Case study: Optimising defouling schedules for oil-refinery preheat trains

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In an oil refinery, crude oil is heated to 360–370°C before entering a distillation column operating at atmospheric pressure where the gas fraction and several liquid fractions with different boiling points (e.g. gasoline, kerosene, diesel, gas oil, heavy gas oil) are separated off. The crude oil is heated in two stages. The preheat train – a series of heat exchangers – heats it from ambient temperature to about 270°C when it enters the furnace, known as the coil inlet temperature. The furnace then heats the oil to the temperature required for distillation.

The purpose of the preheat train is to recover heat from the liquid products extracted in the distillation column. Without this, 2–3% of the crude oil throughput would be used for heating the furnace; with the preheat train up to 70% of the required heat is recovered. It also serves to cool the refined products: further cooling normally uses air or water.

Over time, fouling reduces the performance of the heat exchangers, increasing the amount of energy that has to be supplied. It is possible to bypass units to allow them to be cleaned, with an associated cost and temporary loss of performance. The cleaning schedule thus has an impact on the overall efficiency, cost of operation and emissions.

The group at the Department of Chemical Engineering and Biotechnology at Cambridge developed a scheduling algorithm for this non-linear optimisation problem. It yields a good, though not-necessarily optimal, schedule and can handle additional constraints, such as the presence of desalters with specific temperature requirements within the preheat train. This is now being developed into a commercial software product.

Data from two refineries – one operated by Repsol YPF in Argentina and the Esso Fawley Refinery in the UK – were used to model the systems and test the algorithm.

For the Repsol YPF refinery, when compared with current practice and including a constraint on the desalter inlet temperature, the most conservative estimate of the emissions reduction was 773 t CO/year. This assumed a furnace efficiency of 90%. The emissions reduction increased to 927 t CO/year at 75% efficiency and 1730 t CO/year at 40%. These were based on a stoichiometric estimate of the emissions from the furnace. Using a standard emission factor increased them by 7.4%.

For Esso Fawley, the estimated emission reduction compared to no maintenance was 1435 t CO/year at 90% furnace efficiency. This increased to 1725 t CO/year at 75% and 3225 t CO/year at 40% efficiency.