Feed Quality and Its Effect on the Performance of the Fluid Catalytic Cracking Unit (A Case Study of Nigerian Based Oil Company)

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Abstract

This paper presents results of the study of feed quality and its effect on the performance of the fluid catalytic cracking unit using Port-Harcourt Refinery Company (PHRC) as a case study. The important feed qualities used are the hydrocarbon content and a hydrotreated feed. Data on the feed properties used in PHRC were collected and a product mass balance was carried out on the fluid catalytic cracking unit. Conversion and gasoline yield of the unit were found to be 73.43 vol% and 52.07 vol% respectively. On comparison with cracking of aromatic feed, from literature, with 61.3 vol% conversion and 45.64 vol% gasoline yields, the feed is said to be paraffinic because of its higher conversion and gasoline yield. On comparison with that collected for hydrotreated feed, 80.62 vol% conversion and 63.9 vol% gasoline yield, it is concluded that feed hydrotreating increases conversion and gasoline yield by a significant amount.

Keywords

Feed quality, Performance, Fluid catalytic cracking unit

Introduction

Catalytic cracking has emerged as the most widely used refining process in the world today with about 10.6 mega million barrels of crude oil being processed daily. Two major factors that have increased the need for cracking are the depletion of old lights crude and the increasing demand for gasoline. Over the years, demand for gasoline has increased in contrast with its availability. The fluid catalytic cracking unit (FCCU) is used for gasoline production. Production of gasoline as well as other important products depends to a large extent on the performance of the FCCU (Jones, 1995).

Various parameters can be manipulated to improve the performance of the FCCU. Parameters such as temperature, catalyst and space velocity, as well as material and energy balance have all been used to characterize the performance of the fluid catalytic cracking unit in the past. The feed, being a starting material, gives an excellent base for manipulation to improve product yield. For almost every refining process unit, feed quality is the basic factor in determining yields and economics. In fluid catalytic cracking feed quality is primarily important since it impacts on the heat balance and the ultimate cracking intensity in addition to the fundamental effects on the natural crackability of the molecular structures. Some important aspects of feed qualities are the type of hydrocarbon contained in the feed and hydrotreating (pre-treating) of the feed.

Hydrocarbons are organic compounds of carbon and hydrogen atoms (Dazeley, 1969). Crude oil is a dark-viscous fluid which is complex mixture of hydrocarbons and non hydrocarbon derivatives (over 90% hydrocarbon by weight) found trapped in certain porous geological strata (Dazeley, 1969). Examples of saturated hydrocarbons found in gas oil are paraffins and naphthenes. Paraffins (methane, ethane and so on) have the general formula C_nH_{2n+2}, while naphthenes have the general formula of C_nH_{2n} and are arranged in the form of closed rings(cyclic) and are found in all fractions of crude oil except the very lightest. They are characterized by high octane number. Octane number is a measure for grading gasoline and for expressing the anti-knock rating of a fuel (Dazeley, 1969). Unsaturated hydrocarbons are those with deficiency in hydrogen atoms; unsatisfied carbon atoms. They are ring type (cyclic) compounds which react readily because of their deficiency in hydrogen. They contain at least one benzene ring (C_6H_6). They are also known as aromatics.

In addition to the hydrocarbon content, there are often small quantities of sulphur, nitrogen and oxygen compounds and sometimes metals such as nickel, vanadium and iron. These impurities, if not removed, can have detrimental effect on the equipment, the catalyst, and even the finished product. Hydrotreating offers an excellent feed pretreatment for the removal of these impurities which would otherwise poison the cracking catalyst and reduce its

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efficiency. Hydrotreating selectively hydrogenates these contaminants without destroying the aromatic portions (Adebayo, 1991). Typically, hydrotreating of feed is carried out prior to catalytic reforming. It may also be done prior to catalytic cracking to reduce sulphur and improve product yield as well as upgrading middle-distillate petroleum fractions such as kerosene, and diesel. It is also intended to prevent the catalyst from contamination.

This research work takes a close look at the Port-Harcourt Refining Company limited in order to determine how these stated feed qualities influence the performance of the fluid catalytic cracking unit of the company.

Methodology

Collection of data

Data on the feed and product were sourced for and documented. These sources include various textbooks, handbooks, journals, operating manuals and internet sites. Data collected from PHRC include mass flow rates for feed and products, corrected mass flow rates for feed and products, feed and product specific gravities and constants for feed and product charge.

Data utilization

Some of the data collected were used to carry out the mass balance calculations as presented in Appendix A. Thus, a mass balance was generated as presented in table 1-4.

Table 1. Mass balance for FCC yields in PHRC (operative)

IN	lb/hr	Wt%	Ft3/hr	Vol%
Feed	436334.39		477.39	
Gasoline	201862.41	48.37	266.27	52.07
LPG	5238	12.56	94.58	18.50
LCO	85940	20.60	91.27	17.85
Bottoms	37420	8.97	35.59	6.95
Flue gas	16334.97	3.90	23.69	4.63
Coke	23317.8	5.6	-	-
Total	417273.18	100	511.4	100

Table 2. FCC yield for cracking of aromatic feed

Conversion, vol%	61.3
Gasoline, vol%	45.64
LPG, vol%	11.83
LCO, vol%	14.79
Bottoms, vol%	7.92
Coke, vol%	5.6

Wilcox and Kowalczyk, 2000

Table 3. Feed properties for PHRC and Aromatic feed

Property	Hydro treated	PHRC	Aromatic
Specific Gravity	0.905	0.914	0.934
Sulphur, wt%	0.17	0.98	2.04
Nitrogen, wt%	0.08	0.17	0.38
K-Factor	12.89	12.54	11.67
Aniline point	238	228	176

Table 4. FCC yields for hydro treated feed

Conversion, vol%	80.2
Gasoline, vol%	63.9
LPG, vol%	28.5
LCO, vol%	12.8
Bottoms, vol%	5.02
Coke, wt%	4.79

Campgna et al, 2001

Method of analysis

The method used in determining the effect of the feed quality on the fluid catalytic cracking unit performance involves comparing the yields obtained from the mass balance calculations with those collected from the cracking of aromatic and hydrotreated feeds. The measures used for quantifying are the conversion and yields for gasoline, liquefied petroleum gas, light cycle oil, bottoms and coke.

