LJAST
Libyan Journal of Applied Science and Technology
مجلة ليبيا للعلوم التطبيقية والتقنية

Volume 13 Issue 02
December 2025
ISSN 2958-6119

Residue Upgrading Options for Maximum Gasoline Production From Libyan Crude Oil

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Received 05 November 2025; revised 12 November 2025; accepted 01 December 2025

Abstract
Different refinery configurations are investigated for upgrading projects to increase gasoline production for local market demand.. Libyan is an important contributor to the globe supply of light and sweet crude. It has five domestic refineries, all of them are simple hydro-skimming units. This work, theoretical approach for upgrading of atmospheric and vacuum residue derived from heaviest Libyan crude oil.
Obtained results show that the option3 which included delayed coking has shown the optimum in terms maximum gasoline.
Keywords: Refinery; Gasoline; Catalytic Reforming; Delayed coking; Crude oil.

1. Introduction

Refinery residue is the hydrocarbon oil remaining after distillates have been removed from crude oil. Residue upgrading processes are increasingly important in modern refinery because of the continuing decline in the demand for fuel oil, their main use. The main goal of the typical fuels refinery is the conversion of as much as possible of the barrel of crude oil into transportation fuels as is economically practical. Although refineries produce many profitable products, the high-volume profitable products are the transportation fuels gasoline, diesel and turbine (jet) fuels. The purpose of a refinery is to convert oil higher value petroleum products that are sold to end users. This includes products such as gasoline, diesel, aviation fuel, and asphalt [1].In the simple oil refineries, atmospheric distillation or topping separates the crude into different cuts ranging from lighter fractions though to gasoline, kerosene cuts, diesel cuts and finally atmospheric residue. Moreover, atmospheric residue is generally reprocessed in vacuum distillation tower to separate a light fraction (vacuum distillate) and a heavy fraction (vacuum residue). Additionally, the most common refinery process includes catalytic, hydro, and thermal cracking units to convert heavy hydrocarbons into light hydrocarbons. They also contain other process units like continuous catalytic reforming and fluid catalytic cracking units [3].

The demand for high value petroleum products such as middle distillate, gasoline and lube oil is increasing, while the demand for low value products such as fuel oil and residue based products is decreasing. Therefore, maximizing of liquid products yield from various processes and valorization residues is of immediate attention to refiners [2]. Generally, the crude oil is heated in a furnace and charged to an atmospheric distillation tower, separated into butanes and lighter wet gas, un-stabilized light naphtha, heavy naphtha, kerosene, atmospheric gas oil, and topped (reduced) crude (AR). Different alternatives for the upgrading can be tackled. Either direct upgrading of the atmospheric residue (AR) or as more commonly adopted, first subject the atmospheric residue to vacuum distillation then upgrade the vacuum residue (VR) to more valuable and lighter products using thermally cracked in a delayed coker or visbreaking process. Each refinery has an unique processing scheme which is determined by the process equipment available, crude oil characteristics, operating costs, and product demand. The characterization of crude oils and petroleum fractions specially the bottom products (residue) are very important and will help when the refineries upgraded to produce more valuable distillate products from low valuable product. The optimum flow pattern for any refinery is dictated by economic considerations and no two refineries are identical in their operations [1].

1.1 The Principal Refining Operations Fall into Four Categories

According to the study that was done in 2013,\ on refining options of heavy crude oil in arab countries, the principal refining operations fall into four categories [3].

(1) Separation of crude oil into various cuts.

(2) Quality enhancement of the certain cuts.

(3) Transformation of heavy cuts into lighter cuts (conversion).

(4) Final preparation of finished products through blending.

Figure 1 illustrates the worldwide distribution of the major residue conversion technologies which refineries have installed.

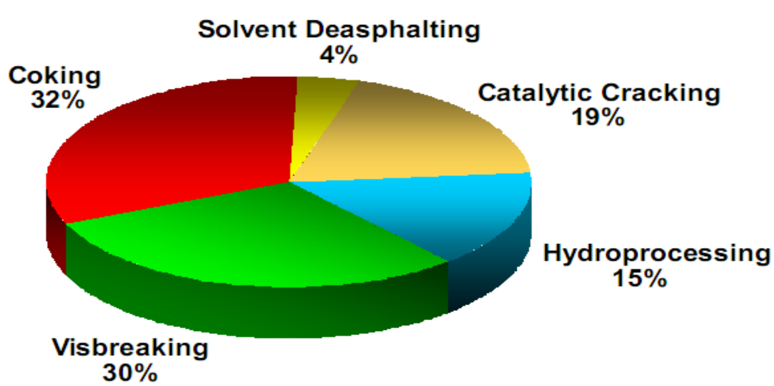

Figure 1 Historical worldwide residue conversion selection [4].

