Tikrit University

The College of Petroleum Processes Engineering

Petroleum Systems Control Engineering Department

Petroleum Refining Processes

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Lecture 14

By

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Fluidized Catalytic Cracking

The fluidized catalytic cracking (FCC) unit is the heart of the refinery and is where heavy low-value petroleum stream such as vacuum gas oil (VGO) is upgraded into higher value products, mainly gasoline and C3/C4 olefins, which can be used in the alkylation unit for production of ultra-clean gasoline (C7 – C8 alkylates). The FCC unit mainly depends on circulating a zeolite catalyst with the vapor of the feed into a riser-reactor for a few seconds. The cracked products are disengaged from the solids and taken out to a distillation column for separation of the desired products. The catalyst is circulated back into the regenerator where coke is burned and the catalyst

Feedstock and Products

The main feedstock used in a FCC unit is the gas oil boiling between 316 °C and 566 °C (600 F and 1050 F). This gas oil can be considered mixtures of aromatic, naphthanic and paraffinic molecules. Gas oil from residue and conversion processes (predominantly coking) can be fed to catalytic cracking units. They must be hydrotreated before catalytic cracking to separate aromatics and remove Sulphur The principal limitation on charge stocks are the Conradson Carbon Residue (CCR) and metal contaminants. The effect of Conradson carbon is to form a deposit on the catalyst. This deposit could be beyond the burning capacity in the regenerator. For atmospheric residue, it is desulphurized first in the ARDS unit. Vacuum residue must also desulphurized and may be deasphalted before used in the FCC Some possible feedstocks are atmospheric distillates, coking distillates, visbreaking distillates, VGO, atmospheric residue (desulphurized) and vacuum residue (desulphurized, deaspalted). Typical feedstock properties are given in Table A1. In addition, products with their corresponding yields and characteristics are shown in Table A2.

Table Feedstock properties of FCC unit

	Desulphurised vacuum gas oil	Atmospheric residue
Specific gravity (15/4 °C)	0.896	0.889
API	26.3	27.5
Gas oil fraction (GO), wt% (boiling point < 343 °C)	7	4
VGO fraction (VGO), wt% (boiling point 343–538 °C)	88.5	52.5
Vacuum residue fraction (VR), wt% (boiling point > 538 °C)	4.5	43.5
Conradson Carbon Residue (CCR), wt%	0.2	4.2
Sulphur, wt%	0.4	0.11
Nitrogen, wt%	0.064	0.19
Nickel (Ni), wppm	0.26	17
Vanadium (V), wppm	0.15	0.5

Table FCC products

Products	Characteristics	Yield (wt%)
Dry gas + H_2S ($C_1 + C_2 + C_3 + H_2$) + H_2S	H_2S must be removed	3–5
LPG: C_3, $C_3^=$. C_4, $C_4^=$	Petrochemical feedstock	8–20
Gasoline	Main product, good octane number	35–60
Light cycle oil (LCO)	Rich in aromatics, high sulphur content, diluent for fuel	12–20
Heavy cycle oil (HCO) + slurry	Very rich in aromatics, slurry of solids, (mainly catalyst coke)	10–15
Coke	Consumed in regenerator	3–5

FCC Reactions

The main reaction in the FCC is the catalytic cracking of paraffin, olefins, naphthenes and side chains in aromatics. The main reactions in the FCC reactor can be summarized as follows:

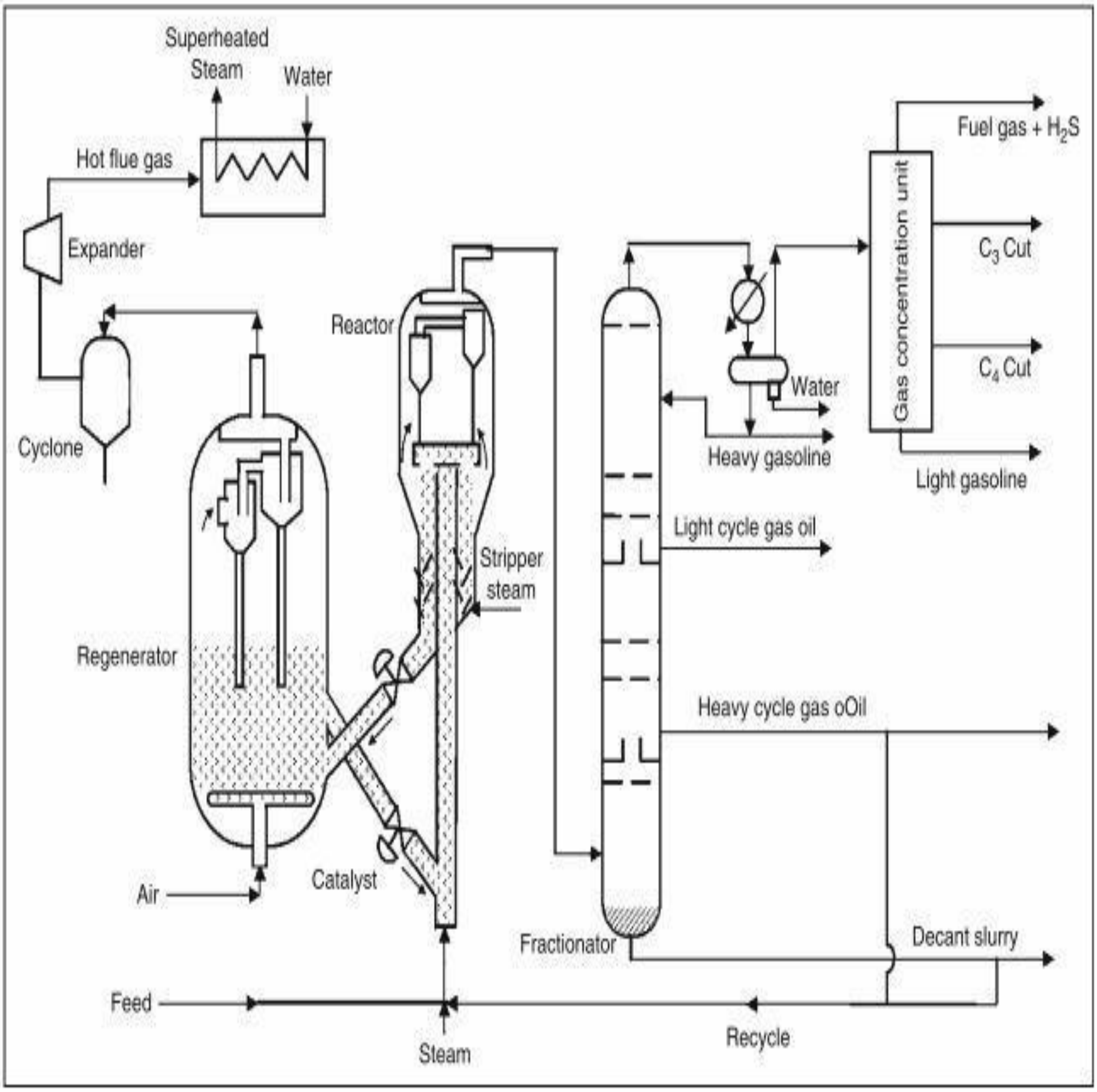
- Paraffins
  Thermal catalytic cracking
  Paraffin cracking → Paraffins + Olefins
- Olefins
  The following reaction can occur with olefins:
  Olefin cracking → LPG olefins
  Olefin cyclisation → Naphthenes
  Olefin isomerisation → Branched olefins + Branched paraffins
  Olefin H-transfer → Paraffins
  Olefin cyclisation → Coke
- Naphthenes
  Naphthene cracking → Olefins
  Naphthene dehydrogenation → Aromatics
  Naphthene isomerisation → Restructured naphthenes
- Aromatics
  Aromatics (side chain) → Aromatics + Olefins
  Aromatic transalkylation → Alkylaromatics
  Aromatic dehydrogenation → Polyaromatics → Coke

FCC Catalyst

The main catalyst which is used in a FCC reactor is the zeolite type. It is in a powder form with an average particle size of 75 μm and an average surface area of 800 m_2/g.

Process Description

The basic configuration of the FCC unit is a reactor (riser) and a regenerator. The catalyst is circulated between them where it is deactivated in the riser and regenerated in the regenerator. The process flow diagram for FCC unit is shown in Figure below. Steam and VGO heated up to 316–427 °C (600–800 F) are fed to the bottom of the riser, which is a long vertical pipe. The regenerated hot catalyst at 649–760 °C (1200–1400 F) is also fed to the bottom of the riser. The riser is the main reactor in which the endothermic reactions take place. The residence time in the riser is 2–10 s. At the top of the riser, the gaseous products flow into the fractionator, while the catalyst and some heavy liquid hydrocarbon flow back in the disengaging zone. Steam is injected into the stripper section, and the oil is removed from the catalyst with the help of some baffles installed in the stripper. The oil is stripped in this way from the catalyst and the spent catalyst is sent to the regenerator at a temperature of 482– 538 °C (900– 1000 F). The coke in the spent catalyst is burned off in the regenerator by introducing excess air, which is used to ensure the efficient combustion of coke. In both the reactor and the regenerator, hydrocyclones are installed to catch any solid particles carried out in the overheated stream. The product gases from the reactor are sent to the fractionator which produces light gases, heavy gasoline (main product), light cycle gas oil (LCO), heavy cycle gas oil (HCO) and decant slurry. The light gases are sent to the gas concentration unit where flue gas, propane, butane, LPG and light gasoline are produced. The operating conditions are usually adjusted to produce the maximum amount of gasoline from the VGO.



Fluid catalytic cracking process flow sheet