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What about reactor advanced process control?

The premise of advanced process control (APC) is that there is money to be made by pushing a unit against its limits while keeping the product qualities at target. This concept is easy to understand but difficult to implement because, while some qualities and unit constraints are measured, many are not. Expressing unmeasured process parameters in a numerical format suitable for our multivariable control tools is the challenge of our industry. Applications that can do it mine gold, and those that cannot join the high pile of APC garbage. Many papers have already been devoted to inferential modeling of product qualities and, hence, this editorial concentrates mostly on other unmeasured constraints.

Whatever a unit makes, the products are usually separated by distillation, and many product quality inferential methods rely on distillation thermodynamics. Column temperature profile, pressure and internal reflux conform to thermodynamic laws and, hence, provide information about the products. But the luxury of well-known thermodynamic principles does not exist when dealing with chemical reactions. How should we handle this problem? Ignoring the effect of unit conditions on by-products and catalyst deterioration is not an option, since that would render the APC counterproductive. As a minimum, we should attempt to model coke deposition on catalyst or other reactor surfaces, this being the most widespread run-time constraint.

Ethylene cracking furnaces. Consider the influence of ethylene cracking furnaces' run length on advanced control. Ethylene plants have a battery of cracking furnaces, processing different feeds at different conditions. These furnaces gradually coke up, and once a month or so come down for decoking, which takes several days. Over-cracking shortens the run length, resulting in a throughput penalty, whereas under-cracking results in a yield penalty.

Decades ago ethylene APC was based on expensive, high-maintenance furnace transfer line analyzers for determining cracking severity for each individual furnace. Such an approach provided reasonable severity control but no sexy optimization. Today, people are reluctant to make use of transfer line analyzers, and yet ethylene plant APC has evolved into a sophisticated closed-loop optimization application. Online ethylene plant optimization APC has been claimed to be more successful than other industrial closed-loop optimizers because the prices of feed and products are known, and kinetic models exist to predict cracking furnace yield patterns.

Not being convinced that ethylene furnace yield models are verifiable for partially fouled furnaces without transfer line analyzers, I still accept the notion that, when feed economics, composition and product prices are known, optimization works better. The optimizer determines furnace coil outlet temperature (COT) and throughput for each of the furnaces to optimize total production. One should pause here for a minute and reflect about the danger of making the wrong severity decision. If the object is to maximize ethylene production, the penalty for premature decoking is quite severe. Comparisons between predicted versus actual run lengths are yet to be presented in the open literature. Suppose one succeeds in modeling transfer line composition but not furnace run length, could that be a basis for plantwide optimization? Would it not be better to remove the furnaces out of the optimizer? A much reduced scope of optimizing the product separation section would still be feasible.

Continuous regeneration reformers. Moving from ethylene crackers to refinery units, reformers come to mind as units whose performance is sensitive to the catalyst coking rate. Reformers convert naphtha aliphatic molecules into aromatic ones, and coke is a by-product of the reaction. Modern continuous regeneration reformers (CCRs) are not as sensitive to the catalyst fouling as older semiregenerative units, but even so, catalyst travels through the reactor for a week or more before moving into the regenerator, and should the catalyst accumulate too much coke, that coke would overload the regenerator and force a throughput cut.

Reformer APC optimizers must consider the trade-off between catalyst fouling versus higher severity or throughput, only that is not easily done. The reforming reactions are a function of feed composition whereas naphtha PNA (paraffin, naphthene and aromatic) content is not measured frequently. Without PNA knowledge it is neither possible to estimate extent of aromatization, nor coke deposition rate. We know of only one commercial model capable of inferring PNA, extent of aromatization and fouling rate from unit conditions. Some units use onstream octane or aromatics analyzers as APC input to help control reactor severity, and that is okay as long as the APC does not attempt to maximize feed. If an APC is configured for feed maximization, it better be able to determine the catalyst coking rate or it would drive the unit right into a regenerator constraint.

I have said in a previous editorial that inferential product property modeling is the Achilles heel of our industry. It would be appropriate to expand the Achilles heel to include reactor fouling rate. I would assess that if we could infer reactor fouling rate in real time we would be able to increase the throughput to that unit by 10% or so without any added investment. **HP**

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