Development of LBB Piping Evaluation Diagram for APR 1000 Main Steam Line Piping

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1. Introduction

This paper presents the piping evaluation diagram (PED) to assess the applicability of Leak-Before-Break(LBB) for APR 1000 main steam line piping. LBB-PED of APR 1000 main steam line piping is independent of its piping geometry and has a function of the loads applied in piping system. Also, in order to evaluate LBB applicability during construction process with only the comparative evaluation of material properties between actually used and expected, the expected changes of material properties are considered in the LBB-PED. The LBB-PED, therefore, can be used for quick LBB evaluation of APR 1000 main steam line piping of both design and construction.

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2. Procedure for Development PED

The method and criteria used for developing the PED of APR 1000 main steam line are based on NUREG 1061, Vol. 3 and SRP 3.6.3. The material properties required for the development of PED were from LBB test results. Generally, the worst case material properties are used in the analysis for ensuring the conservatism of the LBB analysis.

Fig. 1 illustrates the analysis procedure applied for the PED development of APR 1000 main steam line. In the first step of the analysis, the material, size and geometry were selected in the design process of APR 1000 main steam line piping. In the second step, the NOP load range was established. In the third step, the Detectable Leakage Crack Length (DLCL) was calculated. In the fourth step, the applied J-integral for the DLCL and twice the DLCL was computed. In the fifth step, from the applied J-integral and the material J-integral, J/T analyses were performed to find the instability point of the crack. In the sixth step, the SSE load range was calculated in accordance with the NUREG 1061, Vol. 3. Finally, the PED was developed as a function of crack length (the DLCL and twice the DLCL) and the allowable SSE load.

3. Material Properties

The main steam line piping is typically fabricated from SA106 Gr. C. The low material stress-strain curve and J-resistance curve (J-R) are taken from Korean Nuclear Power Plant during construction. The stress-strain data is shown in Fig 2. The data shown in Fig. 2 is used in the finite element analysis. A fit to the data used in the stability evaluation is shown in the Fig. 3. This J-R curve bounds the material toughness behavior in any of main steam line piping of APR 1000.

