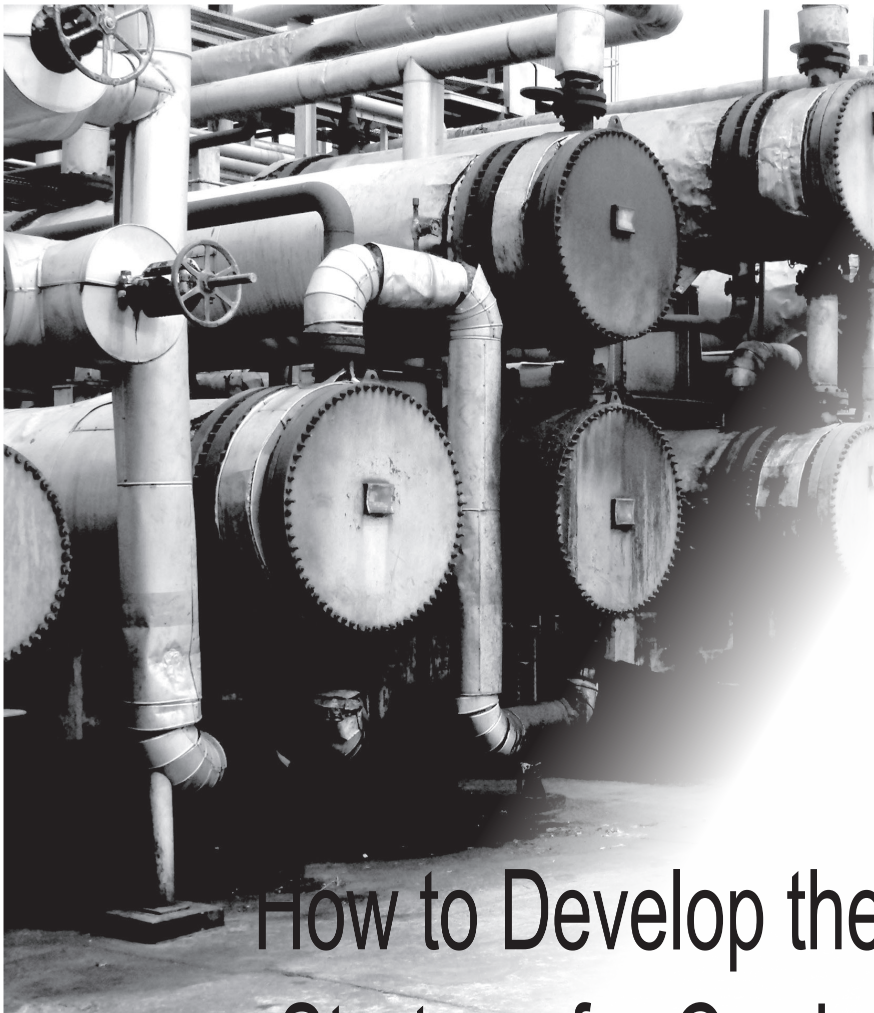

Fouling lowers the overall heat transfer coefficient of exchangers, impedes fluid flow, accelerates corrosion, and causes an increase in pressure drop across exchangers.

This paper outlines how process simulation software and heat exchanger design & rating software can be used to monitor fouling in a crude pre-heat train and industry examples of success using this approach.

How to Develop the Optimal Cleaning Strategy for Crude Pre-Heat Trains?

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Fouling presents itself as a large opportunity for owner operators to reduce operating expenses and maintenance costs. This is especially critical for refineries where profit margins are typically less than 15%.

Fouling in heat exchangers is common throughout the process manufacturing industries. There are many different types of fouling, such as particulate fouling, crystallization fouling, corrosion fouling, chemical reaction fouling, and biofouling—but they all have the same impact on exchangers. According to one study, losses due to fouling in industrialized nations amounts to an alarming 0.25% of the GDP.[1] To combat these losses, owner operators typically spend $40-50k to clean individual heat exchangers—amounting to 15% of the maintenance costs for a typical process manufacturing facility.[1]

Fouling presents itself as a large opportunity for owner operators to reduce operating expenses and maintenance costs. This is especially critical for refineries where profit margins are typically less than 15%. In refining, fouling builds up in preheat trains leading to many different pieces of equipment, including the crude distillation unit. This build up lowers 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.

