

# Asset Performance Diagnostics for Improving Operation Efficiency of Ethylene Cracking Furnaces

- An Example of Energy Saving during Regular Maintenance -

Hirokazu Ota \*1

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*This paper describes a case study of improving the asset performance of ethylene cracking furnaces through energy saving by Yokogawa's Asset Performance Diagnostics service, one of the services of Plant Asset Effectiveness Optimization Services, InsightSuiteAE. During regular maintenance of ethylene cracking furnaces, steam and air are supplied to tubes for decoking to burn and remove coke which may degrade the performance of the furnaces. Steam and air are usually supplied irrespective of the amount of coke deposited in the tubes. However, Yokogawa's Fault Monitoring Diagnostics included in the Asset Performance Diagnostics service can quantify and visualize the amount of deposited coke and can eliminate wasteful steam supply, thus saving energy. Yokogawa is providing maintenance plans based on this solution.*

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## INTRODUCTION

Reducing energy consumption and CO<sub>2</sub> emissions due to the operation and maintenance of plant equipment is becoming a global challenge. Yokogawa offers the InsightSuiteAE plant asset effectiveness optimization services, including the Asset Performance Diagnostics service, as solutions for plant assets to address such challenges together with customers. The Asset Performance Diagnostics service utilizes the InsightSuiteAE asset diagnostics package (hereafter referred to as "ISAE asset diagnostics package") as a tool to monitor, diagnose and visualize the performance and health of plant assets in real time, and thus to address issues efficiently.

This paper describes the application to a cracking furnace of the Fault Monitoring Diagnostics, a multivariate statistical analysis tool included in the ISAE asset diagnostics package. Yokogawa proposed to a customer to minimize the amounts of steam and air supplied for decoking by estimating and quantifying the coke deposition on the inside walls of the reaction tubes of ethylene cracking furnaces.

## BACKGROUND OF INTRODUCTION OF ASSET PERFORMANCE DIAGNOSTICS SERVICE AND ISSUES TO BE SOLVED

This section describes the issues in a petrochemical company which introduced the Asset Performance Diagnostics service and the background of the service introduction.

### Background of the Issues

Energy conservation is a key issue for this petrochemical company and they are actively introducing sophisticated energy consumption monitoring and other asset performance monitoring systems for improving energy efficiency. Implementation of an asset management plan for key equipment is also a major concern for the customer. Among the plant units, the ethylene cracking furnaces are a primary target for improvement, since they consume large amounts of energy.

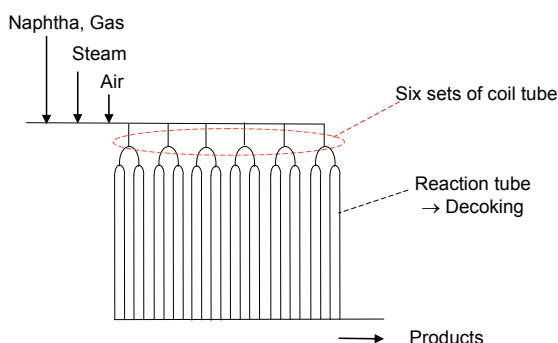
### Issues in Maintenance

When naphtha and gas are cracked in tubes of an ethylene cracking furnace, some coke is deposited on the inside walls of the tubes. As the coke inside the tubes becomes thicker, the overall heat transfer coefficient declines and the tube metal temperature (TMT), the temperature at the outside wall of a tube, rises. Thus, the deposited coke must be removed

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\*1 Vigilant Plant Services Center,  
Industrial Automation Business Headquarters

(decoked) before the TMT reaches its allowable limit. A typical ethylene cracking furnace comprises multiple coil tubes. Six sets of coil tubes are installed in the furnace in this example as shown in Figure 1.



**Figure 1** Schematic view of the configuration of ethylene cracking furnace reaction tubes

During the regular maintenance of this plant, steam and air are supplied into these tubes for decoking. Because there is no means at present to measure the coke thickness inside the tubes, the same amount of steam is supplied to all the tubes regardless of the amount of coke deposition. This may cause the following situations.

