Residual focus

Cover story

Vic Scalco, General Atomics, USA, details how efficient separation can help to increase profits during downturn.

It would be an understatement to say that the COVID-19 pandemic has created one of the most transformative periods in our history. For the oil and gas industry in particular, the pandemic's impact has intensified the need to improve operations to weather the effects and downward demand trends caused by the ongoing crisis, as well as the anticipated uncertainty that is forecast for the months and years ahead.

Technology-led rapid supply response, flat-to-declining demand, investor scepticism, and increasing government pressure regarding environmental impact are also leading the industry into a new era of intense competition and self-examination. There is no question that oil and gas will continue to play a fundamental role in supplying affordable energy and critical products to support worldwide demand. However, without a fundamental shift-change in how the industry manages its processes and available technologies to maximise operations and create greater value, it will be difficult to return to the profitable performance that has historically prevailed prior to the onset of the pandemic.

Reactionary market trends

To answer the question of how to create greater value in this increasingly competitive, multi-trillion-dollar market, refineries need to place each gallon in every barrel under greater scrutiny for profit. The sharp drop in demand has forced some refiners to shut down, while others have reduced crude runs. Furthermore, refiners have considered rerouting process streams, and have explored enhanced integration with petrochemical facilities in an effort to reoptimise refinery processes and generate more profit from day-to-day operations.

The ongoing energy transition away from hydrocarbons is adding to the declining demand. In this environment, it will be increasingly important to execute projects that will drive additional value in the refining system. To bring greater profits to the refining sector, high-margin opportunities are emerging in the petrochemical feedstock market. At the 2020 American Fuel and Petrochemical Manufacturers (AFPM) Summit, several speakers reinforced findings that the pandemic is actually creating demand and market expansion of chemical building blocks such as propylene. Among the strongest projects for refineries to consider are those focused on upgrading the heaviest fractions of the crude oil (resid processing). Upgrading these feedstocks to petrochemicals and marketable fuel components such as high octane alkylate, propylene or high-quality marine fuels will improve industry profit potential in a challenging low product margin environment.

One of the best options available to refiners is to process heavier, low-cost residual streams in the fluid catalytic cracking unit (FCCU), while adapting conditions to produce the ideal product slate. Fluid catalytic cracking (FCC) conversion technology is scaling up, providing more options for competing against a confluence of market and regulatory forces. Many of the options under consideration involve increasing resid conversion through the FCCU.

Unprecedented demand reduction in 2020 lowered FCCU operating rates in most regions. These turndowns changed the traditional constraints on the FCC, especially unit heat balance that can be restored by processing heavier feedstocks. This process, however, has its own set of challenges for the refiner to consider. Production of resid or opportunistic feedstocks poses technical issues beyond those of conventional processing, including removal of contaminants, corrosion concerns, metallurgy selection, and increased levels of asphaltenes, while maintaining high liquid yields. Integration of process configuration technologies and operation of the FCCU, coupled with the proper separation technologies, are paramount to mitigating any technical challenges. If the proper separation technology is not in place, higher severity FCC conditions when processing resid can result in higher main column bottom catalyst fines concentration and increased hazardous waste from fines migration.

Increasing bottom of the barrel profits from the FCC

Upgrading more challenging opportunity feedstocks will provide refiners with greater flexibility and will improve their ability to shift product portfolios to address expanding markets such as marine fuel or bunker pool. In the chase to increase the bottom line, the industry is looking at resid-to-propylene as a reliable means to increase conversion value.

FCC is one of the most versatile and profitable upgrading processes in a refinery. While the FCCU is well-known for its ability to process multiple feedstocks, it has traditionally processed atmospheric and vacuum gas oils (AGOs and VGOs) from the crude distillation unit (CDU). One of the most value-driven advantages of the FCC process going forward is the flexibility to process complex blends of residues, including atmospheric, hydrocracked and hydrotreated residues. Other feeds that can be processed with unit upgrades and advanced catalyst formulations include coker and visbreaking gas oils, demetallised oil, etc.

Equipment upgrades allowing resid FCC operations at high severity involve strippers, injectors, cyclones, improved metallurgy, efficient flue gas, and slurry separation technology. Resid-capable FCCUs operating at high severity require the right catalyst design with the proper catalyst-to-feed ratio, facilitating the diffusion of large resid molecules.