Advances in process modeling

The procedure and case studies outlined in this paper are possible because of advances in process modeling. Process simulation and heat exchanger design and rating software has been available to the process industries since the 1980's; however, recent advances in some process simulators provide process engineers a simulator with a seamlessly integrated rigorous heat exchanger models that increase simulation accuracy by more rigorously modeling heat transfer in exchangers. These advances also bring operational risks

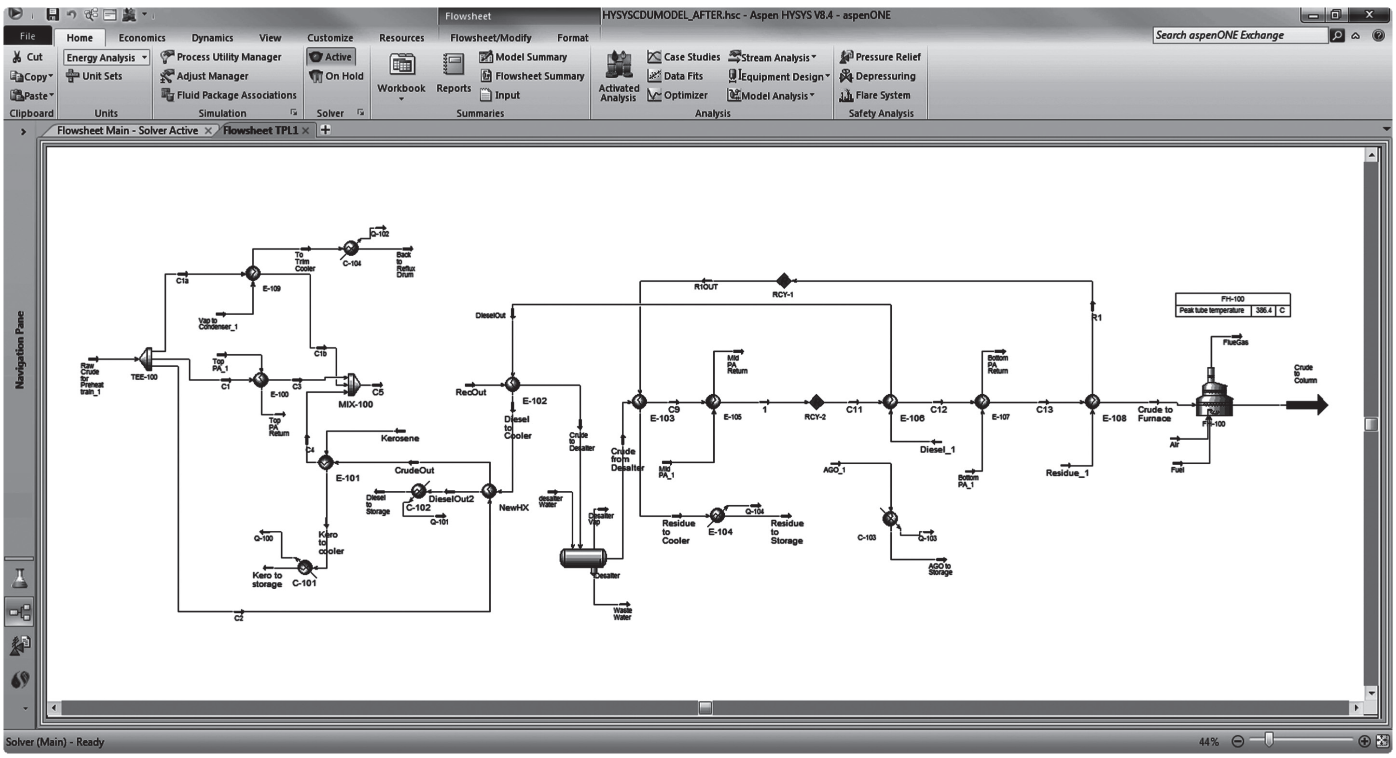

Figure 1: Process model for a pre-heat train, including the fired heater

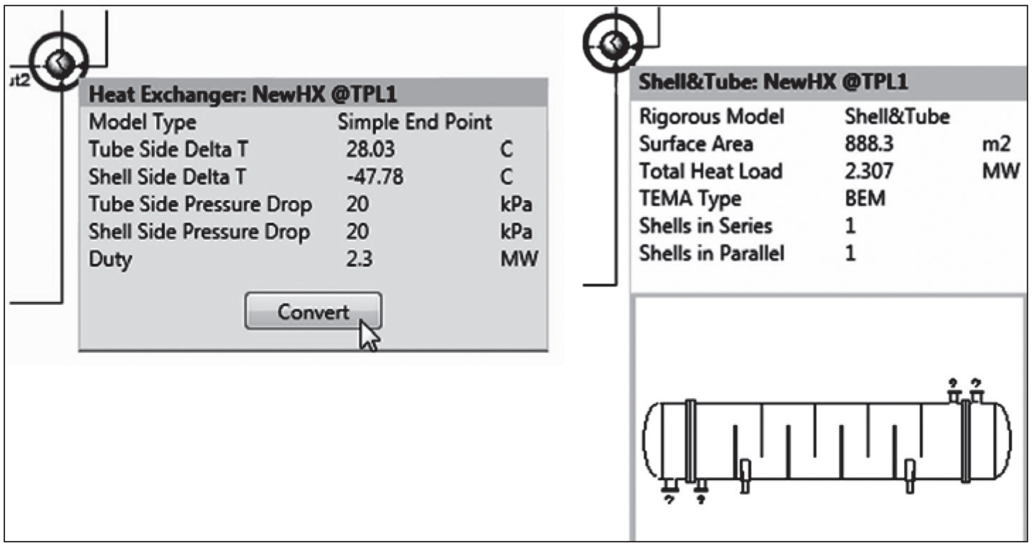

Figure 2: (*Left*) **A simple end point heat exchanger model overview.** (*Right*) **A rigorous heat exchanger model overview**

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, identify optimal exchanger cleaning schedule, and identify the optimal exchanger cleaning frequency to minimize downtime.

Step by step methodology

The following is a generalized approach to developing an optimal cleaning schedule and frequency. While the details of what will be appropriate for a particular plant or application will be dependent on a number of factors, this should provide a good framework for developing a model-based approach to better heat exchanger maintenance and improved exchanger efficiency:

Step One: 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. 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.

Step Two: Develop rigorous heat exchanger models

The next step is to convert the simple end point exchanger models to rigorous models using the existing exchanger design parameters, such as the number of tubes, tubes per pass, 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. When evaluating these exchanger design and rating software options, software should be compared based on the research on which the models are based and the models 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

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. This method has been utilized by refiners worldwide and they can look forward to future innovations in this area as they strive towards process optimization.

performance.

Simple heat exchanger models can be converted to rigorous ones selectively based on engineering judgment, and once you've the necessary exchangers in the pre heat train, as well as the fired heater into a rigorous model, make sure the flowsheet has re-converged, and move on to the next step.

Step Three: Obtain plant data for temperatures and flow rates

Fouling monitoring should start with analysis of plant data from refinery data historian. The most critical pieces of data are the flow measurements and the temperature measurements. The 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.

