Transactions of the 15th International Conference on
Structural Mechanics in Reactor Technology (SMiRT-15)
Seoul, Korea, August 15-20, 1999 D02/6

A Study of Simplified Fatigue Evaluation Method Based on Operating Data

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ABSTRACT

Some fatigue evaluation systems, to monitor cumulative fatigue usage factor in the components of Nuclear Power Plant continually, are previously released. And the Boring Water Reactor (BWR) utility also developed the simplified fatigue monitoring system using the Green's Function method and confirmed the accuracy this system at the stage of joint study in Japan.

In this study, at the first stage the simplified method based on design thermal transient by the Green's Function was established for Feed Water Nozzle. At the second stage above-established simplified method was confirmed the applicability based on actual plants. This paper describes the results at the second stage of this study.

1. Introduction

At the design stage, feedwater nozzle of Reactor Pressure Vessel (RPV) is one of the most critical components from the viewpoint of fatigue evaluation, and highly stresses arise from temperature fluctuation of feed water. Because of this reason, the necessity of fatigue monitoring systems not to use the design thermal cycles but to use the actual plant operating data were discussed. And at the first stage in the BWR utility joint study in Japan, the simplified fatigue monitoring system was developed and verified the accuracy to use Green's Function Method (GFM) for this system by using design thermal cycle [1].

At the second stage, for the purpose to applied simplified fatigue monitoring system to the actual plant, a verification to make a comparison between stress intensity by Fatigue Monitoring System (FMS) and those by Finite Element Method (FEM) were performed using the actual plant same operating data. And evaluated cumulative usage factor (CUF) by Fatigue Monitoring System, FEM and the most simplified fatigue evaluation method which is called Thermal Cycle Counting Method (TCM) also was compared.

The actual plant operating data for a verification were used acquired by On-line Plant Process Data Acquisition System (OPDAS) [2] of Tokyo Electric Power Company's Kashiwazaki-Kariwa Nuclear Power Station Units 3 and 4 (K-3/4) (1,100Mwe BWR-5)

2. Input Data for Verification

An outline of Fatigue Monitoring System for stress calculation and fatigue evaluation is shown in Figure 1.

The actual plant operating data which are used for a verification of this system are used some acquisition data by OPDAS. OPDAS acquire the plant operating data and compress enormous data into useful data in order to analyze for the purpose of decrease the capacity of recording.

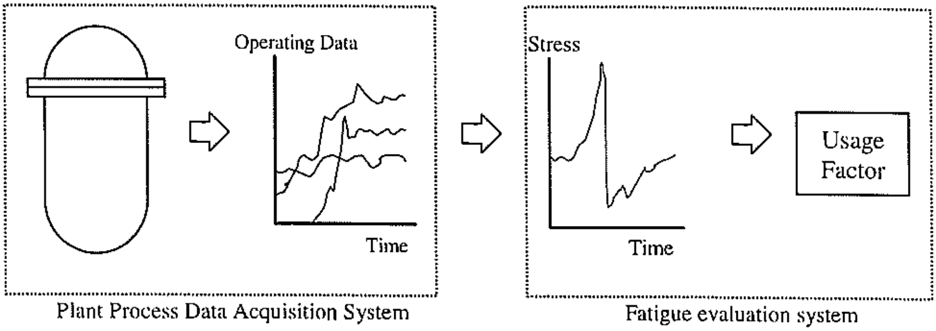


Figure. 1 On-Line Fatigue Monitoring System

Concretely, input data were acquired during startup test period of K-3/4, and were selected to have an effect on thermal stress for feedwater nozzle from all acquisition data. Titles of input data are as follows:,

(1) Reactor Pressure
(2) Feedwater Temperature
(3) Feedwater Flow
(4) Core Cooling Water Temperature
(5) Core Flow

These input data specified the phenomenon which has influence on fatigue evaluation from the data extracted during the startup test term.

3. Verification Result of FMS

For the purpose to applied simplified fatigue monitoring system to the actual plant, a verification to make a comparison between stress intensity by FMS and those by FEM were performed using the actual plant same operating data.

3.1 Comparison with Stress Evaluation Results by FMS and FEM

As of FMS, the history of stress intensity is calculated using GFM. Green's Function itself is determined by FEM to give some temperature step as thermal condition to inside surface of feedwater nozzle [1]. This FEM analysis model is shown in Figure 2. In this verification, same FEM analysis model is applied.

The comparison of stress analysis results are shown in Figure 3. Although a small difference will be looked at by calculation stress at the time of rated power operation, if the evaluation result by GFM and the evaluation result by FEM are compared as shown in this figure, it turns out that the range of fluctuation of stress is almost the same.

When digital value compared, see Table 1, FMS became value small about K-3 : 7% and K-4 : 6% from startup through shutdown compared with FEM. This difference is considered to originate that FEM is non-linear analysis, on the other hand GFM is linear analysis.

Therefor, to apply this FMS to the actual plant, it is necessary to consider the above difference between the evaluation result by GFM and the evaluation result by FEM. So the stress correction factor is introduced to FMS [1]. If a part or a plant for evaluation using GFM is different, since it will become the value, which this stress correction factor also differs from, it needs to be made to decide for every part or plant for evaluation.

Comparison with stress intensity by FMS considered the stress correction factor and stress intensity by FEM is shown in Table 2.