1.2 Challenges Facing Refinery

According to the study that was done in 2013, \ on refining options of heavy crude oil in Arab countries, the challenges facing refinery [3].

(1) Process heavy, high Sulphur cheaper feedstocks.

(2) Bottom of the barrel processing to improve margins.

(3) Improve fuels quality to meet new specifications.

(4) Reduce emissions to meet environmental standards.

(5) Flexibility to meet changing market demands.

1.3 Factors effecting the selection of upgrading and refining scheme

According to the study that was done in 2013, \ on heavy crude oil perspective worldwide and in Arab countries, factors effecting the selection of upgrading and refining scheme are [5].

(1) Location, logistics and utilities availability**.**

(2) Available and proven technology at the time decision.

(3) Market demand for the petroleum product qualities.

(4) Economic considerations.

2. The Main Objectives of The Study

(1) The upgrading projects in many oil refineries must be considered to cover the local consumption of gasoline and utilization of the advantage of high quality Libyan crude oil.

(2) To investigate the optimum conversion process based on the gasoline production yield using some Libyan crude oil as feed stock.

(3) To select the best crude oil which gives more valuable products.

3. Refining Options of Petroleum Residue Investigated

In this work, theoretical approach for upgrading of atmospheric and or vacuum residue derived from heaviest Libyan crude oil (Sarir-Messla Blend crude oil) are investigatedas shown in table 1.

Table 1 Investigated options

	Atm. Dist.	Vac. Dist.	Delayed Coking	Visbreaking	Reforming unit
option1	✓	✓	✓		
option2	✓	✓		✓	

option3	✓	✓	✓		✓
option4	✓	✓		✓	✓

Option3: Atm. Dist. +Vac. Dist. +Delayed Coking +Catalytic Reforming

3.1 Upgrading Process to Maximize Gasoline Product

Typical considered scheme (option 3) is shown in figure 2.

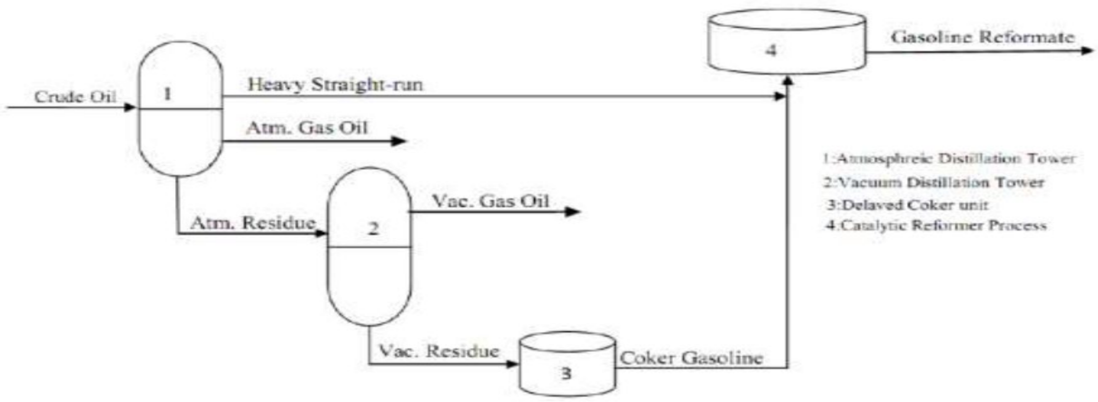

Figure 2 Residue upgrading option3 [3].

As seen from figure4, the crude oil is charged into atmospheric distillation tower where it is separated into butanes and lighter wet gas, un-stabilized light naphtha, heavy naphtha, kerosene, atmospheric gas oil, and atmospheric residue (AR). The AR is sent to the vacuum distillation tower and separated into vacuum gas oil stream and vacuum residua (VR). The VR from the vacuum tower is then thermally cracked in a delayed coker to produce wet gas, coker gasoline, coker gas oil, and coke. The heavy straight-run (HSR) from the crude unit and coker gasoline are taken as feedstock in the catalytic reformer process [3]. A simple correlation for estimating a rough coke yield reported by (Gary and handwerk ,2001)

Coke wt % = 1.6 × (wt % CCR……………………………………………..………………(1)

Gas ($C4^{-)}$ wt % = 7.8 + 0.144 (wt %CCR)……………………………………….……….…….(2)
Naphtha wt % = 11.29 + 0.343 (wt % CCR) …………………………………………..……(3)
Gas oil wt % = 100 – Gas wt % - Naphtha wt % - Coke wt…………………….……….……..(4)