Step Four: Calculate the fouling resistance using plant data

Once you've obtained your plant data, 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, both sides based on fouling input, or you can adjust 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 gas oil, etc., the fouling should be attested to both the hot and the cold side.

Using the Maximum Fouling Operating Mode and plant data, fouling factors should be calculated over a period of time to identify fouling trends. Plotting the fouling resistance versus time, you can obtain an idea of which exchangers foul most quickly.

Step Five: Vary fouling resistances, evaluate cleaning scenarios

Now that the fouling resistances are calculated, it is possible to use the process simulator to evaluate a number of different questions, including how to optimize the heat exchanger cleaning pattern, method, and frequency. You can evaluate taking heavily fouled exchangers offline and switching flow to other exchangers. You can evaluate which exchanger has the biggest impact on fuel savings for the furnace, or you could also evaluate the impact of switching the hot and cold side of an existing exchanger.

Using this method, you can also evaluate the impact of new crudes on heat exchanger fouling, how much furnace duty is required to process a new crude, and what is the optimum blend.

Case Studies

European owner operator

A leading independent crude oil refiner in Europe with a capacity of over 400,000 barrels of crude per day used Aspen HYSYS and Aspen Shell and Tube Exchanger to create a tool for operators to use to monitor fouling and process performance. They needed an easy to use a tool to guide maintenance decisions. By interfacing with Excel, they were able to develop a tool to evaluate rinsing and cleaning procedures resulting in significant savings—upwards of $4MM/year.

Services company working for a middle eastern owner operator

Working for a major middle-eastern owner operator, 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. The tool was used to avoid over cleaning heat exchangers, incurring extra maintenance costs and downtime. Using Aspen HYSYS and Aspen Exchanger Design and Rating's Shell and Tube Exchanger they were able to devise a new tool for use by operators that reduced the time to complete the task from 6-12 hours, to only 10 to 20 minutes—while avoiding over cleaning.

Closing thoughts

Knowing how and when to clean heat exchangers is critical to reduce operating expenses and maintenance costs in refineries. 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. This method has been utilized by refiners worldwide and they can look forward to future innovations in this area as they strive towards process optimization.

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