Leak Detection of High Pressure Feedwater Heater Using Empirical Models

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1. Introduction

Even small leak from tubeside or pass partition within the high pressure feedwater heater (HPFWH) causes a significant deficiency in its performance. Plant operation under the HPFWH leak condition for long time will result in cost increase. Tubeside leak within HPFWH can produce the high velocity jet of water and it can cause neighboring tube failures [1]. However, most of plants are being operated without any information for internal leaks of HPFWH, even though it is prone to be damaged under high temperature and high pressure operating conditions. Leaks from tubes and/or pass partition of HPFWH occurred in many nuclear power plants, for example, Mihama PS-2, Takahama PS-2 and Point Beach Nuclear Plant Unit 1. If the internal leaks of HPFWH are monitored, the cost can be reduced by inexpensive repairs relative to loss in performance and moreover plant shutdown as well as further tube damages can be prevented.

2. Methods and Results

In this section the methodology to monitor the internal leak of HPFWH will be described. The empirical modeling techniques and PEPSE software are adopted to develop a monitoring program and data generation, respectively.

2.1 Performance Evaluation of HPFWH

The performance of HPFWH can be stated as the capability to heat up feedwater in terms of TTD* (Terminal Temperature Difference) and DCA* (Drain Cooler Approach) and the procedure of HPFWH performance evaluation should be followed to ASME PTC 12.1, which is the direction and guidance for determining the performance indicators, TTD and DCA. Trends of TTD, temperature rise (TR*), and DCA are sufficient to monitor and evaluate the performance of HPFWH [2]. The failures of HPFWH can be diagnosed by analysis of parameter trends.

* TTD = saturated steam temp. – feedwater outlet temp.
* DCA = drain outlet temp. – feedwater inlet temp.
* TR = T_{Fwout} - T_{Fwin}

2.2 Previous FWH Leak Monitoring Program

The FWH leak monitoring has been studied for long time. The approach utilizing the instruments existing in plants are used at many plants. One of these approaches is to monitor the actual drain flow, and comparing it to the expected drain flow to detect internal leaks [1]. Condition monitoring by physical modeling technique has been applied to monitor a leak through the partition plate of FWH by OECD Halden Reactor Project [3]. The monitoring for leak through pass partition plate using the measurements of TTD, TR and DCA was suggested by D.C. Karg [2]. Some methods based on mathematical models were suggested by Shapiro [4], and early detection method of FWH leak utilizing process variables was proposed by E. Hansen et al. [5]. Thus, the leak detection utilizing process parameters seems to be feasible and applicable.

2.3 Methodology of Internal Leak Detection

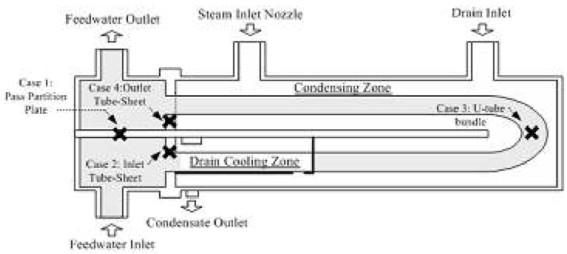
The method proposed here is to use an empirical modeling using process parameters, such as pressure, flow and temperature, to detect internal leaks within HPFWH. It constructs a reliable empirical model using historical data in normal condition and the empirical model estimates the expected TTD and DCA in normal condition. Then, the leaks of HPFWH can be evaluated by comparison of estimated value to measured value for TTD and DCA. Internal leaks in HPFWH result in deviations of TTD, TR and DCA from normal operating conditions. Thus, the deviation of measured value and estimated value for TTD and DCA will be decreased or increased in condition of internal leaks. This is considered that tube leak results in decrease of drain outlet temperature and pass partition plate leak results in decrease of feedwater outlet temperature. Internal leaks will also cause high drain-flow and high level of drain. However, internal leaks are not easy to be detected by the traditional leak detection methods (such as, high level of drain) because it does not work well for HPFWH internal leaks. In this study, the empirical model to estimate the expected normal value was constructed by multivariate regression techniques and the followings are typical examples.

ln (TTD7, ˚F) = -39.089 + 2.527 ln(main feedwater flow, lbm/hr) - 0.093 ln(turbine impulse pressure, psi)
ln (DCA7, ˚F) = -33.092 + 2.188 ln(main feedwater flow, lbm/hr) - 0.058 ln(turbine impulse pressure, psi)

With monitoring the deviations of TTD and DCA, we can detect earlier internal leaks within HPFWH.