- For a tube with a small amount of coke deposition, more steam is used than required.
- For a tube with a large amount of coke deposition, there is not enough steam to decoke the tube thoroughly. Accordingly, in the next operation, the residual coke causes a reduction in the heat transfer efficiency, thereby consuming more fuel than required.
- The residual coke will shorten the operating time of the furnace compared with the case when the coke is fully removed. Thus, the number of decoking operations per year increases, and the consumption of steam increases as well.

**Introduction of the Fault Monitoring Diagnostics of the Asset Performance Diagnostics Service**

One solution to this problem is to optimize the steam supply, which used to be fixed regardless of the amount of coke deposition. To avoid excessive use of steam, steam supply is controlled according to the amount of coke deposition.

To achieve this optimization, the amount of coke deposition in each tube must be quantified without disturbing the production, and hopefully in a simple manner so that operators can perform it by themselves. Fault Monitoring Diagnostics was considered as a tool for measurement which can utilize process data acquired by the existing distributed control system (DCS). This is a multivariate statistical analysis tool which is included in the Asset Performance Diagnostics service.

**ASSET PERFORMANCE DIAGNOSTICS SERVICE**

This section outlines the Asset Performance Diagnostics service focusing on the Fault Monitoring Diagnostics.

**Features of the Fault Monitoring Diagnostics**

The ISAE asset diagnostics package used for the Asset Performance Diagnostics service contains the Fault Monitoring Diagnostics tool, which detects abnormal process situations online and identifies the relevant process variables based on multivariate statistical analysis. This tool has the following features.

- 1) Ease of creating fault criteria
 

The fault criteria of the equipment to be diagnosed can be created by using only process data acquired from field instruments without any complicated calculation formulae that may require the equipment specifications, fluid properties, and other parameters. This means that the fault criteria can be created even when it is difficult to create a rigorous model for setting the criteria.

If abnormal process situations are clearly defined, criteria can be created and verified more quickly than if the process operation is analyzed from scratch.
- 2) Flexibility of adjusting the criteria for equipment to be diagnosed
 

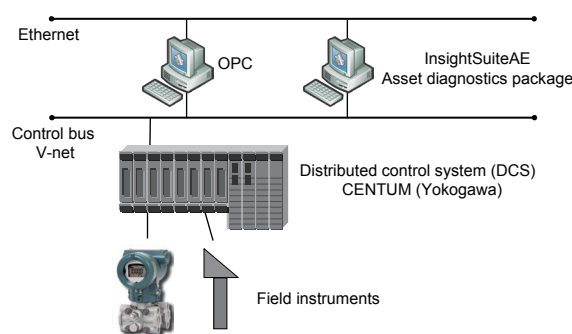
Since the criteria are created using only process data, it is easy to incorporate the special conditions of a specific plant.
- 3) Ease of updating criteria
 

By adding or changing the process database of the judgment model, the fault criteria can be easily enhanced or changed. For example, the criteria can be easily updated depending on operational changes such as feed material, feed rate or seasonal grade changes.
- 4) Visualization of criteria
 

The diagnostic results can be displayed on screen in real time, allowing operators to check the state of the equipment easily.

**Basic System Configuration for the InsightSuiteAE Asset Diagnostics**

When DCS is available, the ISAE asset diagnostics package can be utilized simply by installing this package on a PC and adding the PC on the network (Ethernet) which is connected to the OLE for Process Control (OPC) server, as shown in Figure 2.



**Figure 2** Basic system configuration for the InsightSuiteAE asset diagnostics

**Application to Measurement of the Degree of Coke Deposition**

Considering the features of the Fault Monitoring Diagnostics and the following reasons, we concluded that the Fault Monitoring Diagnostics could be applied to the ethylene cracking furnace of the petrochemical company as a tool for measuring the degree of coke deposition.

- The degree of coke deposition can be estimated using only process data of an existing DCS.
- No additional costs, such as installation of new sensors, are required.
- Using the available historical data, the feasibility of applying the tool for coke measurement can be examined beforehand.
- Using the software, operators can easily check the diagnostic results.