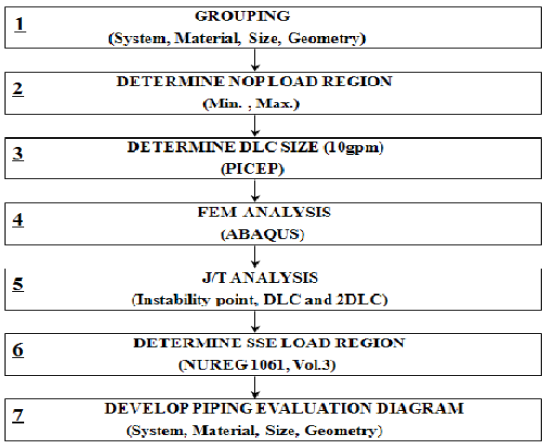

Fig. 1 Procedure of PED

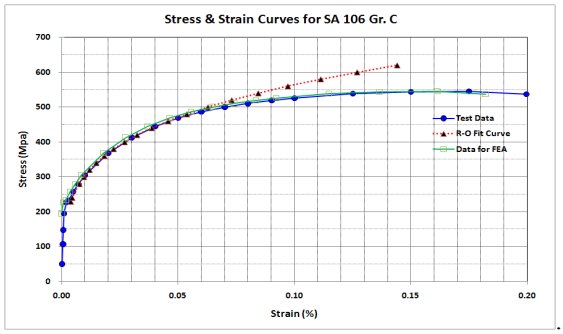

Fig. 2 Stress Strain Curves for SA106. Gr. C

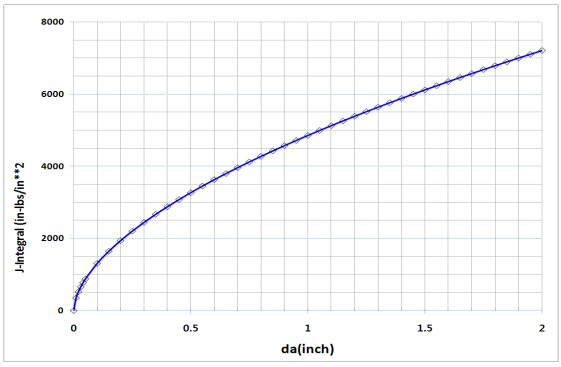

Fig. 3 JR curve for SA106. Gr. C

4. Relation between NOP laods and DLCL

The leakage crack length for a required 10 gpm flow depends upon the pipe loading, thermodynamic conditions and assumed crack surface roughness conditions. The elastic-plastic estimation method is used to find the crack opening displacement for a given loading. The PICEP program is used to calculate the flow for a given crack length and loading. For the purpose of generating analysis data for PED, a plot of moment vs. crack length for a 10 gpm flow is made using PICEP. This is done for main staem line piping of APR 1000 being evaluated for LBB. This provide the relation between normal operating loads and the crack length that gives a 10 gpm flow. The moment vs. length curves for the main steam line piping is shown in Fig. 4

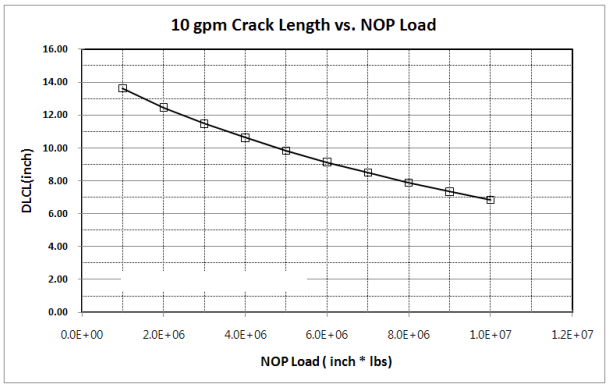

Fig. 4 APR 1000 Main Steam Line
PICEP Results for 10gpm leakage

5. Results of PED

Piping evalualtion diagram for main steam piping of APR 1000 is shown in Fig. 5 and provides LBB acceptance criteria for this piping system. This criteria is based on piping system parameter such as NOP loads and SSE loads. Analyses of preliminary design of this piping system have demonstrated that the LBB criteria are met.

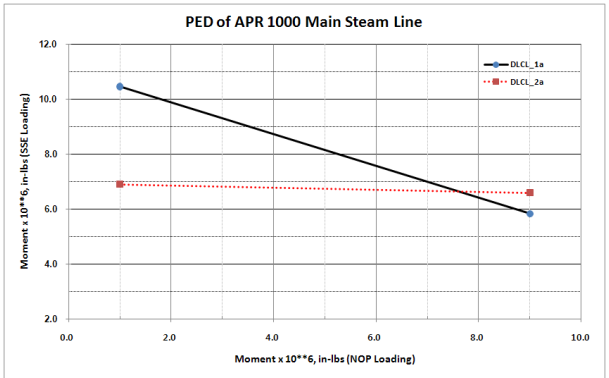

Fig. 5 APR 1000 Main Steam Line PICEP Results for 10gpm leakage

Site-specific information will demonstrate that the final detailed design parameters of main steam line piping of APR 1000 are consistent with NOP loads and SSE loads that the final detailed design meets the LBB criteria of Fig. 5. If design parameters for the main steam line piping of APR 1000 are not enveloped by final loads of this piping system, a new PED for that piping system will be constructed using the methodology mentioned before and the piping design will be revised, as necessary, to meet the LBB criteria of the new PED. If the PED of main steam line piping of APR 100 given in Fig. 5 is applicable to the detailed design of a piping system but detailed design does not meet the LBB criteria of the PED, the design will be revised to meet the LBB criteria of the PED

REFERENCES

[1] US NRC, “Modification of General Design Criteria 4 Requirements for Protection Against Dynamic Effects of Posturated Pipe Rupture”, Fedral Register Notice, Vol. 52, No. 207, 41288-41295, 1987.
[2] US NRC, “Leak-Before-Break Evaluation Procedure”, Standard Review Plan 3.6.3, 2009.
[3] Pipe Break Task Group, “Evaluation of Potential for Pipe Break”, NUREG-1061, Vol. 3, 1984
[4] Norris, D.M and Chexal, B., “PICEP : Pipe Crack Evaluation Program”, EPRI Report NP 3596-SR, 1987.