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A new blowdown compensation scheme for boiler leak detection

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Abstract: In this brief paper, a method is presented for tube leak detection which considers the blowdown effect in industrial boiler operation. This adds to the efficiency of recent advances in identification-based leak detection techniques of boiler steam-water systems.

Keywords: Industrial Boilers, Tube Leaks, Blowdown, Least Squares

1. INTRODUCTION

The availability of utility and industrial power plants is of major importance and, during the past 20 years, substantial efforts have been made to reduce down time. A significant part of this effort deals with early detection of leaks in pressurized systems, especially boiler tubes. In utility boilers, early detection of leaks is primarily a financial issue. High velocity steam escaping from a tube leak can quickly cause extensive damage to the adjacent tubes, which increases repair costs and down-time. High cost replacement power may be needed if a forced outage occurs during peak demand. For industrial applications, for example CO boilers, availability is critical from both an environmental and economic perspective. CO boilers are directly coupled to the coking process with operational run lengths up to 36 months, much longer than the typical annual maintenance cycle in utility applications. Downtime costs reflect current oil prices, and atmospheric diversion due to boiler unavailability has serious impacts on the environment.

One of the old techniques for leak detection is the acoustic method where sound waves are detected by transducers that convert mechanical waves into electrical signals. These are then processed and an increase in the voltage levels is relied upon to indicate the onset and growth of a leak. In practice, however, the application almost always involves several considerations, including significant amounts of interfering background noises, unacceptable sound wave attenuations, and inaccessibility of desired sensor locations. This encouraged ongoing research in statistical analysis and system identification methods. For example, the generalized likelihood ratio method was used in 1987 to identify gross errors in steady state dynamical processes [1]. Also, a Kalman filter-based method was proposed in 2000 for tank leaks and instrument bias detection [2]. In 2002, a least squares algorithm with time varying forgetting factor was proposed that takes into account boiler dynamics (see References [3]-[4] for more details). In this paper, we extend this work by including a model for the blowdown effect. The blowdown is used to control the dissolved solids in the boiler water based on results from periodic boiler water testing. The blowdown effect is important in that it constitutes up to 3% of the boiler mass balance equations, and can contribute to missed or false alarms if it is not compensated for, accurately, in the leak detection method.

2. A NEW BLOWDOWN COMPENSATION SCHEME

The least squares (LS) algorithm uses the following ARX model for the boiler water/steam mass balance:

$$A(q)y = B_1(q)u_1 + B_2(q)u_2 + B_3(q)u_3 \qquad (1)$$

where y is the feedwater flow, u_1 is the steam flow, u_2 is the drum level and u_3 is the drum pressure. The estimated output $\hat{y}$ obtained from this model is compared to the measured feedwater flow forming the error e which is then used in the LS algorithm

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with Forgetting Factor (FF) [3] to get an estimate ($\hat{\theta}$) of the tube leak.

The blowdown system uses a special regulating valve for water removal. The setting for this valve is based on the results from periodic water testing. At Syncrude Canada Ltd., the blowdown system consists of the blowdown tank and associated piping. The internal perforated collection pipe for the continuous blowdown runs the length of the steam drum in the lower section of the drum near the discharge from the risers. The blowdown line leaves the drum through a pair of manual isolation valves and runs down to a header equipped with a manual isolation valve and a metering valve. The metering valve is equipped with a scale to allow accurate setting of the blowdown rate since excessive blowdown is not cost effective. We will refer to this valve setting by u_4.

Using correlation analysis, no correlation exists between the model error "e" and the measured valve setting "u_4" for the sampling time of the model in (1) which is around 10-15 sec. However, by taking an hourly average of "e" and "u_4" a strong correlation was found as seen in Figure 1.

This was the basis to develop a new blowdown compensation scheme as follows:

(1) Identify the "nonregressive" blowdown model:

$$\bar{e} = B_4(q)\bar{u}_4 \tag{2}$$

where $\bar{e}$ and $\bar{u}_4$ are the averaged values.

(2) Run model (2) in parallel to model (1) and use the estimated averaged blowdown error to compensate for the actual error "e".

(3) Use the LS/FF algorithm to calculate $\hat{\theta}$ which is the estimate of the tube leak.

3. INDUSTRIAL CASE STUDY

The proposed technique is used for tube leak detection based on real plant operation data. The data is supplied by Syncrude Canada Ltd. for a period of time in which a leak took place in one of the boilers. The main data collected during this time frame is the boiler feedwater flow, the steam flow, the steam drum level, the drum pressure and the blowdown valve setting. Figure 2 shows the result obtained by applying the blowdown compensation scheme proposed in equation (2). By selecting a threshold of 2 KPPH (Thousand Pounds Per Hour), the LS/FF algorithm gives an early indication of the leak at about the 14^{th} day. The actual leak was detected by the operator at the 34^{th} day and the boiler was shut down for maintenance. This constitutes an early detection of the leak of about 20 days. This early detection is very important since it reduces consequential damage, and alerts operations for maintenance planning.