**EXAMPLE OF INTRODUCTION OF THE ASSET PERFORMANCE DIAGNOSTICS SERVICE**

This section describes an example of applying the Asset Performance Diagnostics service to an ethylene plant.

**Service Implementation Procedure**

At the beginning of implementing the Asset Performance Diagnostics service, we conducted phased studies with the customer to establish an energy management system for energy conservation.

- Step 1: Select ethylene cracking furnaces as a target plant since they consume a large amount of energy, and then collect operation data and analyze the relevant operations including maintenance.
- Step 2: Establish a framework for the evaluation such as means for saving energy and formulas for economic calculation.
- Step 3: Propose an energy conservation program based on the result of Step 2 to the top management of the customer.

These steps are necessary for accurately evaluating the economics of the service because energy and maintenance costs vary depending on the plant and country.

**Measuring the Degree of Coke Deposition and Calculating the Optimum Steam Supply**

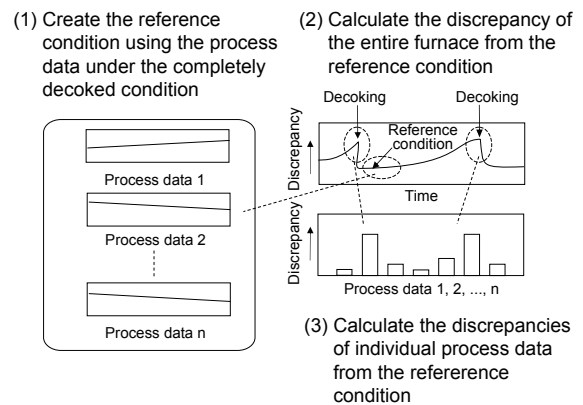
This section explains methods for measuring the degree of coke deposition using the Fault Monitoring Diagnostics in the ISAE asset diagnostics package and for calculating the optimum amount of steam supply based on the coke measurement.

The Fault Monitoring Diagnostics monitors in real time the process status, i.e. whether the process is in a normal or abnormal state, and the causes of faults, the criteria for which are usually represented by process data of multiple variables such as temperature, pressure and flow rate.

For calculating the criteria, we used process data acquired only from the existing instrumentation. We used historical data to create a reference condition as described below, and could thus reduce the time required for data acquisition for creating the reference condition. As a result, it took only about three months to finish all the studies.

1) Creating the reference condition

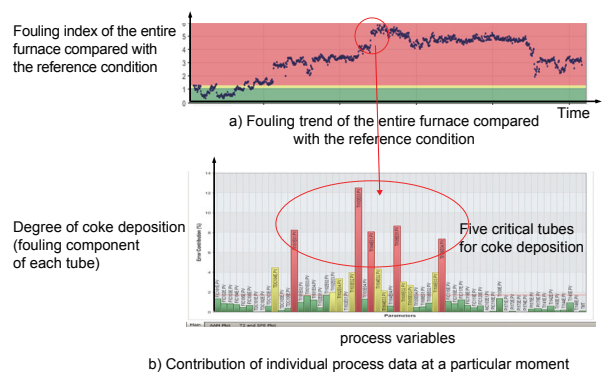
As a reference for further studies, we created a reference condition based on the operation data under the completely decoked condition such as just after turnaround maintenance. Throughout the diagnosis cycle of operation between decoking, discrepancies from the reference condition are calculated and statistically evaluated as the degree of coke fouling of the entire furnace and each tube as shown in Figure 3.



**Figure 3** Outline of evaluation method by the ISAE Fault Monitoring Diagnostics

2) Measuring the degree of coke deposition

As shown in Figure 4 (a), the fouling index of the entire furnace, calculated from the discrepancies of all the relevant process data from the reference condition, generally increases with time. At the end of the cycle, each component of the fouling index is reviewed and major components contributing to the index are selected based on multivariate statistics. Among them, process variables relating to individual passes are compared in the order of discrepancy from the reference condition. The level of discrepancy is assumed to be the degree of coke deposition. Figure 4 (b) shows an example of the result of calculating the degree of coke deposition.



