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APPLYING TECHNOLOGY ADVANCEMENTS TO IMPROVE HEAT EXCHANGER ECONOMIC AND ENVIRONMENTAL PERFORMANCE IN REFINERY CRUDE PREHEAT TRAINS

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ABSTRACT

Fouling of heat exchangers in crude preheat trains is a major refinery operations business factor. It is realised that fouling cannot be completely eliminated, but considerable economic and environmental benefits are available with the proper application of improved technology in both the equipment and software asset management tools areas. This paper presents a technology update of refinery applications of a heat exchanger network analysis software to identify optimal crude preheat train cleaning.

INTRODUCTION

At today's high energy prices, there are significant incentives for a long term strategy to combat fouling problems. The best strategy is a multi-disciplined approach that will include a combination of: detection of fouling through monitoring, prevention through design and modification of crude or surface properties, and mitigation through optimized cleaning.

Measures to reduce or prevent fouling include changes in crude scheduling, logistics, slop management, improved desalter operation, and replacing selected hardware by more fouling resistant designs. To detect fouling and devise optimum cleaning schedules we need tools that can work efficiently with available operating data and come to the proper conclusions.

MONITORING SOFTWARE NEEDS

With hindsight, many operators believe that a large part of the losses due to heat exchanger fouling are avoidable. This has led to the development of specific software to identify interactions between the heat exchangers in a train and to monitor the total heat duty and the associated influence on economic and environmental factors which include capacity impact, energy consumption, and CO2 production. Such software can calculate the benefits of cleaning one or more exchangers and the best time to clean a particular exchanger. Additionally, it should be able to compare practical cleanout strategies to the calculated optimal strategy.

The accuracy of the calculations can be improved and significant savings achieved if fouling trends can be predicted. The optimum run-time for a single heat exchanger can be determined relatively easily by balancing efficiency and margin losses due to fouling against the cost of cleaning. However, determining an optimal cleanout strategy for a train of heat exchangers is complex. In practice, the operation of integrated heat exchanger networks allows manipulation of heat duties in order to mitigate the effects of low levels of fouling. Moreover, some exchangers are controlled to transfer fixed duties. These effects need to be considered in any realistic assessment of optimum cleanout advice.

HEAT-For-Networks (HEAT4N) SOFTWARE

HEAT4N is a flowsheet based software tool that has been developed to monitor the fouling tendency and also to assess the need for cleanout maintenance of individual heat exchangers within complex trains. Ordinarily instrumentation limitations can make it difficult or impossible to estimate missing intermediate temperatures and flow splits. HEAT4N software overcomes this problem using state-of-the-art statistical techniques. Since its introduction in 2003, HEAT4N has been applied at several refineries, which are also actively using the tool to monitor fouling, to predict the effect of different cleanout cycles, and to make decisions on replacing heat exchangers.

Applications of HEAT4N currently focus on petrochemical sites and in particular crude preheat trains, where optimal cleaning strategy is very dependent on determining how heat recovery can be manipulated on-the-run, in order to minimise the impacts of fouling on the profitability of the running unit.

The program GUI (Fig. 1) has many advanced features -- different material streams can be shown by using different colours, temperature and flow tags are shown, and daily or long-term averaged data can be used.

