Develop an Optimal Cleaning Strategy for Crude Preheat Trains

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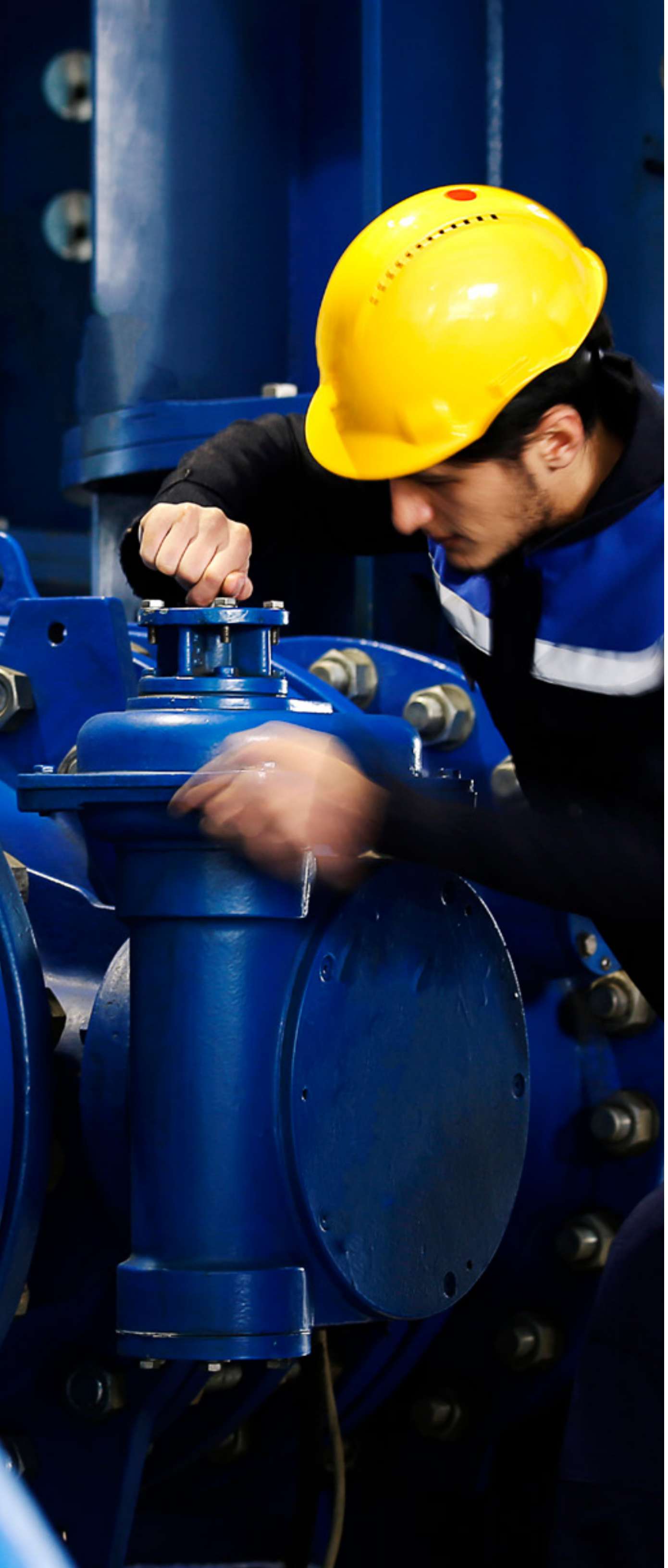

Introduction

Fouling in heat exchangers is common throughout the process manufacturing industries. There are many different types of fouling, such as particulate, crystallization, corrosion, chemical reaction and biofouling. They all have the same impact, lowering the overall heat transfer coefficient of exchangers, impeding fluid flow, accelerating corrosion and causing an increase in pressure drop across exchangers. According to one study, losses due to fouling in industrialized nations constitute an alarming 0.25 percent of the GDP.[1] To combat these losses, owner-operators typically spend $40,000–$50,000 USD to clean individual heat exchangers, amounting to 15 percent of the maintenance costs for a typical process manufacturing facility.[1]

Fouling presents a large opportunity for owner-operators to reduce operating expenses and maintenance costs. In refining, fouling builds up in preheat trains, lowering heat transfer efficiency, which causes the fired heater to burn more fuel to meet the inlet temperature for the distillation column. Ultimately, the furnace becomes a bottleneck because it must reduce throughput to maintain the outlet temperature specification. This reduces the capacity and throughput of the refinery, leading to significant losses.