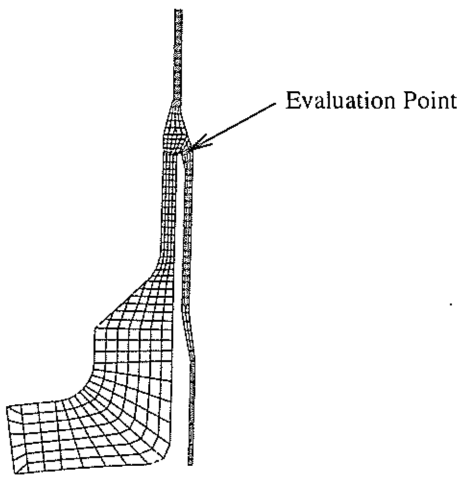
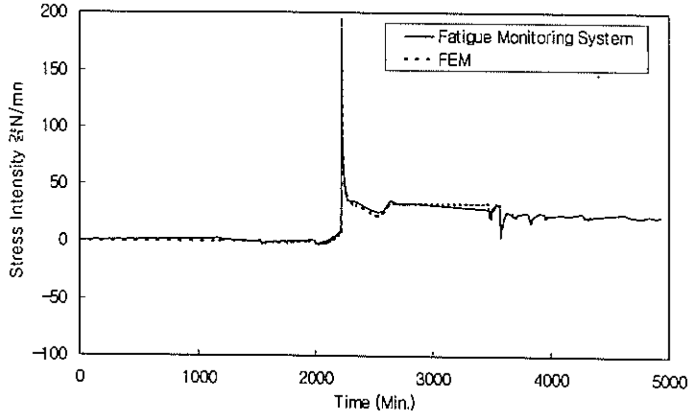
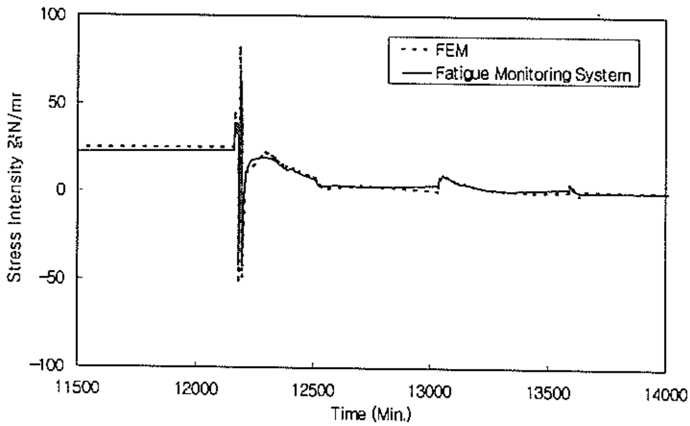


Figure 2 FEM Analysis Model



(a) Startup



(b) Shutdown

Figure 3 Comparison between Stress Intensity by FMS and FEM

Table 1 Comparison between Stress Intensity by FMS and FEM

(a) K-3

		Stress Intensity (N/mm2)		
		FMS	FEM	Error of Rage (%)
Startup	Max.	187	194	
	Min.	-2	-3	
	Rage	189	197	-5
Shutdown	Max.	68	82	
	Min.	-43	-52	
	Rage	111	134	-18
Startup - Shutdown	Max.	187	194	
	Min.	-43	-52	
	Rage	230	246	-7

(a) K-4

		Stress Intensity (N/mm2)		
		FMS	FEM	Error of Rage (%)
Startup	Max.	182	206	
	Min.	-27	-12	
	Rage	209	218	-5
Shutdown	Max.	27	49	
	Min.	-66	-57	
	Rage	93	106	-13
Startup - Shutdown	Max.	182	206	
	Min.	-66	-57	
	Rage	248	263	-6

Table 2 Comparison between Rang of Stress Intensity by FMS and FEM

Plant	Stress Intensity (N/mm2) Startup - Shutdown			Stress Correction Factor
	FMS	FMS*	FEM	
K-3	230	251	246	1.09
K-4	248	266	262	1.07

* : Stress Correction Factor (•) is considered.

3.2 Comparison with CUF by FMS and FEM

Using stress intensity considering the stress correction factor, fatigue analysis for 1 cycle, from startup through shutdown, was performed. Comparison in case of K-3, with CUF by FMS and by FEM is shown in Table 3.

For the purpose of application of FMS to the actual plant, fatigue analysis was performed whole of startup test using FMS and TCM. The number of times for the event during startup test of K-3 are shown in Table 4. And comparison with CFU by Fatigue Monitoring System and by TCM is shown in Table 5.

Table 3 Comparison between CUF by FMS and FEM

	FMS	FEM
CUF (Startup - Shutdown, 1 cycle)	0.000021	0.000010

Table 4 The Number of the Event during Startup Test

No.	Event	The Number of Times
1.	Startup	10
2.	Shutdown	2
3.	Turbine Generator Trip	3
4.	Loss of Power Accident	2
5.	Plant Trip (SCRAM)	2
6.	PLR Pump Trip	4
7.	All MSIV Closing	2
8.	Turbine Generator Trip (W/SCRAM)	1

Table 5 Comparison between CUF by FMS and TCM

	FMS*	TCM
CUF (Startup - Shutdown)	0.0002	0.0431

* : Stress Correction Factor (•) is considered.

4. Conclusion

Even if comparing the fatigue evaluation results by this FMS using the GFM with FEM used at design period, it is certified to have sufficient accuracy and to be fully conservative.

However the stress correction factor (•) was examined by considering some represented plant, an individual examination should be required, in case the fatigue evaluation is performed in the actual plant by using this system.

Moreover, since it is possible to have obtained very small CUF as compared with evaluation of TCM, the design base, in a startup test term, it is certified that this system provides an effective evaluation result to consider the plant life management.

5. Reference

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