5-9 Evaluating the Failure Probability of Aged Piping under Seismic Motion —Structural Reliability Evaluation of Aged Components in Nuclear Power Plants Based on Probabilistic Fracture Mechanics (PFM)—

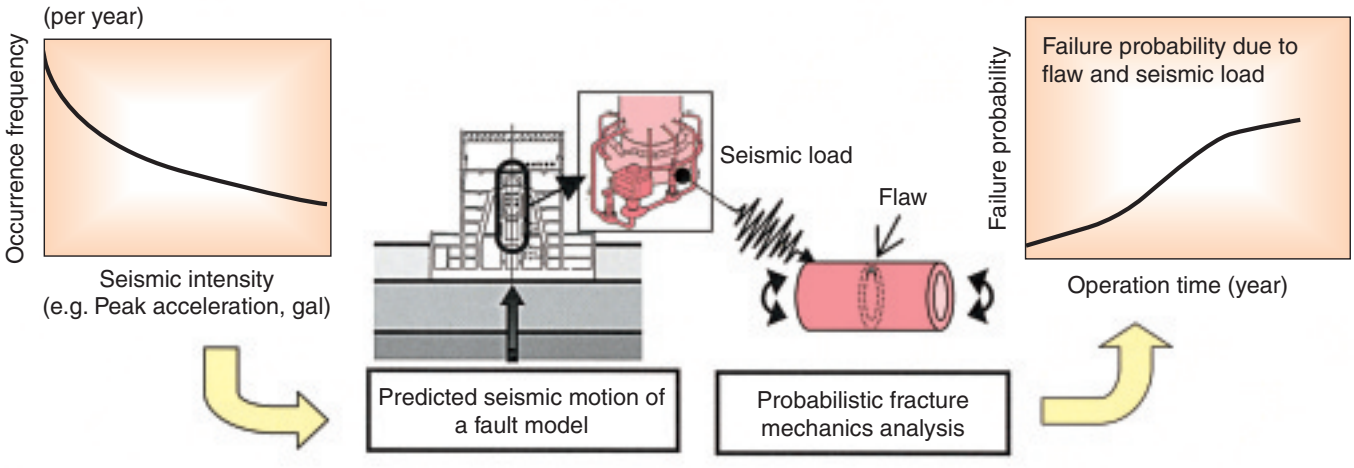

Fig.5-20 The flow of the failure probability evaluation of aged piping under seismic motion
The structural reliability of components such as aged piping during long-term operation is evaluated by PFM analysis method considering aging degradation and the relationship between seismic intensities and their occurrence frequencies (seismic hazard).

Older light water reactors (LWRs) in Japan have been operating for over 30 years. Measures need to be taken against decreases in the structural reliability induced by aging phenomena such as stress corrosion cracking (SCC). The safety evaluation based on seismic hazard for aged plants has also been an important issue. In order to evaluate the structural reliability of aged components in LWRs, the probabilistic fracture mechanics (PFM) analysis is a rational method, most suitable because the uncertainties in aging degradation and predicting seismic motion can be quantified.

We have developed a failure probability analysis method for aged piping based on PFM analysis and the latest knowledge on aging, and a seismic hazard analysis method which takes into consideration the uncertainty in predicting seismic motion. Although these methods were developed separately, we have recently established a structural reliability evaluation methodology merging them together as shown in Fig.5-20. In the first phase, the seismic hazard, i.e., occurrence frequencies of seismic motion of various intensities are evaluated based on the information on past seismic histories around LWR plants and the prediction values of seismic intensity at the plant (e.g. peak ground acceleration) upon occurrence of an earthquake. This seismic intensity is predicted by a fault model, made considering the break process of a fault and propagation characteristics inside the crust. In the next phase, failure probabilities of aged piping for various seismic motions are calculated by PFM analysis. In this analysis, SCC and fatigue crack extension under seismic load are calculated considering the scatter and uncertainties in crack initiation and growth rate, residual stress and material properties. Failure probability is calculated with the random variables expressing uncertainty by a Monte Carlo method. The structural reliability of aged piping against seismic motion can be evaluated by multiplying the failure probability as a function of seismic strength by earthquake probabilities obtained from their frequencies.

In the structural reliability evaluation of aged components under seismic motion, the prediction of the occurrence of very large seismic motion which might cause severe damages to the components is very important even if the occurrence probabilities are very small. This evaluation method developed here makes this possible.

We are going to establish more practical evaluation methods which consider the effectiveness and accuracy of in-service inspection, and will contribute to revisions of codes and standards.

Reference

Sugino, H., Itoh, Y., Onizawa, K. et al., Development of Structural Reliability Evaluation Method for Aged Piping Considering Uncertainty of Seismic Motions, Nippon Genshiryoku Gakkai Wabun Ronbunshi, vol.4, no.4, 2005, p. 233-241 (in Japanese).