Evaluation Method of Sodium Leak for FBR Components

(和文：高速増殖炉機器のナトリウム漏洩評価法の開発)

Background

The evaluation of structure integrity under the presence of crack-like defects is important to complement the design assessment for Fast Breeder Reactor (FBR) components. Sodium leak from a penetrated flaw is a typical phenomenon to be assessed from the viewpoint of structural integrity of the components installed to cope with possible sodium leak. For example, in order to prove the leak-before-break (LBB) concept, the length of the penetrated crack causing a specific value of leak rate must be identified as the crack size with detectable leak. The assumption of an appropriate crack opening area is also needed to make the rational design of safety-concerned equipment possible. However, an evaluation method applicable to sodium leak under the specific condition of FBR such as high-temperature operation or creep deformation has not been sufficiently established yet.

Object

The objective of this study is to develop a comprehensive sodium leak evaluation method for FBR components.

Major results

(1) The comprehensive evaluation method to predict crack opening area and leak rate was newly prepared as shown in Figure 1. The fully plastic solution was extended to evaluate crack opening area for three-dimensional crack problem including elastic-plastic and creep condition. The equation to evaluate sodium leak rate was derived form the Bernoulli's formula together with the correction factors to consider the effect of complicated actual crack configuration.

(2) The propriety of the developed method was confirmed by finite element analyses and water (and other fluid) leak tests using both artificially notched plates and fatigue (or creep-fatigue) cracked structures (plates, pipes, and elbows). Figure 2 shows the comparison between experimental and predicted leak rates for cracked structures. The present method gives good prediction for different cracked models.

The evaluation method has been incorporated as a part of the draft of the guideline for structural integrity assessment, which presented a technical basis for the evaluation of the structural integrity of Fast Reactor main components using the latest fracture mechanics methodology.

Figure 1 Evaluation Flow of Sodium Leak

\[ V' = \sqrt{\frac{2p}{\rho(1.5 + f_1(1 + r) k_f + (1 - r) k_u + k_s) k_h}} \]

- \( p \): Stagnation Pressure
- \( \rho \): Density of Sodium
- \( r \): Membrane Stress Range Ratio
- \( f_1 \): Friction Factor (Function of Reynolds Number)
- \( k_f \): Correction Factor for Surface Roughness
- \( k_u \): Correction Factor for Flow Path Configuration
- \( k_s \): Correction Factor for Cracked Elbows
- \( k_h \): Length of Flow Path
- \( D_h \): Hydraulic Diameter

\[ Q = \rho \cdot V' \cdot S \]

- \( \rho \): Density of Sodium
- \( V' \): Velocity of Sodium Leak
- \( S \): Crack Opening Area

Figure 2 Typical Comparison between Predicted and Experimental Leak Rate

All tests were conducted using water at room temperature.
Materials of structures used for tests were SUS304 or 316FR austenitic stainless steels.
Fatigue crack or creep-fatigue crack was introduced by cyclic loading.

注）和文報告書は作成しておりませんので、予めご了承ください。

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関連研究報告書

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