Energy Analysis of Crude Distillation Unit (CDU) of N'DJAMENA Refinery (CHAD)

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Abstract
This analysis was successfully developed using design and operational data of crude distillation unit of N'djamena Refinery. The plant data were feed into Aspen Hysys software using commingled crude 1 (20%) light crude from Sedigui oil field and commingled crude 2 (80%) heavy crude from H block oil field as the crude feedstock. The ideal work, lost and shaft work were 2.40E+08, 4.29E+08 and 6.69E+08 Btu/hr respectively. The calculated second law efficiency was 35.8%.

Keywords: Energy Analysis, Ideal Work, Second Law Efficiency, Loss Work, Crude Diatillation Unit.

1 Introduction

Analyses of energy losses are of scientific interest and also essential for the efficient utilization of energy resources. The most commonly-used method for analysis of an energy-conversion process is the first law of thermodynamics. However, there is increasing interest in the combined utilization of the first and second law of thermodynamics, using such concepts as energy and lost work in order to evaluate the efficiency with which the available energy is consumed. Energy analysis is a methodology for the evaluation of the performance of devices and processes, it also involves examining the exergy at different points in a series of energy conversion steps. With this information, efficiencies can be evaluated, and the process steps having the largest losses (i.e. the greatest margin for improvement) can be identified [1]. For these reasons, the modern approach to process analysis uses the exergy and energy analysis, which provides a more realistic and view of the process and a useful tool for engineering evaluation [2]. As a matter of fact, many researchers [3] have recommended that energy and exergy analysis be used to aid decision making regarding the allocation of resources, capital, research, development effort, optimization and life cycle analysis [1].

Energy analysis has become a key aspect in providing a better understanding of the process, to quantify

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sources of inefficiency, and to distinguish quality of energy used [1]. Due to the relatively high energy cost as a component of a unit production cost, it is necessary for any unit to carry out analysis of energy utilization.

Hysys provides an intuitive and interactive approach towards process modeling, simulation and optimization. This software creates detailed fidelity plant operation. Through the completely interactive Hysys interface, access to a fine level of equipment geometry, performance detail as well as the ability to completely customize simulation using its OLE extensibility capability is very much possible.

The objective of this work is to analyze the Crude Distillation Unit (CDU) of N'djamena Refinery Company (NRC) through energy perspective. Sites of primary energy loss will be determined. The second law efficiency will also be determined.

2 THEORY

The capacity of crude distillation unit of N'djamena refinery is 100×10^4 t/a. There are two sources of feedstock, one is Commingled crude 1 (20%), light crude from Sedigui oil field and the other one is Commingled crude 2 (80%), heavy crude from H block oil field. Commingled crude 2 is the main operational feedstock for the unit. Product specifications of N'djamena refinery is based on the market demand of petroleum products in Chad. The main market demand in Chad is motor fuel. And there is also a certain amount of demand for kerosene and LPG for domestic consumption.

N'Djamena refinery is fuel type; main product is clean motor fuel, liquid gas and Polypropylene as byproducts. The main products of the crude distillation unit include straight-run naphtha, kerosene, straight-run light diesel, straight-run heavy diesel and crude residue.

Feedstock of the unit is a mixture of two types of crude, property of Chad mixed crude is shown in Table 1.

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Table 1:

Property of feedstock

Item		Unit	Value
API°			33.98
Density @ 20°C		g/cm³	0.8532
Viscosity @	40°C	mm²/s	14.21
	50°C	mm²/s	10.3
S		ppm	500
N		ppm	1200
Salt		mg/l	4.6
Pour Point		°C	25
CCR		% (m/m)	2.59
Ash		% (m/m)	0.011
Acid number		mgKOH/g	0.21
Resin		% (m/m)	6.9
Asphaltene		% (m/m)	0.1
Wax		% (m/m)	19.4
Metals	Fe	ppm	2.3
	Ni	ppm	6.4
	V	ppm	0.4
	Ca	ppm	8.0
	Na	ppm	7.4
	Cu	ppm	<0.1
	Pb	ppm	<0.1
	Mg	ppm	0.5
K			2.3
Type of the crude			Low sulphur paraffin base