This study outlines how process simulation software and heat exchanger design and rating software can be used to monitor fouling in a crude preheat train and will provide industry examples of success using this approach.

Recent advances in some simulators provide process engineers with seamlessly integrated models that increase simulation accuracy by more rigorously modeling heat transfer in exchangers.

Advances in Process Modeling

The procedure and case studies outlined in this article are possible because of advances in process modeling. Recent advances in some simulators provide process engineers with seamlessly integrated models that increase simulation accuracy by more rigorously modeling heat transfer in exchangers. These advances also bring operational risks and warnings to the attention of the process engineer, making it easy to identify costly problems such as vibration, excess operating temperatures, pressures and fouling.

These advances in usability and functionality streamline the workflow to obtain fouling resistances and identify optimal exchanger cleaning schedules to minimize downtime.

Generalized Methodology to Develop Cleaning Schedule and Frequency

While the details of what will be appropriate for a particular plant or application depend upon a number of factors, the following steps should provide a good framework for developing a model-based approach to improve heat exchanger maintenance and increase exchanger efficiency.

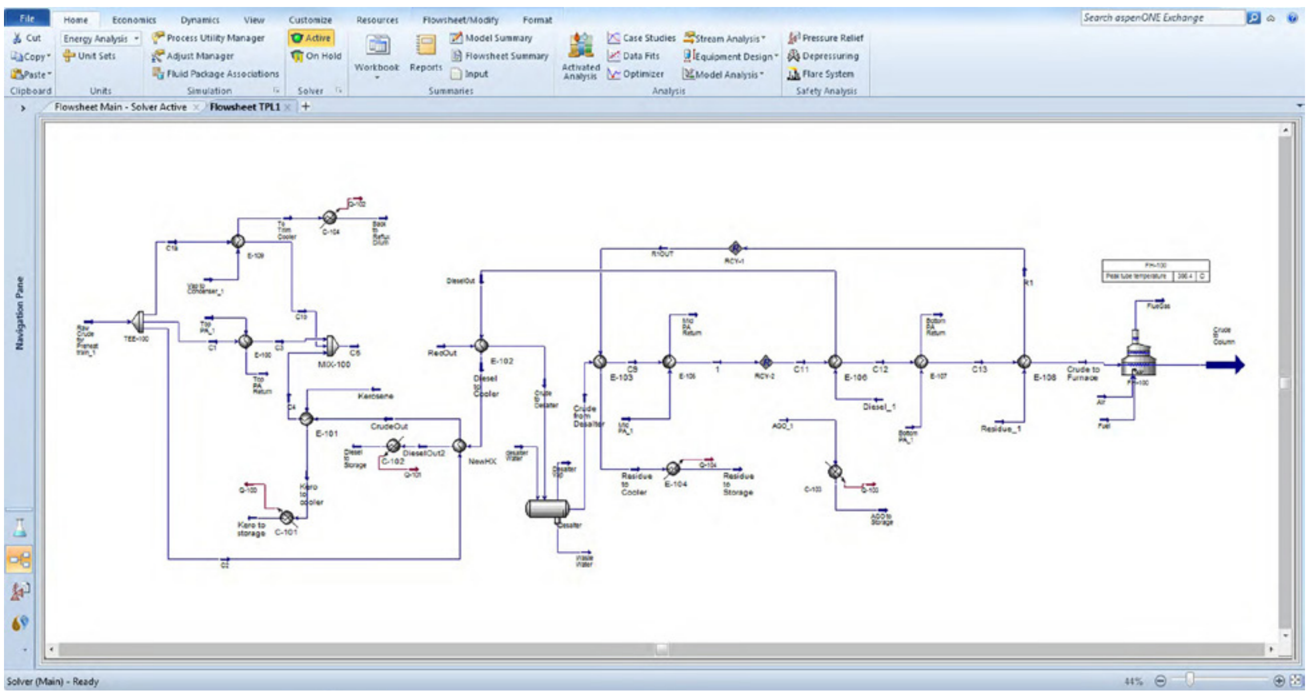

Figure 1: Process model for a preheat train, including the fired heater.

