Optimization of Refinery Preheat Trains: Predictive Maintenance and Operations Improvement

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Abstract

Deciding which heat exchanger to clean, when to clean and how to clean in refinery pre-heat trains is a challenging activity that typically relies on operator's experience. In this paper, an algorithm that allow identifying the most economic cleaning schedule for a given refinery configuration and operating conditions is presented. The method relies on an advanced framework that incorporates rigorous heat exchanger models capable of predicting the fouling behaviour of the refinery as a function of configuration of the individual units and the network, process conditions and time. An industrial case study is presented to illustrate the benefits of the approach, showing that significant improvements over current practice can be obtained.

Introduction

The atmospheric crude distillation unit is the largest energy consumer in the entire refinery. Thus the efficiency of the pre-heat train, which recovers heat from the hot fractionation products, plays a pivotal role for profitability and sustainability [1]. Fouling, the deposition of unwanted material on thermal surfaces, hinders the ability of the pre-heat train to recover heat and forces operators to burn more fuel at the furnace leading to increased costs and environmental impact as well as loss of throughput when the firing limit is reached.

In common practice, maintenance decisions, such as which heat exchanger to clean and when, are driven by a limited amount of information (typically the calculation of the fouling resistance) and operators' past experience. In this paper, advanced models [2]–[4] are used to predict fouling in refinery preheat trains and provide actionable information for predictive maintenance and operations improvement. An improved method for the simultaneous optimisation of cleaning schedules and optimal operations of flow splits is presented and its benefits illustrated with an industrial case study.

Method

The method, implemented in Hexxcell Studio™, allows quantifying and optimising the interactions between cleaning actions and flow split operations and provides information on i) which is the best heat exchanger to clean based on economic considerations including energy at the furnace, potential loss in production and cleaning costs; ii) the preferred cleaning method (i.e. chemical or mechanical); iii) a full cleaning schedule to be implemented over the next year of operations; iv) an assessment of different production scenarios, v) the optimal operation of flow split for the given cleaning schedule proposed.

The algorithm evaluates different cleaning and/or control scenarios at decision points distributed over the time horizon to be explored. At each decision point, the algorithm selects the best heat exchanger to clean, among those that satisfy certain pre-defined constraints, and the best split fraction, according to the key performance criteria in a future operational window. The decision times can be pre-defined at a fixed frequency, or triggered by threshold value of the operation of the network. The algorithm can handle inequality constraints that set limits on the economic savings, energy savings, and/or coil inlet temperature (CIT) value and allow assessing different types of cleanings. The definition of the cleaning scenarios can include simultaneous cleanings of different shells in the network and various cleaning types (mechanical, chemical, or both).

Case Study

The case study involves the hot end of the preheat train of a mid-size oil refinery comprising of five heat exchangers of which four are arranged in parallel branches. Fouling in each of the exchangers is predicted with deposition models fit to and validated against extensive sets of plant data. For simplicity and for the sake of comparison among different alternatives the inlet conditions are assumed constant. In the example, a logic based on economic key performance indicators (KPIs) is selected as a criterion to optimise the operation of the train over an operation period of 1500 day corresponding to a run in between major shutdowns. The economic trade-off involves the costs of fuel in the furnace (which increase with fouling), possible losses in production if the furnace reaches its maximum capacity and the cost of cleaning. The flow split optimization is analysed in a range of 30 % to 70 %.

Results

Five scenarios are defined to show all the capabilities of the cleaning scheduling algorithm:

1) Cleaning scheduling with fixed split fraction at 50 %;
2) Flow split control, without cleanings;
3) Simultaneous cleaning scheduling and flow split control.

The analysis of the results, summarized in Table 1, show that the schedule implemented by the refinery (Case A) allowed a significant saving, estimated in \$3.57 MM, compared to the no action case (Case 0). However, it is estimated that the cleaning scheduling with a fixed flow split proposed by the algorithm (Scenario 1) would have saved a further \$0.5 MM. Scenario 2 (only flow split control) provides significant savings of \$2.2 MM compared to the no action case (Case 0). This indicates that the branches are not balanced in terms of energy recovery once fouling start occurring thus the original design that may be appropriate in clean conditions, is not the optimal configuration for real life operations. However, optimising the flow split alone does not provide any benefits compared to Case A, showing that implanting a cleaning is necessary to maintain the profitability of the operation. Finally, the results show that the simultaneous optimisation of cleaning scheduling and flow split (Scenario 3) provides the most benefits to the refinery, quantified in \$2.7 MM savings over Case A and in over 50% additional savings compared to the case where the flow split was kept fixed at the nominal value. This is expected as the interaction between the flow split distribution and the cleaning of a heat exchanger provides more alternatives that satisfy the process constraints, increasing the number of cleanings that are economically advantageous.

Table 1. Results of cleaning scheduling and flow split control defined using Hexxcell studio

Case	**Cleaning scheduling**	**Flow split control**	**Economics**				**Cleanings**					
			Fuel cost [MM\$]	Cleaning cost [MM\$]	Total cost [MM\$]	Savings w.r.t. A [MM\$]	E01AB	E02AB	E03AB	E04	E05AB	Total
0	No	50%	63.84	0	63.84	-3.57	0	0	0	0	0	0
A	Actual	50%	59.33	0.94	60.27	0	5	3	2	4	3	17
1	Yes	50%	59.12	0.68	59.80	0.47	9	0	0	7	0	16
2	No	Yes	61.55	0	61.55	-1.28	0	0	0	0	0	0
3	Yes	Yes	56.51	1.11	57.62	2.65	14	0	0	13	0	27

Conclusions

An algorithm for the simultaneous optimisation of cleaning schedules and flow split operation, implemented in Hexxcell Studio™, has been described and applied to an industrial case study. The paper highlighted the importance of i) using predictive fouling models in planning pre-heat trains operations, ii) considering simultaneously cleaning actions and flow split control when planning a cleaning schedule. The case study presented allowed to quantify expected benefit of the framework in $2.7 MM savings. by comparing current practice to the model output.

References

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