Source: [4]

Table 2:
Distillation results

Fraction	Yield		Density @ 20°C	K	Acid number	Sulphur
	Narrow fraction yield	Volume yield				
°C	(m)%	(v)%	g/cm³		mgKOH/g	μg/g
<15	0.21	0.21				
15-65	1.87	2.08	0.6499	12.6	0.115	7.1
65-80	1.23	3.31	0.6970	12.2	0.036	6.1
80-100	2.18	5.49	0.7252	11.9	0.023	9.1
100-120	2.33	7.81	0.7424	11.8	0.038	14.0
120-145	3.56	11.37	0.7628	11.7	0.036	23.0
145-165	2.54	13.92	0.7784	11.7	0.030	36.6
165-180	2.12	16.03	0.7889	11.7	0.033	50.5
180-200	2.04	18.07	0.811	11.7	0.041	67.8
200-230	3.79	21.85	0.8074	11.8	0.034	102
230-240	1.42	23.28	0.8201	11.8	0.040	140
240-260	3.21	26.49	0.8331	11.7	0.055	197
260-275	2.53	29.02	0.8391	11.7	0.105	237
275-300	4.43	33.45	0.8410	11.9	0.197	286
Fraction	Yield		Density@ 20°C	K	Acid number	Sulphur
	Narrow fraction yield	Yield				
°C	(m)%	(v)%	g/cm³		mgKOH/g	μg/g
300-320	3.26	36.71	0.8430	12.0	0.261	384
320-350	4.97	41.68	0.8522	12.0	0.424	512
350-365	1.38	43.06	0.8680	12.0	0.586	617
>350	56.94	100	0.9020			0.08%

Source: [4]

Table 3:
Products quality control

Production Name	Controlled Target	Remarks
Naphtha	ASTM D86EP>1700°C	Reforming feedstock
Kerosene	ASTM D86 EP>300°C gravity @20°C, 0.775~0.830 Freezing point >-470°C	To kerosene tank farm after kerosene refining
Straight-run light diesel	ASTMD 86 95%> 365°c Flash point < 55°C	To diesel tank farm after diesel refining
Straight-run heavy diesel	Flash point < 55°C	Feedstock for diesel hydro-refining unit
Crude residue	Satisfy the require of FCC feedstock	To meet feed requirements for FCC unit

Source: [4]

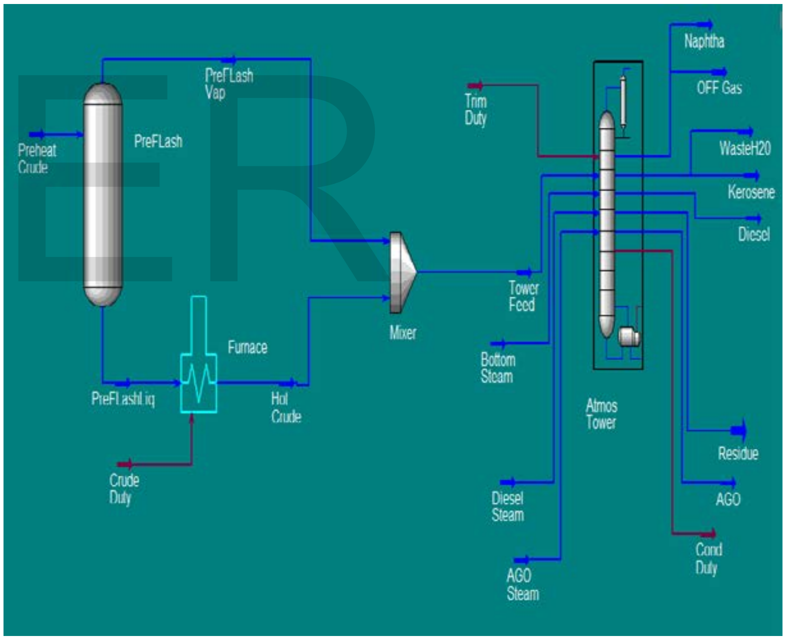

Figure: 1 Converged simulated process flow diagram

3 ANALYSIS

Energy is a measure of the maximum capacity of a system to perform useful work as it proceeds to a specified final state in equilibrium with its surroundings.