2.4 HPFWH Modeling and Data Generation

To develop the empirical model, we need historical data providing the various behaviors of HPFWH. Since it is not easy to acquire the operation data from power plants under normal and leak conditions, we use PEPSE (Performance Evaluation of Power System Efficiencies) software developed by Scientech in USA to develop a simulation model which produces simulation data under various conditions. Fig. 1 shows internal leak locations considered in PEPSE model and they correspond with leak locations assumed by E. Hansen [5].



Case 1: Pass partition plate leak
Case 2: Inlet tube-sheet leak
Case 3: U-region leak
Case 4: Outlet tube-sheet leak

Fig. 1 Leak locations considered in PEPSE simulation

2.5 Demonstration of Leak Monitoring System

Fig. 2 shows the results in normal condition. The upper graph displays operating data (blue) by PEPSE model and estimated data (green) by the leak detection program. The deviation in the lower graph remains to zero due to normal condition. Fig. 3 shows monitoring results for TTD5A in various leak condition from 0% to 20% and the deviation increase in accordance with leak rate increase. Fig. 4 shows the monitoring results for DCA7A in various leaks and power conditions and the deviation is increased as well.

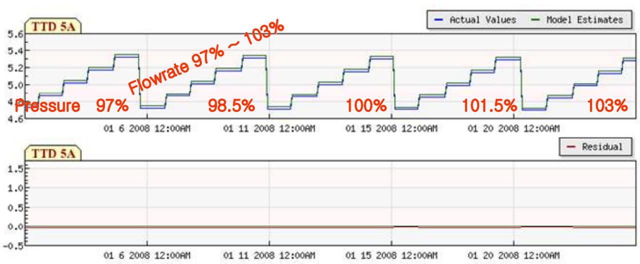


Fig. 2 Leak monitoring program results for normal condition in TTD5A (feedwater flowrate: 97%~103%, main steam pressure: 97%~103%)

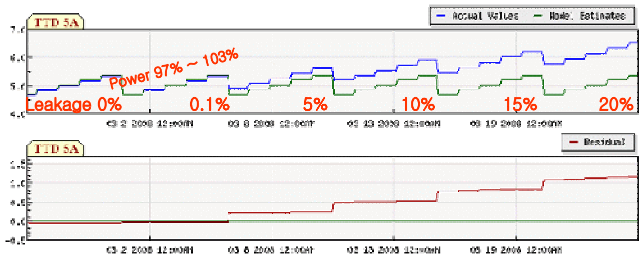


Fig. 3 Leak monitoring program results of leak condition for TTD5A

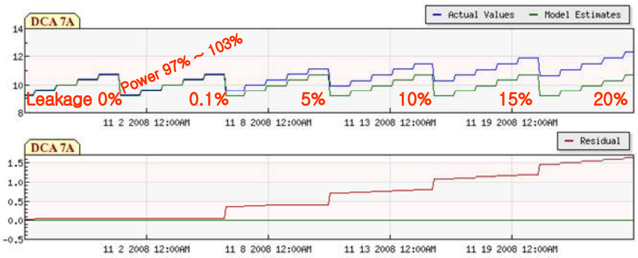


Fig. 4 Leak monitoring program results of leak condition for DCA7A

3. Conclusions

This study was carried out to develop the methodology for the leak detection of HPFWH and the leak monitoring program was developed using data produced by the PEPSE simulation model. The developed program demonstrates that it is sufficient to detect earlier internal leak within HPFWH by monitoring the deviations of TTD and DCA. This work also demonstrates that empirical modeling techniques can be used for leak monitoring detection of equipment. The program was developed based on web environment and can be used easily by connection to PI systems at site.

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