SMiRT-12 / K. Kussmaul (Editor)

D04/3

TREND OF OPERATING DATA MONITORING AND FATIGUE EVALUATION SYSTEMS FOR BWR IN JAPAN

Y. Takahashi[1], K. Igi[1], O. Maekawa[2] and M. Tani[3]

[1]Tokyo Electric Power Co., [2]Toshiba Corporation, [3]Hitachi, Ltd., Japan

Abstract

Considering the plant life extension (PLEX) of nuclear power plants are expected to have in the future, Japanese electric utilities operating BWR plants are carrying out a research project jointly with equipment fabricators to develop an on-line plant process data acquisition system (OPDAS) and procedures for reactor pressure vessels fatigue evaluations.

OPDAS systems, developed under that research project, have been installed at Tokyo Electric Power Company's Kashiwazaki-Kariwa Nuclear Power Station Units 3 and 4 (1,100-MWe BWR-5 plants) and are now efficiently recording and storing basic data, necessary for RPV fatigue evaluation, from the commissioning test stage. As a part of the continuing joint research effort, practical procedures are being developed that would enable the use of this representative OPDAS basic data as the basis for evaluating the actual RPV fatigue experience at other operating plants.

1. Introduction

Studies are being conducted from many different perspectives on how to extend the service life of nuclear power plants. In Japan, interested organizations including the Japan Power Engineering and Inspection Corporation (JAPEIC), are carrying on research activities to develop technologies for plant life extension.

Assuming that nuclear power plants (NPPs) normally have a design life of 30 to 40 years, the first generation of commercial reactors in Japan will be at the end of their design life in the 2000s or 2010s.

However, if the design margin of NPPs can be verified on the basis of their design concepts and their operational experience, their actual service life may be extended. This, in turn, is expected to help increase their total electric output and reduce their generating cost over their whole service life.

The reactor pressure vessel is considered to be the most critical component of NPP when their PLEX is considered with respect to: 1) deterioration factors, such as fatigue, corrosion, irradiation effects, aging and wall thinning; 2) diagnostic techniques for valuating components deterioration; and 3) repair techniques, specifically those for the renewal or replacement of components.

As far as the RPV is concerned, the most influential deterioration factors noted above are fatigue damage and neutron-irradiation embrittlement. The degree of individual component deterioration resulting from irradiation can be determined through surveillance tests, but it has been hardly feasible to assess the fatigue damage of components based on their actual operating data.

To provide an effective means of RPV fatigue evaluation in view of predicted NPP PLEX in the future, Japanese electric utilities operating BWR units have been working jointly with equipment vendors to develop an on-line plant process data acquisition system (OPDAS) and study RPV fatigue evaluation procedures.

This paper reports on the current state of these research activities and on the perspective of their future developments.

2. Development and Application of OPDAS

A basic concept of OPDAS was developed and fabricated from 1987 to 1988, based on the results of an extensive feasibility study conducted in 1985 through 1986 on how to extend the NPP service life. The detail design of the system for plant application was worked out specially for Tokyo Electric Power's Kashiwazaki-Kariwa Nuclear Power Station Units 3 and 4, of which the former was given the initial fuel loading and brought into the commissioning test stage in September 1992 and the latter is expected to enter that stage in October 1994. The system installed in Unit 3 of the nuclear power station is now gathering basic plant operation data, including those of the commissioning test data. The following are major features of the OPDAS:

Table 1 List of sampling parameter

Purpose	Data name	Type*1	Num.of signals
Feedwater nozzle	Feedwater nozzle and safe end temp.	A	4
	1st feedwater heater outlet temp.	A	2
	Recirculation loop temp.	A	2
	RPV Pressure	A	1
	Feedwater header pressure	A	1
	Feedwater flowrate	A	2
	Recirculation loop flowrate	A	2
Support Skirt	RPV bottom head, support skirt temp.	A	4
	RPV drain line temp.	A	1
	Core plate differential pressure	A	1
	RPV Water Level	A	1
Main stud bolt	RPV top head, stud bolt and shell flange temp.	A	5
	Main steam flow rate	A	1
	Main steam temp.	A	1
Simplified fatigue evaluation	Generator power	A	1
	Turbine bypass valve opening angle	A	1
	Turbine revolution	A	1
	1st feedwater heater pressure	A	2
	2nd feedwater header pressure	A	2
	Feedwater pump trip	D	6
	Turbine trip	D	1
	Generator trip	D	2
	RPV pressure high	D	4
	Reactor Scram	D	4
	Recirculation inlet valve open	D	4
	Recirculation outlet valve open	D	4
	Recirculation pump on	D	2
	Recirculation pump trip	D	2
	RHR start-up	D	2
	Reactor operating mode	D	4
	Safety/relief valve open	D	30
Total	(Analog Value :35, Digital Value : 65)		100

*1 Type A: Analog value D: Digital Value

2.1. Sampling Parameters

Selected evaluation locations cover the feedwater nozzle, support skirt (bottom head) and main stud bolt which are subject to severer fatigue usage factors than other parts of the RPV in relation to the design basis thermal cycles. From among the process measuring locations set for monitoring the operation of the components, a decision was made to acquire data for temperatures, pressure and flow rates - parameters necessary for fatigue evaluation purposes. Data is gathered at some 100 points (see Table 1).

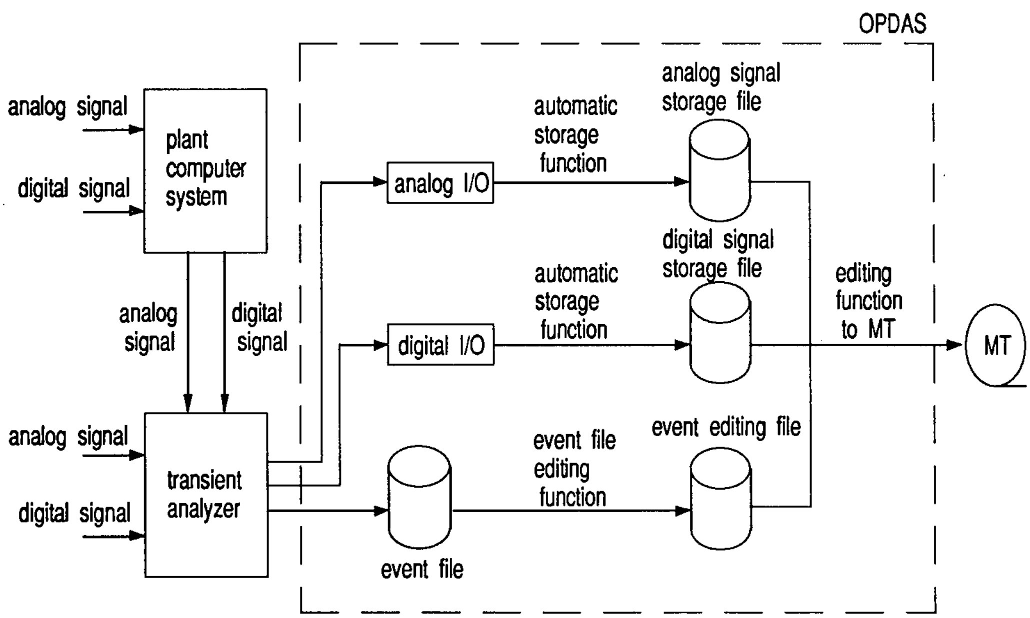
2.2. Functions

The OPDAS is comprised of a process computer, transient recorder, related software, hard disk, and magnetic tape output device for data storage. Fig. 1 shows a flowchart of data collection.

For reliable collection of plant operation data, data sampling is done every minute during normal operation and at 100 msec intervals during transients. In order to store data automatically and efficiently, the OPDAS compresses normal operation data for storage by a data compression algorithm which is based upon the rate of change of the data.

These OPDAS features provide the capability to sample plant operation data over a full cycle of operation without requiring any operation by an operator. Plant process data collected for each cycle of operation are output to a magnetic tape for permanent storage during a periodic refueling outage.

