Question 50: What methods or operating parameters do you use to monitor/diagnose FCCU regenerator air and catalyst maldistribution? What can be done operationally to mitigate air and catalyst maldistribution? What mechanical changes have been successful at improving air and catalyst distribution?

DAVID HUNT (W. R. Grace & Co.)

Maldistribution of air and/or spent catalyst can be diagnosed by several different symptoms.

Localized regenerator afterburn is a common symptom of non-optimal air and/or spent catalyst distribution. Regional CO bed breakthrough will combust and afterburn in the regenerator dilute phase and cyclones indicating a stochiometric imbalance of air and coke. In a partial combustion operation, localized afterburn confirms confined oxygen breakthrough from the bed resulting in CO combustion in the dilute phase and cyclones. The use of combustion promoter in either operation (full or partial combustion) is commonly used to reduce afterburn for FCCU's with non-ideal air and spent catalyst distribution.

Excessive catalyst losses are another symptom of poor air distribution resulting in localized high catalyst entrainment exceeding the capacity of the cyclones in that region of the regenerator. High velocity from a partially plugged distributor could also increase catalyst attrition producing higher catalyst losses.

Poor air distribution may also result in zones of de-fluidized catalysts within in the regenerator. High catalyst losses maybe observed due to cyclone diplegs attempting to discharge into the de-fluidized zone resulting in dipleg backup. If the regenerated catalyst enters the standpipe from any zone of de-fluidized catalyst, poor pressure builds in the standpipe maybe observed reducing unit catalyst circulation capacity or stability.

A change in air or spent catalyst distribution may also be identified by a shift in temperatures within the bed, dilute phase or cyclone outlet. Ideally these temperatures will all be similar, say within +/- 10°F. If the temperature difference increases suddenly, over time or across a shutdown then a deterioration of air or spent catalyst distribution may have occurred. Or in similar fashion if the cyclone with the historical "hottest" outlet temperature reduces and another cyclone moves to the "hottest" position then the refinery might suspect an air or spent catalyst distribution change.

Dark catalyst particles observed when the regenerated catalyst has a "salt and pepper" appearance is also a confirmation of non-ideal spent catalyst distribution and/or air maldistribution. An experienced operator "eye" is valuable in this instance.

Refiners should monitor air distributor differential pressure (dP) and compare against the expected dP calculated from the distributor design and operating conditions. Lower than expected air distributor dP suggests damage such as a hole, worn restriction orifices or distributor-arm separation from the header.

Higher than expected dP could mean a partially plugged distributor. Both issues can result in non-optimal air distribution.

The air distributor minimum dP should be maintained within licensor requirements. Minimum dP is generally maintained within a fraction of the catalyst bed differential pressure or height. Higher bed heights will require additional distributor dP to assure air distribution across the bed and to avoid catalyst ingress within the air distributor. Downward pointed distributor nozzles may require less dP relative to upward pointed nozzles. In general, a minimum dP of 1.0 psi is adequate for most circumstances.

It's difficult to significantly alter the air and spent catalyst distribution while operating. If poor air or spent catalyst distribution is resulting in afterburning or high catalyst losses which are constraining the unit, the operator may consider the following:

- Use of a combustion promoter: semi-continuous injection of promoter or premixing with fresh catalyst is often more beneficial than of one or two daily injections

- Air placement optimization for regenerator designs with multiple air rings or air distributors

- Bed level optimization to minimize afterburn (generally higher bed height) or catalyst losses (generally lower bed height)

- Use of supplemental O2 to reduce catalyst entrainment and losses

- Higher regenerator pressure to reduce catalyst entrainment and improve combustion kinetics

Non-ideal spent catalyst distribution remains a challenge in today's FCCU's despite continuous technology advancement over the last 75 years. Surprisingly, regenerators with symmetric spent catalyst distribution and robust air distributor designs in good mechanical condition can observe afterburn suggesting non-ideal air and spent catalyst distribution.

Computational Fluid Dynamic (CFD) modeling is a useful tool to confirm spent catalyst distribution for a given design and evaluate design options. (1) Optimized delivery of the catalyst to the spent catalyst distributor can also be evaluated by CFD. Licensors offer these services as part of their study and design work as well as other consulting firms.

Finally, gamma scans and radiotracer evaluations are useful studies to confirm air and/or spent catalyst distribution and provide a justification to make planned repairs or modifications during an upcoming turnaround or unit shutdown. (2)

2. Simulation as a Tool for Learning from Historical FCCU Operations, Sam Clark, AFPM Cat Cracker Meeting, 2018, Houston TX, CAT 18-980

3. FCC Regenerator Catalyst Loss Case Study, William Mixon (Tracerco), Nicolas Larsen (Marathon Petroleum Corporation), APFM Cat Cracker Meeting, 2018, Houston TX, CAT 18-653

CHRIS STEVES and ZHEN FAN (Norton Engineering Consultants, Inc.)

Looking at the afterburn (if in full burn operation) and the distribution of that afterburn at each cyclone is the primary way to evaluate the regenerator air/catalyst distribution. Cyclones with a high afterburn are probably coke rich/air deficient and CO gas from the regenerator bed is mixing with excess O2 from an oxygen rich section of the bed and causing a high afterburn.   Poor air/catalyst distribution can either be a result of the design of the unit, or mechanical damage to the air grid/ring or catalyst distribution system that should be repaired during the next available turnaround.

The distribution of air from the air ring may be impacted by bed level in the regenerator, and adjustments to the bed level can be used to evaluate the impact on afterburn. Of course, running with a higher regenerator bed level may impact catalyst losses and needs to be balanced against any potential improvement in air distribution and afterburn.

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