**Figure 4** An example of visualizing the degree of coke deposition of tubes by the ISAE Fault Monitoring Diagnostics

3) Calculating appropriate steam supply

After calculating the degree of coke deposition, we calculated the total steam supply appropriate for decoking and the steam supply for each tube based on the discrepancy of the degree of fouling of the entire furnace from the reference condition and the degree of coke deposition of each coil tube.

**Expected Economic Effects**

The degree of coke deposition of each tube is calculated by using the Fault Monitoring Diagnostics. Based on the estimated coke deposition, decoking operation optimizes the amounts of steam and air supply for decoking and the interval between decoking operations. The following effects can be expected by decoking optimization.

- Extending the operation period between decoking operations by one day
- Reducing the steam and air used for decoking
- Extending the life of the coils by reducing the average operating temperature

In this example, the diagnostics was conducted on one ethylene cracking furnace. Since this plant has similar multiple furnaces, the following amounts of utilities will be saved every year if the same best practice is applied to all the furnaces.

- Electricity: 240,000 kWh (134 tons CO<sub>2</sub> equivalent) [estimation]
- Steam: 1,700 tons (265 tons CO<sub>2</sub> equivalent) [estimation]
- Fuel: 300 tons (795 tons CO<sub>2</sub> equivalent) [estimation]

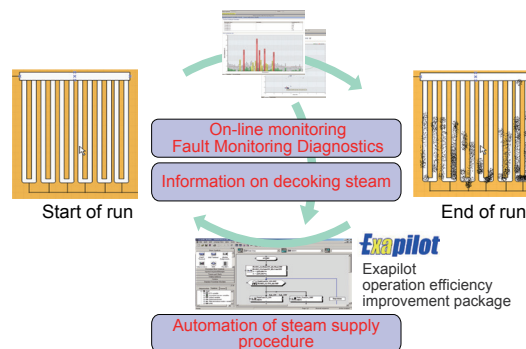
**Proposal of Maintenance Plan**

As the third step of this service, Yokogawa developed and proposed the following maintenance plan focused on energy consumption.

- Conducting controlled decoking based on the predicted coke deposition for the targeted cracking furnace from the next regular maintenance.
- Applying the same best practice to the other furnaces of the plant.

**Future Development**

To automate this series of operational procedures from estimating coke deposition to adjusting the air and steam rate to each tube, Yokogawa proposed the Exapilot operation efficiency improvement package<sup>(1)</sup>, which assists and guides the plant operators, as shown in Figure 5. The customer is now considering its introduction.



**Figure 5** Automation of ethylene cracking furnace diagnostics and maintenance

**Comments from the Customer**

The customer appreciated our services and recommendations as follows.

- The InsightSuiteAE asset diagnostics package can monitor the overall health of plant equipment, and is easier for engineers to use than other companies’ diagnostic tools.
- The diagnosis results are displayed on-screen, enabling the engineers to easily monitor the equipment in real time.
- We are very satisfied with the InsightSuiteAE that helps improve the energy efficiency and the maintenance workflow.

**CONCLUSION**

We proposed to the customer to introduce the Asset Performance Diagnostics service using the ISAE asset diagnostics package as a means of optimizing the decoking operation. The service demonstrated that the tool could predict the degree of coke deposition inside the tube walls, where no sensor could measure it. It also established the best practice of the furnace maintenance plan to save energy. Although the economic benefits of the proposal are still being verified, it is reported that the actual volume of steam reduction is as much as was estimated.

The financial value of the service benefits varies depending on the local utility supply scheme of the plant, and whether electricity and steam are imported or not.

The Fault Monitoring Diagnostics introduced in this paper can be applied to maintenance works other than decoking by utilizing the historical process data during daily operation. Other ethylene companies have used it not only for decoking but also for other equipment. We are planning to apply the diagnostics to equipment other than cracking furnaces considering the usefulness of this diagnostics tool.

**REFERENCE**

(1) Yasunori Kobayashi, “Exapilot, Assistant Package for Improvement of Operational Efficiency,” Yokogawa Technical Report, Vol. 43, No. 3, 1999, pp. 17-20 in Japanese

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