Question 45: What are the recent improvements in hydroprocessing units' advanced process control? What is your experience with their reliability?

PEDERSEN (UOP LLC, A Honeywell Company)

As we have all probably experienced, efficient and reliable unit operation can benefit significantly from the application of advanced process control, or APC. For example, most hydrocracking units have implemented some level of advanced control to stabilize fractionation operation or control conversion. Advanced control projects typically pay off very quickly. In the past, the industry has typically focused on implementing advanced process control to optimize one aspect of a processed unit.

Recent developments in advanced process control have been to a take a broader perspective and apply APC to optimize operation across multiple units, or even across the entire processing site. A typical goal might be to maximize a particular product while assuring that the right components are available to meet all of the product quality specifications. To achieve that objective requires methods to track stream characteristics. Online sensors are available to measure base stream properties. These are generally inexpensive and very reliable. From these base stream measurements, we can use correlations to calculate key product quality properties to make sure that we have the proper components to blend a finished product. Of course, a key to success with any online sensors or analyzers is to make sure there is a proactive maintenance program to keep them operating.

To get to the point of the question, let's consider one example. In this case, we have a simple schematic showing part of a refinery system. Three crude units are listed on the left with the FCC unit at the top, two diesel hydrotreaters in the middle, and a hydrocracker at the bottom. For this example, we will focus on increasing diesel product volume. By tweaking the operation of the two diesel hydrotreaters, and with some adjustments in fractionation in the upstream crude units, we can gain some volume increase.

However, if we take a broader view of the whole system and look at other intermediate streams and their allocation, further opportunities are recognized, as demonstrated on the next slide. A step increase in hydrocracker distillate product yield results, due to non-intuitive adjustments in operation of other units.

And finally, product quality specs are achieved by ensuring that blend components are all tuned consistent with the total blended product strategy. Another application might be APC for hydrogen network optimization.

TEMME (Albemarle Corporation)

From what I have seen in the field, it is somewhat limited to the reliability issues with product sulfur analyzers and recycle hydrogen purity analyzers. They are not always consistent performers. They have been seen to drift. Yes, there is the potential for product control via the product in the fractionation tower operation, such as product flashpoint or product haze; but not so much for cold flow product properties, because they will not be easily manipulated in the fractionation tower. So from what I have seen, more potential impact control upstream at the crude unit is possible. Because once the raw feeds get to the hydrotreaters, there is not as much control, especially with heavy feed distillation tails; specifically, higher endpoints. The point to be made here is that heavy feed tails can really significantly impact a hydrotreater performance and cycle length.

On the next slide, we have a chart for ULSD operation. The box to the right shows the process conditions. This is a really typical middle-of-the-road operation of 450 [psia (pounds per square inch absolute) hydrogen partial pressure unit. It is CoMo catalyst system. The baseline would be the 660°F D86 endpoint feed as the middle bar, with that being the reference point. The relative starting WABT reference point is set at 0 with a relative cycle length of one. If you go up on the feed endpoint by 20°F to 670°F D-86, which would be D2887 of about 750°F, you can see an 8 to 10°F start-of-run WABT increase and a corresponding 15 to 20% cycle length loss. Whereas if you go the other way -20°F reduction in feed endpoint, it is just the inverse.

Now obviously, the important point is to look at the hydrogen partial pressure. A higher hydrogen partial pressure unit is not going to have as much variation as this chart is showing. So it is important to work with your catalyst vendor to do what-if scenarios. The bottom line is: If margins are good, feed endpoints will obviously be pushed up and you will get as much bang for your buck on your catalyst investment.

MORELAND (Valero Energy Corporation)

Valero's experience with APC in the hydrotreating area: Most of the uses are around fractionation and cutpoint optimization of the different cuts. We also have some experience with temperature control for conversion in hydrocrackers, and that has been a good experience. We are taking a look currently at excursion prevention, particularly early runaway detection. We have not implemented that yet, but it is being studied now. And then, we have had mixed results around product sulfur controls and ultra-low sulfur diesel depending on the sulfur analyzer. We have some cases where it works very well and some cases where it has been disabled.

