Development of a Web-based Thermal Fatigue Evaluation Program for the Normally Stagnant Non-isolable Reactor Coolant Branch Line Piping

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1. Introduction

Thermal fatigue cracking and leakage induced by thermal stratification, cycling and striping have been observed in several PWR plants. These thermal hydraulic phenomena are developed by the interaction between valve leakage and turbulence penetration from the reactor coolant piping. However, the cracking caused by thermal cycling mechanisms was not considered in early plant design. Therefore, to evaluate the unconsidered thermal effects, several guidelines have been established. Especially, MRP-146 guidelines which are issued by EPRI presents enhanced assessment methods [1]. The final goal of this work is to develop thermal fatigue evaluation technology for the reactor coolant branch line piping of nuclear power plants based on EPRI guidelines. In this context, the structure of web-based thermal fatigue evaluation system named 'Reactor Coolant Branch Line–Thermal Fatigue Evaluation System' was designed. Efficiency and accuracy of main modules such as thermal stratification and thermal cycling parts will be verified by further detailed computational fluid dynamics analyses and structural analyses.

2. Methods and Results

In this section the thermal fatigue evaluation methods which are presented by EPRI are briefly described. In addition, the structure and contents of the developed evaluation system are depicted.

2.1Evaluation Methods

The evaluation target of MRP-146 guidelines is the normally stagnant branch lines attached to the reactor coolant piping that are greater than one-inch nominal diameter. Because the thermal cycling mechanisms are different in up-horizontal/horizontal (UH/H) and down-horizontal attached piping, screening criteria and assessment methods are described according to the line geometry in MRP guidelines.

As shown in Fig.1, for the first step branch lines which should be minutely evaluated are classified by applying screening criteria. Detailed evaluation procedures and methods for these lines are presented in MRP-132 and MRP-146S [2, 3]. Since thermal stratification and cycling in UH/H lines is caused by the

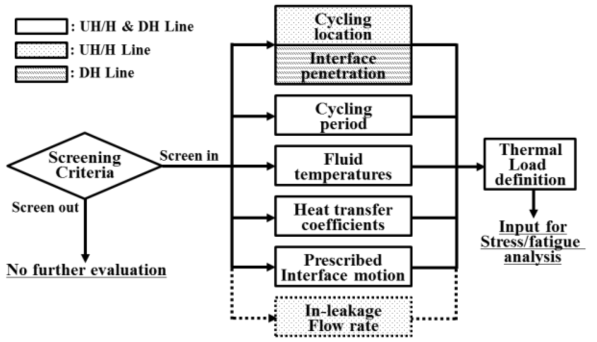

Fig. 1. Thermal cycling evaluation procedure which is described in EPRI MRP-146, MRP-146S and MRP-132.

interaction of swirl flow with in-leakage, there are several evaluation processes related to the in-leakage of UH/H lines. On the other hand, thermally stratified flow in DH lines is developed by the cyclic penetration and retreat of the swirl flow so that the evaluation procedure for DH line has a part related to the interface penetration. The thermal load definition which is finally derived is considered as an input for the stress and fatigue analysis.

However, since these evaluation methods consist of complicated calculation, it is difficult to effectively apply the MRP guidelines to regulate the practical piping system. Therefore we develop a web-based thermal fatigue evaluation program using Microsoft Visual C#, Java, Microsoft Visual Studio 2005, and HTML languages.

2.2 Program Structure

The developed program is composed of two modules as shown in Fig. 2: thermal stratification and thermal cycling evaluation modules. Each module is established base on MRP-146S and MRP-132 guidelines respectively but it consists of similar processes such as input, screening, calculation and output. For the first, several key parameters are entered into the system through the input window like as Fig. 3. When the target branch line does not satisfy the screening criteria, the calculation process is skipped. Finally, all results at each step are reported as a text file and that file can be exported from the system and converted to an input file for thermal stress analysis. In addition, a database for temperature-dependent water was also established. Appropriate properties are automatically considered according to the temperature based on this database.

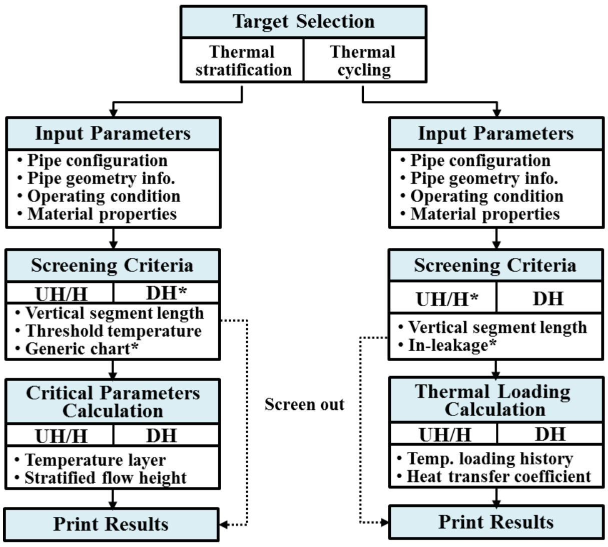

Fig. 2. The program structure of a web-based thermal fatigue evaluation system.

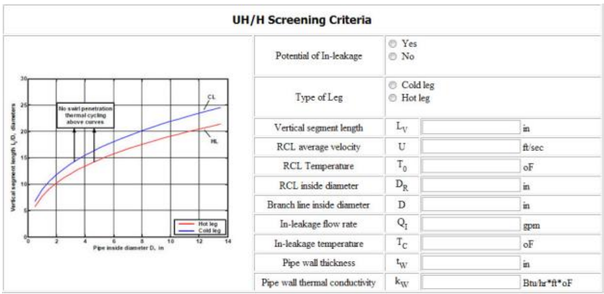

Fig. 3. The input window of thermal cycling evaluation module.

2.3 Verification

Example calculations on a safety injection line (UH configuration) and a RHR suction line (DH configuration) are provided in MRP guidelines to illustrate application. In accordance with, we verified the developed program by comparing the results from the developed system with the example calculation results which is presented in MRP guidelines. The comparing results guarantee the accuracy and efficiency of the developed program. However, to verify the accuracy of evaluation methodology in MRP guidelines, we will conduct further detailed computational fluid dynamics analyses and structural analyses.

3. Conclusions

The proposed system provides thermal fatigue evaluation for normally stagnant branch lines attached to the reactor coolant piping in nuclear power plants. In this web-based system, it is possible for users to determine the detailed evaluation target based on screening criteria and calculate key parameters to analyze thermal stresses and thermal fatigue. In conclusion, it is anticipated that the proposed system can be used for more efficient thermal fatigue evaluation of branch lines related to thermal stratification and cycling.

REFERENCES

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