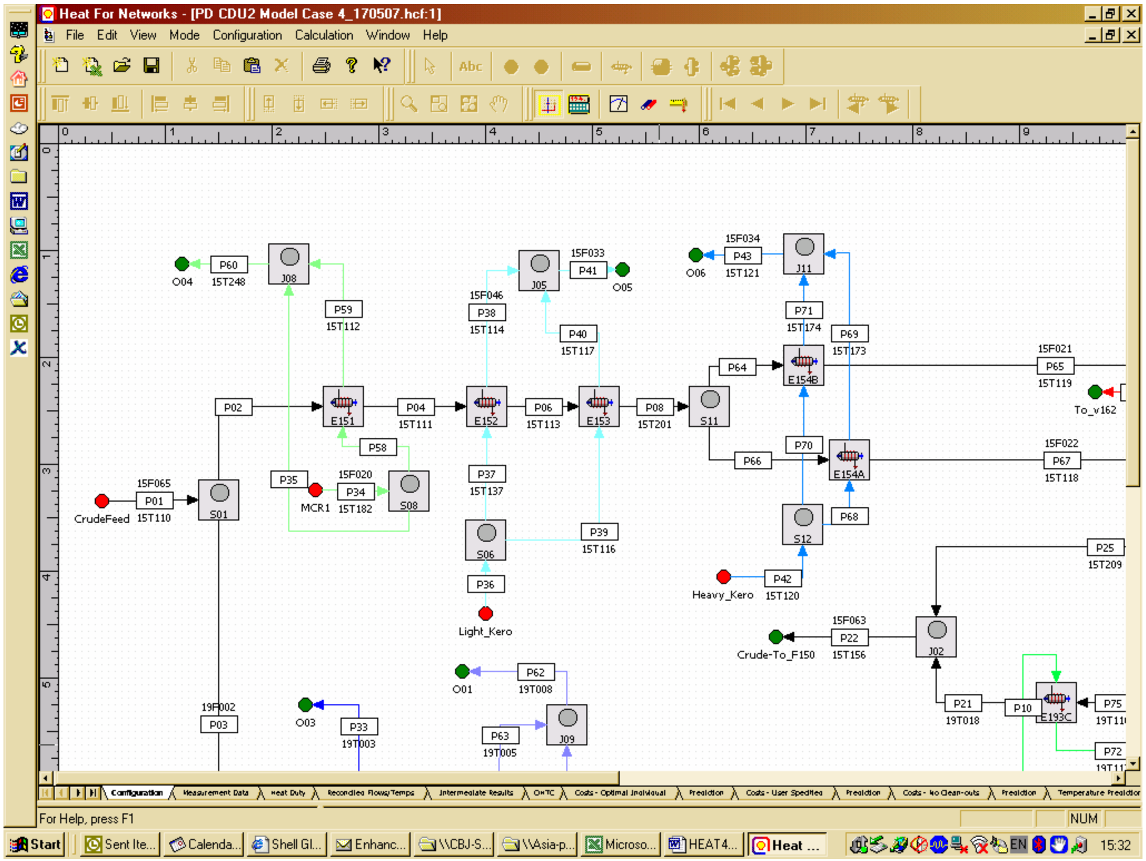

Figure 1 HEAT4N Graphical User Interface

HEAT4N ANALYSIS

A HEAT4N analysis starts with the development of a configuration model from the process flow schemes. In the data pre-processing phase, flow and temperature data are cleaned (i.e. outliers and non-physical values are removed) and reconciled using statistical methods. After these steps information about wrongly calibrated or broken instruments is presented.

The reconciled data are then used to calculate the overall heat transfer coefficient (OHTC) and heat duty for every heat exchanger in the train. The calculated OHTC's can then be used to fit a fouling model, as can be seen in Fig. 2. The different estimated trends are used to determine an average fouling model which is then used to predict future fouling trends.