GARY HAWKINS (Emerson Process Management)

One major advancement in implementing APC is being able to run the multivariable controller within the DCS. This eases the implementation effort by virtually eliminating the development time to synchronize the data between the DCS and a separate system running the APC. Another advancement is the modularization of multivariable control strategies across similar unit operations within the refinery: not process units, but unit operations such as distillation, compression, etc. Although the distillation columns and fractionators in a refinery process different streams, from a controls perspective, they are all virtually identical with respect to the control structure: the variables measured and the "knobs to turn". They all have a level in the bottom and an overhead receiver, heat input, heat removal, reflux, side cuts, and pumparound heat removal in fractionators. Granted, there are differences between how the feed and heat are delivered to the crude column, FCC main fractionator, and hydrocracker product fractionator, but the rest is essentially the same with respect to maximizing the product stream of highest value. This has led to the development of "shrink-wrapped" APC, already designed and ready to install and commission. This makes it easy to deploy and easy to duplicate results. Also see Question 41.

PAUL KESSELER and **WILLIAM POE** (Schneider Electric)

We are not aware of any major improvements to APC technology when applied to an individual hydroprocessing unit. The one improvement we have observed is the use of online sulfur content analyzers. There are some analyzers that have proven to be accurate and reliable, thus allowing the APC to directly control the final product sulfur content by adjusting reactor temperatures. Additionally, feed maximization was possible by reducing the charge rate whenever the reactor temperature could not be increased any further due to operating constraints. The more significant improvements we have seen involve the application of an APC to a group of multiple hydroprocessing units, as well as the hydrogen production unit(s), as an overall group. APC was used to coordinate both the hydrogen production and hydrogen consumption and keep the hydrogen usage in balance. Hydrogen consumption was adjusted by either changing unit charge rates or reactor temperatures. The net results of this application were:

?Elimination of hydrogen venting to the fuel gas system,

?Stabilization of the hydrogen header pressure and faster recoveries from upsets,

?Increased hydrogen production capacity,

?Increased overall severity (hydrogen usage) by one or more hydrogen consuming units, and

?Substantial economic benefits. The reliability of this application has been quite good. Operations has a much easier time running this section of the refinery now and therefore tends to leave these applications online as much as possible.

ALLAN KERN (APC Performance)

I have 35 years of refinery process control experience, including over 15 years in direct support of operating hydrocracking units, and have published numerous papers, including papers on hydrocracker control, hydrocracker expert systems, and hydrotreater temperature control. I have led the deployment of advanced controls on numerous hydrotreaters and hydrocrackers.

In the course of this experience, I identified a number of “gaps” in the traditional hydrocracker reactor control and optimization practice (which basically comprises auto-depressure systems, multivariable control, and bed temperature quench overrides). I have also designed modified practices to close the gaps, eliminate risk of unnecessary depressure events, robustly reject excursions without loss of cracking conditions, and fully stabilize and optimize ongoing operation.

These updated practices primarily include “auto-quench” (which utilizes quench as advantageously as possible, under ALL conditions, to prevent reaching depressure conditions in the first place), “smart” bed outlet temperature controllers (to robustly reject small and large excursion disturbances while preserving and maintaining optimum reactor cracking conditions), and a model-less multivariable controller that is easily deployed and highly reliable (because excursion control is already addressed in the base-layer controls), leading to highly reliable optimization and much more reliable/achievable “conversion” control.

Conversion control is defined as automatically adjusting the reactor ABT (average bed temperature) target based on fractionation section constraints (to balance the reaction and fractionation sections) or, on two-stage units, to control the second-stage surge drum level (to balance the first- and second-stage reactions).

Tags

Catalysts

Hydrocracking Catalyst

Hydrogen

Optimization

Reliability

Year

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