1. Build a process model.

The first step is to build a process model of the preheat train, including the furnace, preceding the crude distillation unit (Figure 1). While building the process model, it is considered a best practice to utilize simple linear heat-curve-based (end-point) heat exchangers, as this allows the flowsheet to solve in less time and makes it easier to get the flowsheet to converge.

2. Develop rigorous heat exchanger models.

The next phase is converting the simple end-point exchanger models to rigorous models using the existing exchanger design parameters, such as the number of tubes, tubes per pass, Tubular Exchange Manufacturers Association (TEMA) type, etc. These details can be found on the heat exchanger specification sheet from the manufacturer.

Some process simulators have integrated exchanger design and rating capabilities, which allow the user to convert heat exchanger models from simple to rigorous without leaving the process simulator. Software should be compared based on the research on which the models are based and their industrial acceptance. Other important considerations include the quality of the integration between the exchanger software and the process simulator, the ease of use and the performance.

Simple heat exchanger models can be converted to rigorous models selectively based on engineering judgment. Once the necessary exchangers are in the preheat train, and the fired heater into a rigorous model, ensure that the flowsheet has re-converged before moving on to the next step.

3. Obtain plant data for temperatures and flowrates.

The most critical pieces of data should be used to calibrate the process simulation model. It is possible that the plant data may not be heat and mass balanced, in which case the data must be reconciled.

4. Calculate the fouling resistance using plant data.

Once the plant data is secured, the next step is to incorporate the process data into the simulation for each rigorous heat exchanger. Using the maximum fouling operating mode, the process simulator can determine the fouling factors for a variety of scenarios, including hot-side fouling only, cold-side fouling only, or both sides based on fouling input—or adjustments can be made to both sides, using equal fouling.

These different calculation types account for the many ways in which fouling can be distributed on a heat exchanger. For example, on the cold side of an exchanger, the fouling can be from salt deposition, hence, it can be mostly attributed to the cold side. In comparison, on the hot side of an exchanger with crude, vacuum residue, vacuum gasoil, etc., the fouling should be attributed to both the hot and the cold sides.

Fouling factors should be calculated over a period of time to identify fouling trends. Plotting the fouling resistance vs. time can determine the exchangers that foul the fastest.

5. Vary fouling resistances, evaluate cleaning scenarios.

Once the fouling resistances have been calculated, it is possible to use the process simulator to evaluate a number of different questions, including how to best optimize the heat exchanger cleaning pattern, method and frequency. Heavily fouled exchangers can be evaluated offline by switching flow to other exchangers; the exchanger that has the biggest impact on fuel savings for the furnace can be determined, or the impact of switching the hot and cold sides of an existing exchanger can be assessed. Using this method you can calculate the impact of new crudes on heat exchanger fouling, the amount of furnace duty required to process new crude and the optimum blend.

Case Studies

A leading independent European crude oil refiner with a total throughput capacity exceeding 400 Mbpd used an advanced process model and software system to develop conceptual design and operation improvements.[a] This refiner also enlisted an innovative heat exchanger software and modeling program to evaluate fouling and process performance for the crude preheat unit and heat exchanger network (HEN).[b]

By interfacing with Excel, the refiner was able to evaluate rinsing and cleaning procedures, resulting in significant savings of close to $4 million USD annually.

A services company was challenged to increase the usability of an in-house tool to monitor pipe fouling in heat exchangers in a crude preheat train.[b] The tool was used to avoid the over-cleaning of heat exchangers, incurring extra maintenance costs and downtime. Combining the process optimization and heat exchanger modeling programs, a new tool was devised that enabled operators to reduce the time to complete the task from 6–12 hours to only 10–20 minutes, while avoiding over-cleaning.[a, b]

Using process simulation and heat exchanger design and rating tools, process engineers have the ability to develop cleaning and operating strategies that can mitigate the impact of fouling on fired heater operating costs and constraints, while maintaining process throughput.

NOTES

a Aspen HYSYS® is a process modeling system that enables the optimization of process design and operations.

b Aspen Shell and Tube Exchanger is a program that generates design for all major industrial shell-and-tube heat exchanger equipment and applications. It includes single-phase condensation and evaporation and is a unique tool to monitor fouling and process performance for exchangers.

LITERATURE CITED

1 Ibrahim, Hassan Al-Haj, Fouling in Heat Exchangers, University of Auckland, Centre for Continuing Education, InTech Open, Auckland, New Zealand, October 2014.

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