Fig. 1 System Configuration of OPDAS



3. Development of RPV Fatigue Evaluation Procedure

Procedures currently proposed for NPP fatigue usage factor evaluation may be broadly divided into two methods. One method is to count the transient phenomena experienced in plant in accordance with the event categorized in a design basis thermal cycle and assess the fatigue usage factors of RPV by multiplying the number of cycle. The other method assesses fatigue usage factors of components by calculating their stresses directly through simple stress evaluation based on actual measured data acquired during plant operation.

3.1. Development of Simplified Evaluation Procedure

Since the second half of the 1980s, two fatigue evaluation procedures have been developed in Japan for BWR RPVs:

(1) Procedure Based on Comparison with Thermal Cycle
This is a simple system of evaluating RPV life based on comparison with the defined design basis thermal cycles. More specifically, the degree of RPV fatigue is assessed by finding the plant operating conditions from such elements as pressure, temperatures, generator output, reactor water level and turbine speed.

(2) Procedure Based on Process Data Pattern Classification
This procedure evaluates RPV fatigue based on pattern classification of pressure, temperatures and other process data. Although a little more complex than the method described in (1), it can make more accurate assessment which is closer to the actual condition.

3.2. Validity of Simplified Evaluation Procedures

The reliability and validity of these fatigue evaluation procedures must be assessed quantitatively before either of them is adopted for application to actual plants. For this purpose, two different approaches have been taken in examining the validity of these simplified evaluation procedures. One is a study on the design margin of the RPV in assessing its fatigue based on actual plant data, and the other is a study on a practical evaluation method based on a chronological stress analysis (a simple method of detailed evaluation).

3.2.1. Study on RPV Design Margin in Fatigue Evaluation Based on Actual Plant Data

In the design of the RPV, stress analysis is made based on the established design basis thermal cycles to assess the RPV integrity over the whole service life of the plant. Since this thermal cycle is developed for RPV design, such factors as temperature and pressure transients are usually set conservatively, compared with actual plant data.

When NPP PLEX is taken into account, meanwhile, the assessment of the margin between the original design method and the actual phenomena is an important topic to be dealt with in evaluating the RPV fatigue usage factor.

As a typical example of the situation described above, Fig. 2

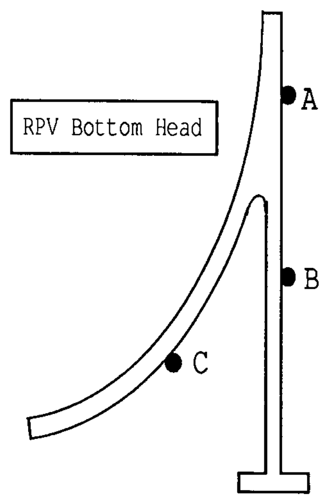
compares the temperature distribution in the RPV support skirt at the end of plant startup as determined by an analysis performed in the design stage, with the results of another analysis performed on the basis that optimizes boundary condition applied in the analysis by a parametric survey based on measured temperature data. Stress analysis findings based on this case indicate that the peak stress intensity, and therefore the final value of peak stress intensity amplitude in performing fatigue evaluation, is about half of the design stress and that the fatigue usage factor for each cycle of start-to-shutdown operation has significant margin as compared to the analysis at the design stage.

In the future, the assessment of each representative location and plant event made by analyses at the design stage will be compared with the actual plant experience, based on actual plant data, to find the disparity between them in an effort to quantitatively determine their design margins. Through these studies, we are also planning to quantitatively determine the validity and margin of this simplified evaluation procedure.

Fig.2 Difference between the design stage and the optimize boundary base at the end of start-up

(℃, deg)

Location	Design Stage Analysis	Measured Temp.	Optimize Base Analysis
A	230	259	260
B	63	148	145
C	210	228	230
A-B	167	111	115



3.2.2. Study on Practical Evaluation Based on Operating experiences (Simple Method of Detailed Evaluation)

In conducting the study discussed above, fatigue calculations based on RPV stress analyses in all cases of actual plant operation cannot be considered a practical method in terms of such elements as the required calculation time. To cope with this problem a survey is being conducted on some other approaches, specifically a method of evaluation using Green's function, to identify feasible evaluation procedures for finding the RPV stress.