Recycling of smaller fines from efficient bottoms separation technology will assist in fluidising the larger fresh catalyst and lower fresh catalyst uptake in the resid cracking process. This action alone is worth millions to the refiner annually. Proper productivity within the FCC generates

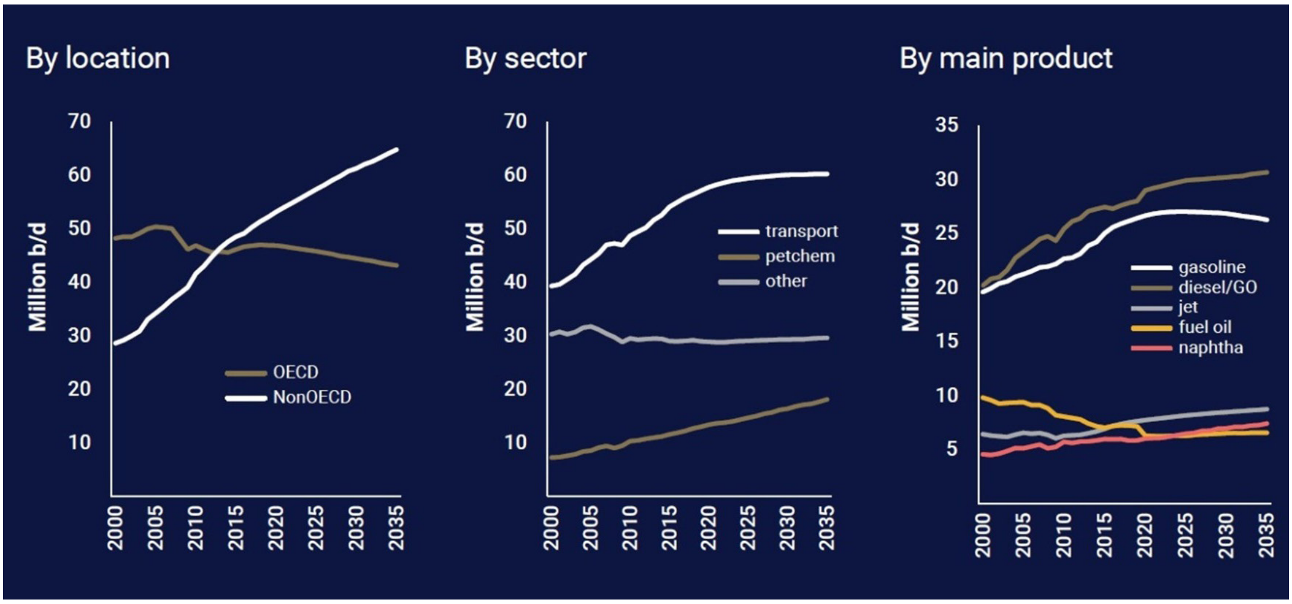

Figure 1. Global demand outlook. Source: Wood Mackenzie Macro Oils Service.

valuable cracked products without the coke and gas penalty experienced with improper catalyst productivity. The result will leverage resid processing and efficient downstream integration into the petrochemical value chain. This may motivate refiners to increase their focus on resid processing to provide a feedstock cost advantage while meeting on-spec product demand.

With advancements in high-severity processing, complications can arise in improving lower valued products. Many of the options for resid feedstocks present unique processing challenges. Efficient separation technology is required not only for the flue gas, but more importantly for reducing the concentrated main column bottoms to meet fine concentration levels for the bunker fuel and marine market. The International Maritime Organization (IMO) has imposed new restrictive regulations (MARPOL VI/IMO 2020) calling for < 60 ppm and lower sulfur content.[1]

Bunker fuel challenges for FCC slurry

As the pandemic's effect on lowering demand subsides, marine fuel and bunker fuels will continue to face the same pressures as oil, with peak demand and incremental economics driving decision making. The long-anticipated arrival of the 0.5 wt% sulfur limit in marine fuels, in keeping with IMO 2020 bunker fuel regulations, was expected by some to severely limit global market outlets for at least 3.3 million bpd of low-quality high-sulfur fuel oil (HSFO): > 3.5 wt% sulfur. Instead, the demand loss resulting from the COVID-19 pandemic and the unexpectedly high number of shipping vessels installing scrubbers created a unique market environment in which the value of HSFO exceeded expectations.[2]

This may well be a temporary situation as markets return to a new normal following the pandemic. In the long-term, however, streams such as FCC bottoms will be increasingly hard to blend into very-low-sulfur fuel oil (VLSFO) fuels but may have a home in the larger-than-anticipated HSFO products if the fines content is contingent.[3]