3.2 Material Balance of Visbreaking Unit

The material balance using empirical correlations of visbreaking data base compiled by (Maple,1993).Products Yield

$$\text{Conversion} = \%\ \text{conv} = \left(\frac{Gas\ wt\ \% + Naphtha\ wt\ \%}{Feed\ (VR)\ wt\ \%} \right) \times 100 \quad (5)$$

$$\text{Gas wt\%} = 0.189825 \times \%\text{Conv} + 0.677163 \quad (6)$$

$$\text{Gasoline wt\%} = 0.738321 \times \%\text{Conv} + 0.260174 \quad (7)$$

$$\text{Residue wt\%} = -0.146668 \times (\%\text{Conv})^2 - 2.203644 \times \%\text{Conv} + 98.677947 \quad (8)$$

$$H_2S \text{ in Gas wt \%} = 0.02023 \times \text{Conv} + 0.06043 \times \text{wt \% } S_f - 0.156 \quad (9)$$

$$\text{Gas oil wt\%} = 100 - \text{Gas wt\%} - \text{Gasoline wt\%} - \text{Residue wt\%} - H_2S \text{ wt} \quad (10)$$

3.3 Material Balance of Catalytic Reformer Unit

The catalytic reformer is one of the major units for gasoline production in refineries. Catalytic reformer whose objective is to upgrade low octane naphtha to high – octane components for use as motor fuel. The typical feedstock to catalytic reformers are heavy straight-run (HSR) gasoline's and naphtha's (70–175°C) and heavy hydrocracker naphtha's. The material balance using empirical correlations of catalytic reforming data base compiled by (Fundamentals of Petroleum Refining, First edition, 2010).

$$H_2 \text{ wt\%} = -12.1641 + 0.06143 \times C_5^+ \text{ vol\%} + 0.099482 \times RON_R \quad (11)$$

$$C_1 \text{ wt \%} = 11.509 - 0.125 \times C_5^+ \text{ vol \%} \quad (12)$$

$$C_2 \text{ wt\%} = 16.496 - 0.1758 \times C_5^+ \text{ vol\%} \quad (13)$$

$$C_3 \text{ wt\%} = 24.209 - 0.2565 \times C_5^+ \text{ vol\%} \quad (14)$$

$$\text{Total } C_4 \text{ wt\%} = 27.024 - 0.2837 \times C_5^+ \text{ vol\%} \quad (15)$$

$$nC_4 \text{ wt\%} = 0.585 \times \text{total } C_4 \text{ wt\%} \quad (16)$$

$$iC_4 \text{ wt\%} = 0.415 \times \text{total } C_4 \text{ wt\%} \quad (17)$$

$$C_5^+ \text{ vol\%} = 142.7914 - 0.77033 \times RON_R + 0.219122 \times (N + 2A)_F \quad (18)$$

4. Results and Discussion

4.1 Material Balance of Atmospheric and Vacuum Distillation

These calculations can be done using the Excel spreadsheet crude unit. Table 2 illustrate crude units material balance of Sarir - Massla Blend crude oil.

Table 2 Material Balance of Atmospheric and Vacuum Distillation

Feed	Vol %	BPD	Sp.gr	API	(Ib/hr)/BPD	Ib/hr	Wt %
Crude Oil	100	220,000	0.8364	37.68	12.21	2686200	100
Products							

Cut Point °C	Product	Wt %	Vol %	API	(Ib/hr)/BPD	BPD	Ib/hr
	Gases& LPG	1.03	1.55	-	-	3410	37521.44
C5-70	Light Naphtha	5.6	7.18	85.42	9.51	15796	150219.96
70-175	Heavy Naphtha	16.07	17.94	58.6	10.86	39468	428622.48
175-235	Kerosene	9.31	9.82	46.4	11.6	21604	250606.4
235-350	Atm. Gas Oil	19.85	19.97	40	12.04	43934	528965.36
350+	Atm. Residue	48.14	43.54	21.8	13.47	95788	1290264.36
350-550	Vac. Gas Oil	31.18	29.21	28.75	12.88	64262	827694.56
550+	Vac. Residue	16.95	14.33	11.5	14.44	31526	455235.44

4.2 Material Balance of Delayed Coker Unit (optio1)

Table 3 contain a summary of results of delayed coker unit.

Table 3 Product Yields of Option1

Feed	vol %	BPD	Sp.gr	API	(Ib/hr)/BPD	Ib/hr	CCR wt%
Vac. Residue	100	31526	0.9897	11.5	14.44	455235.44	21.46
Products							
	vol %	BPD	Sp.gr	API	(Ib/hr)/BPD	Ib/hr	wt%
Coker gas	-	-	-	-	-	49576.23	10.89
Coker gasoline	24.33	7669.94	0.7583	55.11	11.07	84904.96	18.65
Coker gas oil	39.29	12386	0.9094	24.09	13.28	164444.6	36.12
Coke	-	-	-	-	-	156309.6	34.336

4.3 Material Balance of Visbreaking Unit (option2)

Table 4 contain a summary of results of vibreaking unit.