This result is also compared to the LS/FF algorithm with no blowdown compensation which gives an early detection of the leak at the 31^{st} day as seen in Figure 3. This shows the importance of incorporating the blowdown effect in the design.

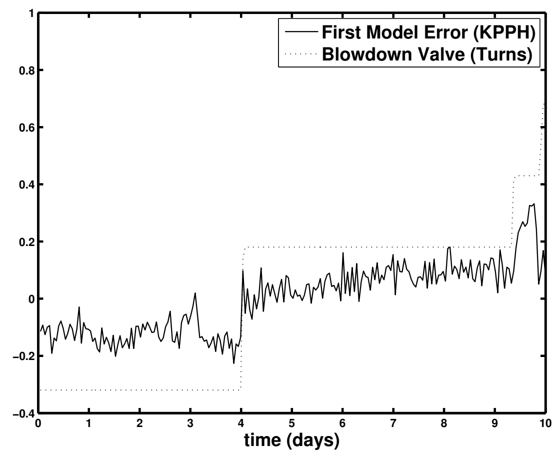

Fig. 1. Model error vs Blowdown valve setting (Real-time data during normal operation).

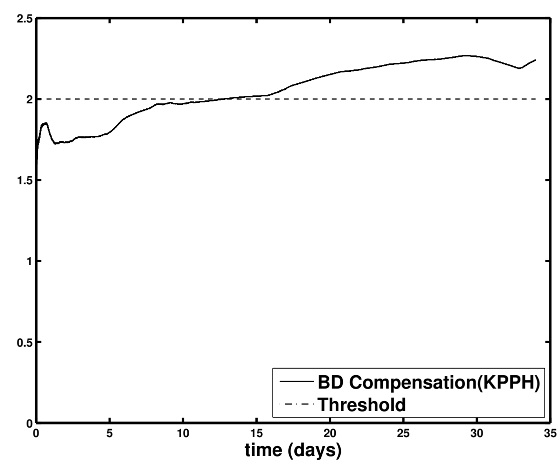

Fig. 2. Least Squares with Blowdown Compensation (Analysis result of real-time data during a period of a known tube leak).

4. CONCLUSION AND FUTURE WORK

This paper shows the application of the Least Squares with Forgetting Factor (LS/FF) algorithm in the boiler tube leak detection problem. Boilers having a blowdown system to control the dissolved solids in the water are considered. It is shown that a strong correlation exists between the error of the LS/FF algorithm and the blowdown effect. A new

[3] For more information on this algorithm see reference: System Identification-Theory for the User, second edition, L. Ljung, ©1999 Prentice Hall, NJ, Chapter 11.

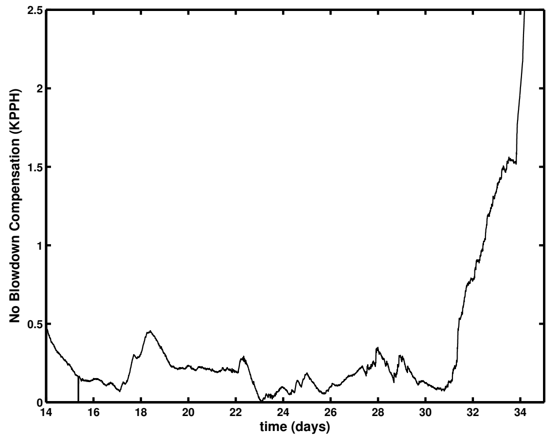

Fig. 3. Least Squares with no Blowdown Compensation (Windowed time frame).

real-time compensation scheme is proposed to continuously update the tube leak estimates obtained from the least squares algorithm. The validity of the new results is assessed on real plant operation data supplied by Syncrude Canada Ltd., showing that early detection of actual leaks can be obtained using the proposed approach.

It is important to note that the models used in (1) and (2) are critical for the accuracy of the obtained results and, therefore, must be well identified and validated. The blowdown model in particular is necessary to avoid missed or false alarms, and special care has to be taken in selecting its sampling time. In general, the sampling times must be carefully designed since they strongly affect the fidelity of the models.

Future work includes the use of more sophisticated models that are based on the mass and energy balance equations of the boiler. The application needs also to be extended to different types of boilers in addition to the radiative heat transfer type that was considered in this paper. This includes once-through steam generators and convection-type boilers. Future work also includes the configuration of the operator alarms, and other fault detection applications in process plants.

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