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Natural gas fuels the integration of refining and petrochemicals

Maximising the use of natural gas in a refinery-petrochemicals complex offers higher margins and lower carbon emissions

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Article Summary

Rising oil prices and weak fuel demand in the recent past have had a significant impact on gross refinery margin (GRM). Historical data show that refineries with bottom-of-the-barrel processing facilities and an integrated petrochemicals complex have performed well to stay ahead of the competition because of their greater flexibility to maintain a healthy GRM. A robust refinery configuration that is flexible enough to process a variety of crudes, including difficult opportunity crudes, along with an integrated petrochemicals complex is key to sustaining a healthy GRM.

However, simple integration of a refinery and a petrochemicals complex may not be enough. Integration should be smart enough to address volatility in the market by ensuring a healthy GRM and minimising environmental impact by reducing carbon footprint. Use of natural gas fuel addresses this issue to some extent by enabling the recovery of valuable components from refinery off-gases and facilitating the release of a good quantity of naphtha for the generation of a valuable petrochemicals feedstock. It also enables the production of more middle distillate from bottom-of-the-barrel processing and helps reduce the carbon footprint of the overall complex. The price differential between crude and natural gas, especially in countries where natural gas is readily available, makes the use of gas a hugely profitable proposition. Even in countries where both natural gas and crude are imported, there is a case for gas that needs to be looked into. This article aims to explore various options available to refiners to enhance their GRM and reduce their carbon footprint through the use of natural gas.

Refinery fuel consumption and generation

A refinery consumes fuel gas and fuel oil produced from various refinery processes. No supplementary fuel is required for refinery operation. Generally, naphtha is used as feed and fuel for the hydrogen generation unit and gas turbines. A typical fuel consumption pattern in a refinery is shown in Figure 1.

Fired heaters in various process units consume about 40-50% of fuel. The utility system, including boilers and gas turbines, consumes about 30-40% of fuel and the hydrogen generation unit consumes about 15-20% of fuel. The contribution of the hydrogen generation unit includes both feed and fuel. Typically, a refinery with secondary processing facilities such as fluid catalytic cracking (FCC) and hydrocracking consumes about 8-10 wt% of crude throughput as fuel, including naphtha used in the hydrogen generation unit and gas turbines. If the refinery is integrated with a petrochemicals complex, which is highly energy consuming, fuel consumption is significantly higher. This fuel requirement is satisfied by fuel oil and fuel gas generated from various process units.

Fuel oil is mainly generated from the vacuum distillation unit and the FCC unit's main fractionator bottoms in the absence of bottom-of-the-barrel processing facilities in the refinery. Vacuum residue is generally taken through a visbreaker unit to produce fuel oil. Generation of fuel oil can vary between 5 and 50% of feed to the vacuum distillation unit, depending upon the type of crude processed, while fuel oil from the FCC unit's main fractionator bottoms can vary between 4 and 6 wt% of the FCC unit's feed.

A typical contribution of fuel gas generation from various process units of a refinery using Arabian Heavy and Arabian Light crude mix is shown in Figure 2. Delayed coker, FCC unit, gasoline block (catalytic reforming unit with isomerisation or alkylation), crude distillation unit and hydrocracker/hydrotreaters (naphtha, kerosene, diesel and VGO) contribute typically about 40%, 16%, 17%, 2% and 25% respectively towards fuel gas generation from the refinery.

Many modern refineries have an integrated petrochemicals complex to improve profitability. A significant amount of fuel gas is also generated from the naphtha cracker complex, while a small amount of fuel gas is generated from the aromatics complex (excluding the catalytic reforming unit). Typically, about 16-17 wt% of feed is converted into fuel gas in the ethane cracker, while about 17-18 wt% of feed is converted into fuel gas in the naphtha cracker. Fuel oil generation from the ethane cracker is negligible, but it can be as high as 10 wt% of feed for the naphtha cracker.

A petrochemicals complex is also a major energy consumer. A steam cracker consumes lot of power in its cracked gas compressors and refrigeration compressors. Typically, 600-620 kWh of power is required for one ton of ethylene production. Generally, a naphtha cracker is a net exporter of fuel gas and fuel oil, while an ethane cracker is a net consumer of fuel gas. A paraxylene complex is a net consumer of fuel gas/fuel oil and power. About 0.3 tons of fuel gas and 320-360 kWh of power are required for one ton of paraxylene production. Refinery products such as fuel gas, fuel oil, naphtha and diesel are used to satisfy the fuel and power requirement of the steam cracker and aromatics complex. Natural gas can be utilised as fuel for an integrated refinery-cum-petrochemicals complex while maintaining flexible product objectives.

Use of natural gas in the refinery

Natural gas or regasified liquid natural gas can be used in a refinery for various purposes:

• Fuel for process and utility heaters, replacing fuel oil
• Feed and fuel for the hydrogen generation unit, replacing naphtha
• Fuel for gas turbines, replacing naphtha
• Fuel for process heaters, replacing fuel gas.

Each of these cases will be discussed in detail.

Natural gas as fuel for process and utility heaters, replacing fuel oil

Use of natural gas as a fuel to replace fuel oil provides the opportunity to either reduce or eliminate fuel oil generation from the refinery by utilising bottom-of-the-barrel processing technology. So far, the delayed coker unit is one of the most economical options for this type of processing. Other technologies that are available and used presently offer lower yields of distillates and do not eliminate fuel oil generation completely. New technology such as slurry hydrocracking, which is on the verge of commercialisation, promises to offer a better distillate yield and minimum residue generation. However, our discussion is restricted to the delayed coker, since it has a proven operational track record. Typically, a distillate yield (combining naphtha and diesel) of about 65% is obtained from the delayed coker, which may result in 10-12% more distillate from the refinery. Additional naphtha generated from the delayed coker can be used as feedstock for the naphtha cracker. Moreover, off-gas from the delayed coker contains good amounts of ethylene, ethane and propylene.