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Thermodynamic evaluation of a kerosene pre- Fraction unit using energy and exergy analysis

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ABSTRACT

This work applies the method of energy and exergy analysis over first step of linear alkyl benzene (LAB) production namely kerosene pre fraction plant, to determine unit energy and exergy performance and loss, besides of opportunities for improvement based on operational data. For this purpose macroscopic energy and exergy balance was developed over main equipment including electro pumps, heat exchangers, air coolers, and distillation columns. The results shows that total energy performance of plant is 92.62% by 19.76 MW energy lost, while from exergy perspective, unit performance is 78.08% by 17.92 MW exergy lost. Maximum local exergy lost occurs in the feed pre heater exchanger by 27% performance which is designed to recover energy from top product of second column, furthermore results shows that upgrading low quality energy in air coolers based on heat pump concept would protect energy and exergy emission to the environment and reduce 40% of total lost energy and 16% of total lost exergy in plant.

1. Introduction

Linear alkyl benzenes are a group of organic compounds, which are mainly produced as intermediate in the production of surfactants, for use in detergent industry [10] the continued demand for LAB worldwide is directly linked with the fast moving consumer goods (FMCG) industry as over 95% of produced LAB is used for the production of detergent powders and liquid detergents, increasing population growth in various industrial sections has triggered demand for cleaners used for various household and industrial purpose such as glass, rug, metal and other industrial cleaners, and home cleaners ("LAB Market Analysis By Application Report," 2015) Kerosene a derivative of crude oil is extensively used in the production of LAB, as reported by united states department of energy statistics world total kerosene consumption for all purposes is equivalent to about 1.2 million barrels per day, raw Kerosene is stripped of light and heavy ends by distillation process to meet desired normal paraffin for production of LAB.

In the other side growing trend in energy consumptions make more emphasis on energy management and development of industries toward environmental sustainable processes to save energy costs and production benefits [16,18,7]. Thermodynamic analysis is an effective tool in unit performance evaluation, this analysis can help us to find location, causes and magnitude of process inefficiencies, in other words energy analysis indicates energy loss and differences that exist between actual and theoretical performances and exergy analysis shows us system ideality approach condition and covers miss leadings which may be seen due to only energy based efficiencies which do not discuss about energy quality [3], energy can be divided in two parts, one that could be used to produce work or exergy and the other one which cannot do this and is called anergy [5], exergy is maximum work that could be done using environmental parameters as the reference state, in fact “exergy is property of system and reference environments” [2]. Exergy

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Nomenclature

e	Specific energy, kJ/kg
ex	Specific exergy, kJ/kg
h	Mass enthalpy, kJ/kg
$\dot{I}$	Irreversibility rate, kW
$\dot{m}$	Mass flow rate, kg/s
P	Pressure, Pa
$\dot{Q}$	Heat rate, kW
R	Gas constant, kJ/kg. K
s	Mass entropy, kJ/kg. K
T	Temperature, K
$\dot{w}$	Work rate, kW
x	Mole fraction
z	Mass fraction
γ	Activity coefficient
β	Correction factor
η	Energy efficiency
ψ	Exergy efficiency
ω	Heat exchanger effectiveness
ε	Heat exchanger effectiveness

Abbreviation

API	American Petroleum Institute gravity
COP	Coefficient Of Performance
FMGC	moving consumer goods
LAB	linear alkyl benzene
LHV	Low Heating Value
LMTD	Logarithmic Mean Temperature Difference

Superscripts

ch	Chemical
ph	Physical

Subscripts

cv	Control volume
em	Electro motor
in	Inlet
i	Component i
j	Component j
mix	Mixture
out	Outlet
r	Reference
0	Environment

destruction or lost work is directly connected to entropy generation and all of the real processes contain exergy destruction due to mechanical friction, heat transfer, diffusion and mixing effects [1,12]. The usual energy analysis of chemical processes evaluated them on energy quantity only, the present study aim is to use first and second law of thermodynamics to evaluate energy and exergy performances over kerosene pre fraction plant considering material and energy streams emphasis on importance of energy quality based efficiencies beside determination of critical points which should be set as priority for modification.

2. Methodology

2.1. Process description

Based on UOP design consideration a L.A.B production plant is divided to five major steps namely: Pre fractionation, hydro treating, Molex, Pacol and detergent alkylation as shown in Fig. 1 Through these processes Hydro treated kerosene and high purity in linear paraffin, are dehydrogenated to olefins and The resulting product reacts with benzene in the presence of a catalyst to produce the LABs [11]. The feed of Pre fraction unit is straight run kerosene Which contains considerably more non-linear than linear hydrocarbons in carbon range of 9–18, and duty of kerosene pre fractionation unit is to prepare feed specification such that the carbon number range will be from 10 to 14. Under studied plant receives approximately 141 t of raw kerosene per hour and produce 100 t of desired products by distillation process as demonstrated in Fig. 2, the raw kerosene, after being preheated in the feed/Rerun

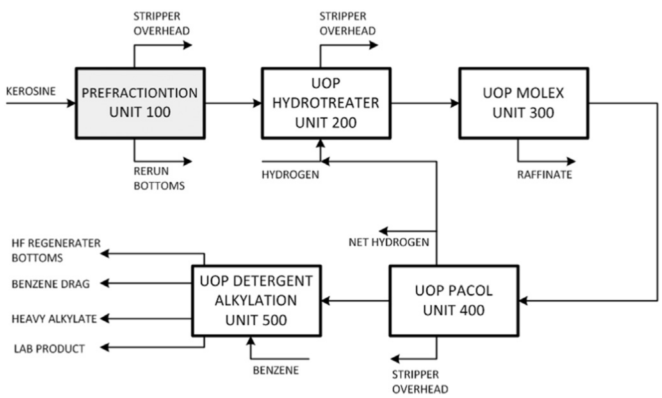

Fig. 1. block diagram of LAB production process.