Results

The results of various analysis conducted are presented in table 5 and 6.

Table 5. Differences in FCC yields between PHRC feed and aromatic feeds

	PHRC	Aromatic	Change
Conversion, vol%	73.43	61.3	12.13
Gasoline, vol%	52.07	45.64	7.42
LPG, vol%	18.50	11.83	6.67
LCO, vol%	17.85	14.79	3.06
Bottoms, vol%	6.95	7.92	-0.96
Coke, wt%	5.6	5.6	0

Table 6. Differences in FCC yields between hydro treated and PHRC feeds

	Hydrotreated	PHRC	Change
Conversion,vol%	80.2	73.43	6.77
Gasoline,vol%	63.9	52.07	11.83
LPG, vol%	28.5	18.50	10.0
LCO, vol%	12.8	17.85	-5.05
Bottoms, vol%	5.02	6.95	-1.93
Coke, wt%	4.79	5.6	-0.81

Discussions

Table 6 shows that the yields from cracking of PHRC feed gives a conversion of 73.43 vol% and a gasoline yield of 52.07 vol% with a total LPG yield of 18.50 vol%. Yields from cracking of aromatic feeds were 61.3 vol% conversion, 45.64 vol% gasoline and 11.83 vol% LPG. It follows that as the feed hydrogen content decreases so does the conversion level, gasoline and LPG yields. The lower conversion achieved when cracking aromatic feed could be due to the presence of high percentage of nitrogen compounds in oils. Since these nitrogen compounds are basic (or can become basic on cracking), they can poison the acidic FCC catalyst resulting in lower FCC conversions.

Another contributing factor is that as the number of ring structures increases, there is an increase in the chance that dehydrogenation from contaminant metals will cause multi-ring aromatics to form leading to condensation and coking on catalyst (Campagna et al, 2001). Another very interesting observation on the effect of feed hydrogen content is in the ratio of LCO to bottoms. For aromatic feed we have LCO: bottoms ratio of 14.79:7.92 vol% while for PHRC feed we have LCO: bottoms ratio of 17.85: 6.96 vol%. This could be due to the fact that as the percentage of aromatics in the feed increases, there is a significant rise in the number of molecules (or molecular fragments) that simply cannot be cracked (Jones, 1995)

On comparison of hydrotreated feed quality with that of PHRC, hydrotreated feed has lower specific gravity of 0.09 numbers, lower sulphur content by 0.81 wt%, lower conradson carbon residue (CCR) by 0.18 wt%, lower nitrogen content by 0.09 wt%, higher K-factor by 0.35, higher aniline point by 10.0 . The reduced specific gravity increases the API gravity thus improving the crackability of the feed (OSHA). This is indicated by the increment in the K-factor. Sulphur compounds are highly objectionable in commercial products on account of their unpleasant smell or bad odour. It also corrodes iron and steel used in refinery process equipment, piping and tanks (Adebayo, 1991). The lower sulphur content reduces the possibility of formation of sulphurous compounds which could cause corrosion or can be harmful to the unit or environment.

Table 6 presents the results of the difference betwen FCC and hydrotreated yields of PHRC (assumed unhydrotreated) feeds. For hydrotreated feed, FCC conversion is higher by 6.77 vol%, gasoline yield is higher by 11.83 vol%, LPG is higher by 10.0 vol%, LCO is lower by 5.05 vol%, bottoms is lower by 1.93 vol% and coke is lower by 0.81 wt%. The decrease in LCO and bottoms and increased gasoline and LPG can be linked to the side reactions of hydrocracking and hydroprocessing. Gary and Handwerk (2001) reported that hydrocracking and hydroprocessing decrease the boiling point of the feed by decreasing the molecular weight. A decrease in boiling point as a result of decrease in molecular weight gives rise to lighter fractions which can easily be cracked into more desired products as manifested in the increased gasoline and LPG yields. The decrease in the coke weight percent can be linked with the saturation of aromatics by hydrogenation. This reduces the extent of coking on the catalyst.

Conclusions

The existence of numerous variables which have markedly important impact on the FCCU performance cannot be ignored. However, since performance is characterized by efficiency and conversion. This was basically a proof of the efficiency of a unit, far more than any other single variable, FCC feed qualities have a great impact on FCCU performance. For straight run VGO feeds, hydrogen content is an excellent indicator of the conversion and yields that can be expected from the FCCU. Hydrotreating greatly improves the intrinsic qualities of FCCU feeds, thus improving their crack-ability as shown in the form of a higher conversion of 80.62 vol%.

In Port-Harcourt Refinery the most important refinery in Nigeria today, gasoline production is definitely not matching the amount of crude oil available. Therefore, apart from total and regular turn around maintenance required by the FCCU as well as the entire plant for optimum performance, efforts should be made to set up a means of hydro treating of feed for FCCU so that gasoline yield can be improved to meet or keep up with its ever increasing demand by the Nigerian populace.

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