According to an analysis, stress obtained by a two-dimensional finite element analysis model agrees well with one obtained by the Green's function method. In the future, we are planning to make a more extensive survey covering other conceivable methods.

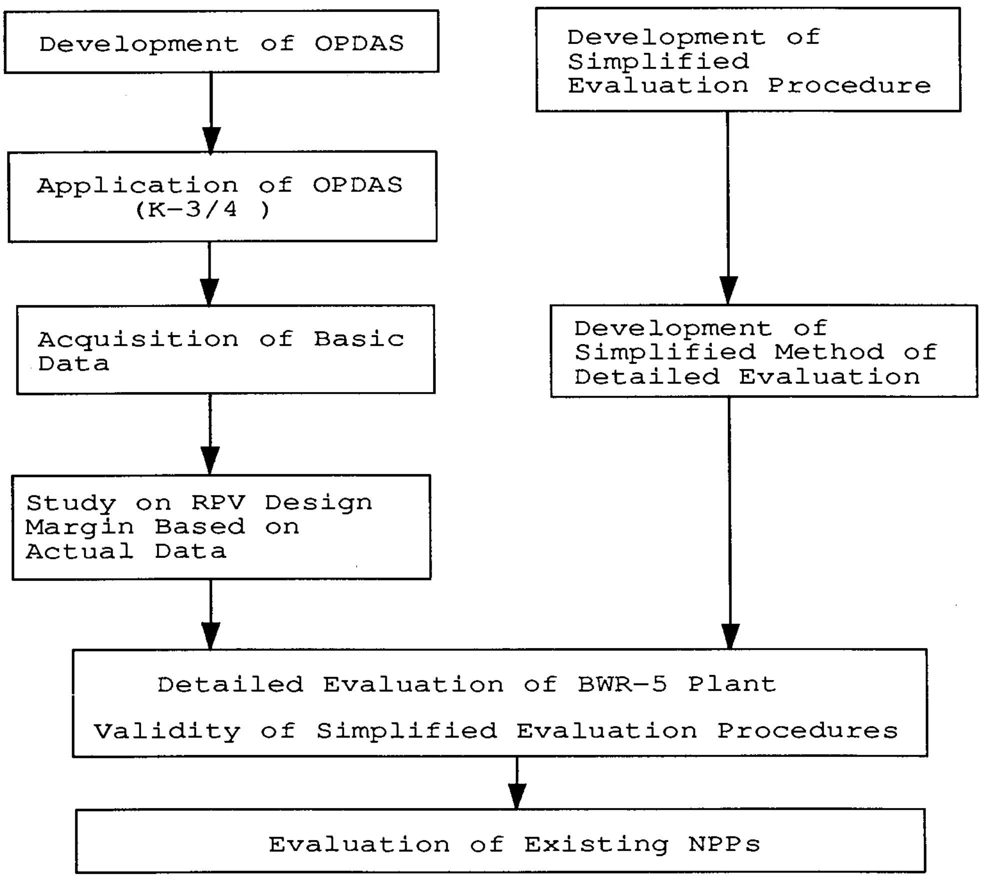
4. Conclusion and Future Prospects

Figure 3is a flowchart of the completed studies on BWR plants in Japan.

The installation OPDAS systems at Units 3 and 4 of the Kashiwazaki-Kariwa Nuclear Power Station provides an efficient means of gathering basic data on various operating conditions, including transients, of these BWR-5 plants.

In the future, we are planning to study fatigue evaluation procedures based on the fundamental data obtained using the OPDAS, in an effort to quantitatively determine the RPV fatigue usage factors of these new plants. Along with this study, an attempt will be made to develop a data based on existing NPPs from their past operation data covering plant pressure, temperatures, generator output, reactor water levels and turbine speed so that the data can be made available for future PLEX studies.

Fig. 3 Trend of RPV Fatigue Evaluation



REFERENCES

Takahashi, Y. (1991). Application of Plant Data Acquisition System to Kashiwazaki-Kariwa N.P.S.Units 3 and 4, Paper D05/3 SMIRT-11.