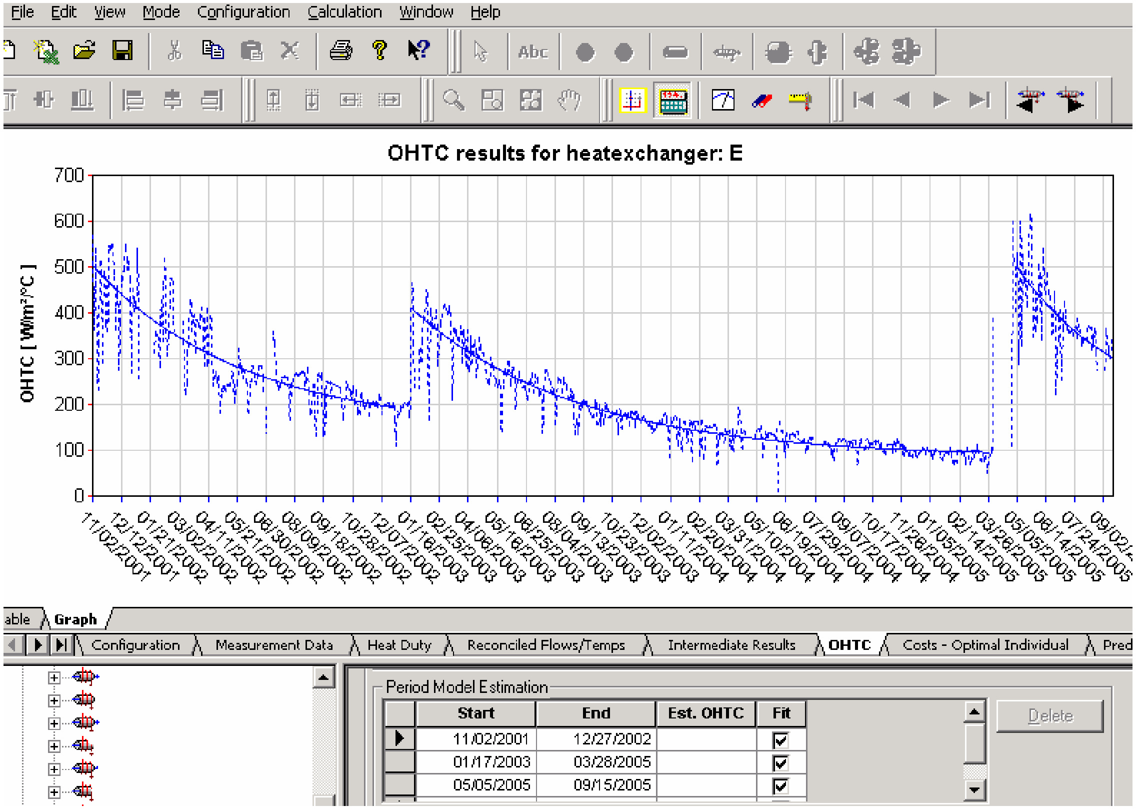

Figure 2 Trends are fitted through the daily calculated OHTC's

The estimated models, together with cost parameters are used by the tool to determine an optimal clean-out scheme. The results are shown in tabular format, as in Table 1. The effects of the optimal schedule on the temperatures and heat duties everywhere in the train are also calculated and displayed in tables or in plots. Table 1 shows an optimal cleaning advice and regret costs generated for each heat exchanger in a train. The first column contains the heat exchanger name. The second column is the average "efficiency" of the heat exchanger, with which problem heat exchangers can be recognized. The third column contains the advised optimal cleanout period, so the advice for HX1 is to clean after 0.8 years. The fourth column is the average overall cost containing the efficiency loss and cleanout costs over the prediction time (in this example the throughput and product quality loss costs are not taken into account, although these may be significant). The last column contains the cumulative regret costs, related to postponing the advised cleaning actions by one year. It can be seen in this column that postponing the clean-out action for one year for some heat exchangers doesn't influence the average overall costs of the train. For example the advice for HX2 is to clean it after 4.4 years, which means in this case no cleaning is necessary during the prediction period, so the regret costs are nil. However, for HX3 the regret costs are 96k.

Table 1 Typical HEAT4N Result Table

Name of heat exchanger	Actual/clean duty	Optimal clean-out frequency [years]	Average Overall Costs [euro/day]	Cum. Regret costs in 1 year [euro]
HX1	92	**0.8**	140	27330
HX2	93	**4.4**	184	0
HX3	76	**0.6**	1306	95610
HX19	68	**0.6**	1826	64146
HX20	96	**4.7**	106	0
HX21	82	**0.7**	464	66998

With HEAT4N it's also possible to evaluate other cleanout scenarios, for example a user-defined maintenance strategy, or the effect of no cleaning at all. Fig. 3 shows that the effects of different clean-out strategies on the furnace inlet temperature (FIT) can be dramatic. The green line corresponds to the advised optimum clean-out scheme. The blue line shows a user-specified clean-out scheme, which leads to a lower averaged FIT compared to the green line. And the black line is a worst case scenario where the heat exchangers aren't cleaned out at all.

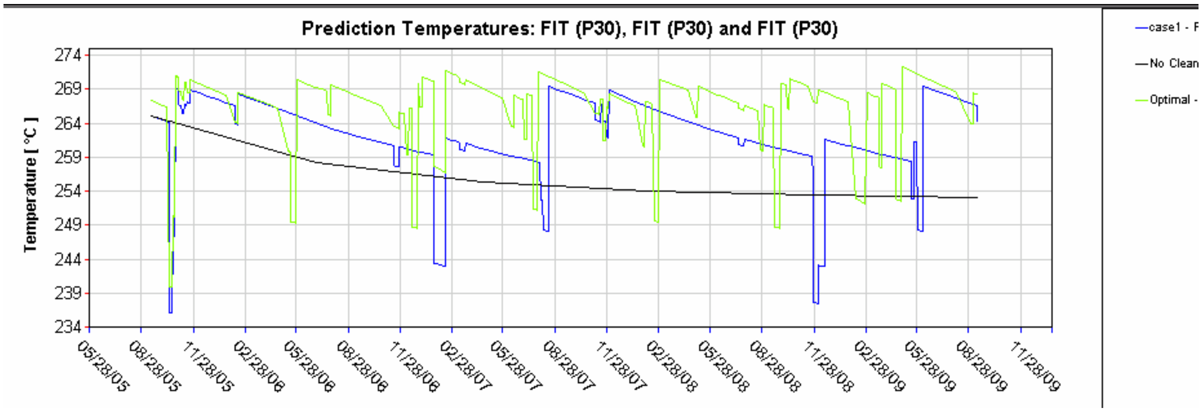

Figure 3 The effects of clean out strategy on FIT

Reports with all the information delivered by the tool, such as cost information, can automatically be generated for different fouling scenarios. This way the effect on the costs of different fouling abatement strategies can be compared. A convenient way to use HEAT4N is to determine an optimal clean-out schedule, evaluate fouling mitigation strategies and compare the results with the base case, which represents current practice, so that a good estimate of the cost savings is obtained. Experience shows that refinery operators don't often have the tools to determine the optimal clean-out schedule; they only perform cleaning based on opportunity or previous experience. The above example shows that the clean-out period of some heat exchangers can be extended, whereas others should be cleaned more often. This demonstrates that clean-out optimization can have a beneficial effect not only on the maintenance budget, but also on efficiency improvement.

For example, many older process plants with parallel heat exchangers lack bypasses, necessary for online bundle isolation and cleaning whilst the unit remains online. The economic penalties of taking parallel networks out of service for cleaning can be quantified together with the savings used to install appropriate bypassing facilities. Indeed, the business case for procuring replacement heat exchanger bundles for highly fouling bundles can also be determined and justified for situations where the maintenance cost elements are a large part of the total cost of the cleaning activity. In this situation it may be more economic to purchase replacement heat exchangers, rather than clean fouled exchangers with a high frequency.

For several refineries HEAT4N has been used to develop a long term clean-out strategy for a single crude preheat train, resulting in a sustained increase in the Furnace Inlet Temperature of several degrees Celsius. This caused significant fuel savings, margin benefits, and savings because of a reduction in CO2-emissions.