One of these products, FCC slurry oil at a 4 – 5% yield, is the lowest value product from the FCC unit. It is a highly aromatic, low-API material containing FCC catalyst. Because of the catalyst content and high aromaticity, environmental restrictions make easy disposal of sludge from settling tanks expensive. In addition to this, processing the catalyst-laden slurry can cause severe erosion of refinery equipment. To manage the challenges for FCC slurry oil presented by the IMO regulations, operators have benefitted from investing in separation technology solutions to meet the regulation requirement of < 60 ppm catalyst fines in marine fuel to increase the revenue from the FCC bottoms. To achieve this level of clarity, there are only a couple of options that are proven to be efficient at this level.

Figure 2. Gulftronic electrostatic separator and RFCC unit.

Slurry oil particulate removal technologies

Historically, holding tanks have been used to allow solids to settle out of the main column bottoms or slurry oil. The resultant decant oil solids content is a function of the sedimentation tank design, the physical characteristics of the slurry, the temperature of the storage tank, and whether settling aids are used. It should be noted that another product generated along with clarified oil is sludge, which is classified as hazardous waste and requires special treatment and expense for its disposal. Depending on the tank size and rate of slurry oil production, estimated costs per cleaning are in the range of US$1 – 4 million. In the absence of countermeasures, increasing resid feed to the FCCU increases the rate of slurry oil production and sludge formation. This level of separation is slow, and without some form of blending it is unable to meet the market requirements for high-value clarified slurry oil.

Perhaps the least expensive capital and maintenance cost method for removing solids from slurry oil is the liquid phase cyclone separator or hydroclone. Liquid phase hydroclones have been in the departiculating slurry oil service for over 50 years. Unfortunately, the hydroclone method only allows reduction in solids levels to approximately 300 – 500 ppmw, which does not provide the refiner with as much product application flexibility as other, more effective removal methods. The dynamics of the hydroclone allows for approximately 10% of the feed slurry to be sent back to the riser, increasing coke makes and eroding profits. Although centrifuges have been used to remove solids from slurry oil, their use has been limited and it is difficult to generalise.

The first membrane filters were put into slurry oil service in around 1990. Mechanical filtration operates at temperatures up to 600˚F and employs tubular porous metal elements. The solids collect on the inside of the elements while the filtrate passes through to the outside. Some filters use porous sintered woven wire mesh metal filters and operate at 400 – 650˚F. Others employ a 2 – 5 µm woven wire filter element, using light cycle oil (LCO) as a backwash at 350˚F, and claim 85 – 95% solids removal from the feed slurry.

Due to the limitation in smaller particle removal, until the creation of a solids layer, the mechanical unit has difficulty separating fines below 18 µm, and these units are also highly-susceptible to plugging from asphaltenes and waxes in resid use. The process of mechanical separation is the most expensive out of all the separation technologies to maintain on an annual basis, due to the replacement cost of cartridges, expensive backflush medium requirement, and labour-intensive cleanings when out of service.

Electrostatic precipitators are commonly found at the top of the FCCU to remove catalyst fines from stack emissions. A similar efficient process has been found for the removal of solids from liquids in the main column bottoms from resid FCCU: the di-electrophoresis electrostatic separator.

Electrostatic separation of FCC catalyst fines from slurry oil has been in commercial operation for over 30 years with over 50 systems in operation worldwide. Improved continuously over this period, electrostatic separation is a robust, automatic process that is capable of removing sub-micron catalyst fines from slurry oil or other hydrocarbon streams.

This technology is not affected by the presence of asphaltenes, making it an excellent choice for removing solids not only from resid FCC derived slurry oil, but also from gas oil crackers. Increased profits from efficient separation, low maintenance costs, and a solid return on investment (ROI) have resulted in electrostatic separator units being the most sought-after fines separation technology on the market today.

The following is an example of applying the electrostatic separator in place of tank settling and remedial removal and disposal:

Refinery A operates an FCCU with a throughput of 80 000 bpd. The FCCU has a slurry oil product flow of 6.0 vol% of feed, or 4800 bpd at 0.0 API. The FCCU uses an electrostatic separator to remove fines from 3000 ppm to < 50 ppm. This is equivalent to approximately 2.25 tpd of fines.

Assuming 2 tpd of sludge for every 1 tpd of fines, a total of 4.5 tpd of sludge and fines would have accumulated in the storage tank. In one year, the accumulation would be approximately 1600 t.