The system ideal work is given by:

$$W_{ideal} = \Delta H - T_0 \Delta S_G \qquad \text{(Eqn 1)}$$
$$\Delta H = \Sigma n h_e - \Sigma n h_i \qquad \text{(Eqn 2)}$$
$$S_G = \Sigma n \Delta S - \Sigma \theta / T_0 \qquad \text{(Eqn 3)}$$

The second law system efficiency for work requiring is given by:

$$\eta = \frac{Wideal}{Ws} \qquad \text{(Eqn 4)}$$

Where;

ΔH = Enthalpy change

T_0 = Reference temperature

S_G = Total entropy generation

ΔS = Entropy change

θ = streams heat losses

h_e = Specific enthalpy

h_i = Specific entropy

η = Efficiency

4 Results

The analysis results of Crude Distillation Unit of N'djamena Refinery Company using Aspen Hysys are presented below.

Table 4:

Crude distillation Unit overall energy balance

Reference points: T_0 = 77°F P_0=14.7Psia h_0 = -6.288e+005 Btu/lbmole s_0 = 735.5 Btu/lbmole°F

Input	T°F	P(Psia)	m,lbmole/hr	h,Btu/lbmole	S,Btu/lbmole°F	h_s,Btu/hr	S_s,Btu/hr°F
Preheat crude	450	75	3814	-2.02E+05	270.6	-7.70E+08	1032068.4
Tower Feed	641.1	65	3814	-1.53E+05	319.4	-5.84E+08	1218191.6
Bottom Steam	375	150	416.3	-1.02E+05	40.29	-4.24E+07	16772.727
Diesel Steam	300	50	166.5	-1.02E+05	41.8	-1.70E+07	6959.7
Ago Stream	300	50	138.8	-1.02E+05	41.8	-1.42E+07	5801.84
Total						-1.43E+09	2279794.3
Output							
Naphtha	165.6	19.7	1.49E+03	-1.18E+05	80.16	-1.76E+08	1.20E+05
Off gas	165.6	19.7	4.35E-04	-7.90E+04	57.83	-34.340504	0.0251445
Waste H_2O	165.6	19.7	707.2	-1.21E+05	15.67	-8.59E+07	11081.824
Kerosene	450.8	29.84	669.6	-1.44E+05	183.4	-9.62E+07	122804.64
Diesel	576.9	30.99	513.9	-1.65E+05	284.5	-8.46E+07	146204.55
Residue	697.8	32.7	764.1	-3.23E+05	725.1	-2.47E+08	554048.91
Ago	717.9	31.7	389.8	-1.77E+05	425.6	-6.90E+07	165898.88
Total						-7.58E+08	1.12E+06

Table 5:

Crude Distillation Unit streams heat losses

Q Streams, Btu/hr		Q/T_0, Btu/hr°F
Crude duty	-1.86E+08	-2.42E+06
Trim duty	-7.31E+07	-9.49E+05
Cond duty	-8.04E+07	-1.04E+06
Total		-4.41E+06

Table 6:

Crude Distillation Unit second law analysis summary

Properties		Value
Enthalpy change (ΔH) ,	Btu/hr	6.69E+08
Entropy change (ΔS) ,	Btu/hr°F	1.16E+06
Total entropy generation (Sg) ,	Btu/hr°F	5.57E+06
Lost work (T_0Sg) ,	Btu/hr	4.29E+08
Ideal work (W_{ideal}),	Btu/hr	2.40E+08
Useful work (Ws) ,	Btu/hr	6.69E+08
Efficiency (η),	%	35.8

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5 Conclusion

In this study, an energy analysis of Crude Distillation Unit (CDU) of N'djamena Refinery Company (NRC) Chad Republic was analysed. In the considered Crude Distillation Unit, the ideal work, lost and shaft work were 2.40E+08, 4.29E+08 and 6.69E+08 Btu/hr respectively. In addition, the calculated second law efficiency was 35.8%.

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