA) versus the probability of occurrence

$$P(x) = Scale.\alpha.\beta^{-\alpha}\, x^{\alpha-1}\, e^{-(\frac{x}{\beta})\alpha}, \qquad (1)$$

where parameters α and β are determined as a matter of geophysical research. The values depend on the given country and site.

3.2. Next steps

After having determined the seismic hazard the following steps have to be proceed:

2. Obtain SSE (safe shut-down earthquake) design PGA value.
3. Solve for PGA value at $1x10^{-6}$ probability of occurrence, and obtain ratio of PGA at $1x10^{-6}$ to PGA at SSE.
4. Determine the highest SSE stress location.
5. Determine the materials of interest at the critical localization.
6. Determine the pipe cross-sectional dimensions at critical location.
7. Determine normal operating conditions/stresses.
8. Determine strength values for materials of interest.
9. Determine the SSE stresses.
10. Determine the linearly scaled seismic stresses for the $1x10^{-6}$ seismic even.t
11. Apply seismic scaling factor for plant site to correct the linearly scaled stresses from Step 10 and add the normal operating conditions.
12. Apply nonlinear correction factor to the elastic N + $1x10^{-6}$ seismic stresses from Step 11 to obtain the nonlinear stress S_{NL}.
13. Determine the elastic-plastic correction factor (Z-factor) for the critical flaw size evaluation.
14. Determine EPFM-corrected stress S_{EC} for use in limit-load equations.
15. Determine the minimum critical surface flaw depth from limit-load equations.
16. Calculate the a/t value corresponding to ASME Service Level D loading.
17. Compare BE a/t value to the ASME Code a/t value from Step 16.

4. Conclusions

The so-called redefinition of large LOCA prepared by US NRC is based on the theory of transition break size (TBS). For the reactors of PWR type the TBS is characterized by the piping with diameter of 360 mm. In the paper a numerical example is presented to prove that the postulated circumferential crack satisfies the requirements of ASME Code, Section XI.

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