The electrostatic separator adds value by upgrading the slurry oil quality for high-grade coke production. Assuming a product value increase of US$2/bbl of slurry oil, the added value is the following:

4800 bpd slurry oil product x 365 days x US$2.0/bpd = US$3.5 million/yr

The only meaningful process cost for the electrostatic separator is for recycle flow. For this scale, the recycle flow rate would be 2 vol% of the effluent, or 100 bpd. At a cost of US$1.0/bpd, this cost is:

100 bpd recycle x 365 days x US$1.0/bpd = US$36 500

Ignoring the labour and material costs of tank cleaning, it is important to consider the cost of landfill for the sludge removed. Assuming landfill is US$1.0/lb, the cost is 1600 tpy x US$2000/t = US$3.2 million/yr.

The annual savings would be: US$3.5 million - US$0.04 million + US$3.2 million = US$6.7 million/yr

The road to resid

Prior to now, most propylene was produced from naphtha-based steam crackers and new world-scale propane dehydrogenation units, with a smaller fraction (> 30%) coming from high-severity FCC units using ZSM-5 based catalysts to increase propylene yields. Using resid FCC units (RFFCs) has also increased the concentration of fines in the main column bottoms (MCB). More than 40 RFCCs from multiple licensors have successfully exceeded objectives towards maximising propylene production.

Fortunately, technology for efficient resid processing through the FCCU will serve to increase propylene conversion beyond the pandemic. The reduction of catalyst fines in this process must be achieved in order to increase profits from the processing of specialty product feedstocks, higher value fuels, and blend stocks. This separation is paramount to increasing market value, reducing downstream erosion, and evading disposal concerns.[4]

The FCCU is a truly dynamic unit with licensor unique operation. When faced with transforming operating scenarios and shifting market economics, being prepared to process resid with the proper fines control in place will allow a refiner to remain nimble and maximise the overall profitability of the resid FCCU operation.

Investing in a specialised catalyst, FCC licensor optimisation, modern separation technology, and industry-leading separation understanding will secure increased revenue in the race to high propylene yields. More flexibility in separation expands the refiner's portfolio and increases revenue from the bottom of the barrel alongside processing a wide range of feedstocks, from heavy resid to VGO.

References

1. TAN, F., et al, 'How the World's Oil Refiners Plan to Grapple with Their Fuel Output After 2020', Reuters, (28 September 2018).
2. 'IMO 2020: Mayhem or Opportunity?', Wood Mackenzie, (12 November 2019), https://www.woodmac.com/
3. HICKIN, P., 'Coronavirus Impact Masking Post- IMO 2020 Risks for Marine Fuels', S&P Global Platts, (24 February 2020).
4. SINGH, R., LAI, S., DHARIA, D., TechnipFMC Process Technology; CIPRIANO, B., HUNT, D., W. R. Grace & Co., 'Conventional FCC to Maximum Propylene Production', *Hydrocarbon Processing*, (September 2020).

Bibliography

- 2020 AFPM (Virtual) Summit, 'Industry Leadership Panel', (25 August 2020).
- CUNNINGHAM, N., 'Goldman Sachs: Prepare for a Global Consolidation of Refineries', Oil Price, (2 July 2020).
- 'Short-Term Energy Outlook: Global Liquid Fuels', US Energy Information Administration, (6 October 2020), https://www.eia.gov/
- HUNT, D., et al, 'Parkland Refining and Grace Collaborate to Increase FCCU Catalyst Circulation Capacity', Catalagram, No. 125, (Spring 2020).
- VAN HULL, K., 'Reason to Believe: Why Build an Ethane Steam Cracker in A Time of Low Ethylene Margins', (7 July 2019), https://rbnenergy.com/
- DILIP, D., et al, 'Introducing PropyleneMAX® Catalytic Cracking (PMcc®)', Catalagram, No. 125, (Spring 2020).
- WAGNER, K., and FARMER, D., 'OlefinsUltra® HZ Technology Improves Propylene Yields', Catalagram, No. 108, (2010).
- 2020 AFPM (Virtual) Summit, 'Running Slurry Recycle Through Derated FCC to Maintain ROT and Regenerator Temperatures', (26 August 2020).
- 'Global Downstream Outlook to 2035', McKinsey & Company, (16 July 2019), https://www.mckinsey.com/
- 'China's Building Mega Refineries Just as Fuel Demand Stalls', Bloomberg News, (6 October 2020).