Table 4 Product Yields of Option2

Feed	BPD	Sp.gr	API	(Ib/hr)/BPD	Ib/hr	S wt %
Vac. Residue	31526	0.9897	11.5	14.44	455235.44	0.323
Products						
Conv. = 8 wt %	BPD	Vol %	API	(Ib/hr)/BPD	Ib/hr	Wt%
Gas	-	-	-	-	9995.89	2.20

Gasoline	2582.63	8.19	58.36	10.87	28073.20	6.17
Residue	21763.24	69.03	6.16	14.99	326231.02	71.66
H_2S in Gas	-	-	-	-	115.44	0.03
Gas oil	6600.28	20.94	18.50	13.76	90819.89	19.95
Total	-	-	-	-	455235.44	100
S in H2S	-	-	-	-	-	94.118
S in Gasoline	-	-	-	-	-	0.08
S in Gas oil	-	-	-	-	-	0.174
S in Residue	-	-	-	-	-	5.30

4.4 Material Balance of Catalytic Reformer Unit (option3)

Table 5 contain a summary of results of catalytic reformer unit.

Table 5 Product Yields of Option3

Feed	vol%	BpD	API	(Ib/hr)/BpD	Ib/hr
Hv SRN	83.7	39468	58.6	10.86	428622.48
Coker gasoline	16.3	7669.94	55.11	11.07	84904.96
Total	100	47137.94	-	-	513527.44
Products					
	wt%	BpD	API	(Ib/hr)/BpD	Ib/hr
H_2	2.0	-	-	-	10475.01
C_1	1.6	-	-	-	8320.44
C_2	2.6	-	-	-	13292.48
C3	3.92	-	-	-	20116.36
Tot C_4	4.58	-	-	-	23522.12
n- C4	2.7	-	-	-	13760.44
i- C4	1.90	-	-	-	9761.68
C_5^+ vol%	79.11	37290.82	44.4	11.74	437801.04

4.5 Material Balance of Catalytic Reformer Unit (option4)

Table 6 contain a summary of results of catalytic reformer unit.

Table 6 Product Yields of Option4

Feed	vol%	BpD	API	(Ib/hr)/BpD	Ib/hr
Hv SRN	93.9	39468	58.6	10.86	428622.48
Gasoline	6.1	2582.63	58.36	10.87	28073.2
Total	100	42050.63	-	-	456695.6681
Products					
	wt%	BpD	API	(Ib/hr)/BpD	Ib/hr
H_2	2.0	-	-	-	9315.74
C_1	1.6	-	-	-	7399.62
C_2	2.6	-	-	-	11821.41
C3	3.92	-	-	-	17890.09
Tot C_4	4.58	-	-	-	20918.94
n- C4	2.7	-	-	-	12237.58
i- C4	1.90	-	-	-	8681.36
C_5^+ vol%	79.11	33266.25	45	11.70	389349.86

Observation results show that option3 more effective than other options in terms of gasoline production yield. as shown in figure 3. Selected options will be depended on the economic evaluation issues.

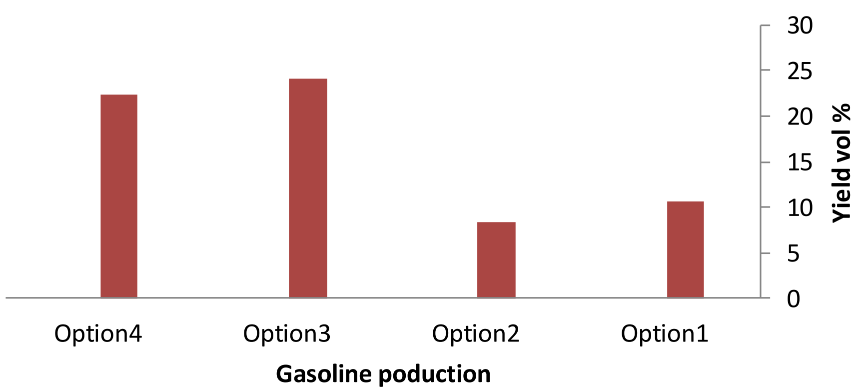

Figure 3 Comparing the deference between four options of gasoline production

5. Conclusion

Different options have been considered to produce more gasoline to cover the local demand fuel.

1. Observation results show that option3 more effective than other options in terms of gasoline production yield.
2. Results have revealed that Option3 has provided the best production rates compared with Option4.
3. In terms of thermal cracking units, Delayed coking Option1 more effective than Visbreaking unit ption2.

6. Recommendation

Upgrading existing Libyan refineries must be recommended.

1. Selected option will be depended on the economic evaluation issues.
2. Extensive feasibility study should be considered based on which crude be refined or exported.

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