TECHNO-ECONOMICAL STUDY ON THE PRODUCTION OF HIGH OCTANE GASOLINE IN LIGHT NAPHTHA PLANT

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Received 12 April 2023
Accepted 20 August 2023
DOI: 10.59957/jctm.v59.i1.2024.9

ABSTRACT

The Indonesian government is optimizing the production of high-octane gasoline by utilizing existing ingredients that are plentiful and rarely used in Indonesia to keep up with the rising demand for it. Although light naphtha, a by-product of the oil refinery process, has the potential to be transformed into fuel with a high Research Octane Number, its application has not yet been fully realized. The objective of this study is to carry out a study of the economic and technical feasibility of high-octane gasoline plants. A 10,000 barrel/day production potential has been built into the plant. In order to reach the RON objective of 98 for high-octane fuel, light naphtha, which has a Research Octane Number of 73, will need to be increased. The production process includes isomerization, depentanizing, and adsorption. From a technical perspective, this plant can produce high-octane gasoline from light naphtha with RON 98. From an economic perspective, the Net Present Value is $ 138,247,252; Internal Rate of Return of 29.38 % per year; Pay Out Time is 3 years 5 months; and Break Even Point is 49 %. Overall, based on technical and economic perspectives, this power plant is feasible.

Keywords: *gasoline, light naphtha, isomerization, economical analysis, upgrading.*

INTRODUCTION

Gasoline is one of the products that human needs in the nowadays era. All of the activities, such as plant operations, transportation, or just small activities need energy that it can get from fuel. According to Badan Pengatur Hilir Minyak dan Gas Bumi (BPH Migas), gasoline consumption in Indonesia nowadays is around 1,5 - 1,7 million per day and is projected to increase by 8 % per year. In 2025, the consumption will reach 2,6 million barrels per day [1]. With this great number of gasoline consumption, Indonesia needs to maximize the production of gasoline through some pathways such as building a new oil rig, increasing the capacity of production, upgrading the light hydrocarbon, and so on, so that it can reduce the number of import and to fulfill the fuel consumption in Indonesia. Besides the quantity that must be increased, it is also important to upgrade the gasoline specifications. This problem can cause severe effects. Besides the non-efficiency of the machine working, a lower Research Octane Number (RON) can cause more dangerous emissions that can cause the death of people. The International Council on Clean Transportation (ICCT) research stated that in 2030, all countries need to implement the Euro VI gasoline standard. In order to realize the ICCT plan, this techno-economical study of the pre-design of High Octane Mogas Component (HOMC) from light naphtha that is one of light hydrocarbon in order to maximize the capacity and also upgrading the light hydrocarbon so that the production capacity of light naphtha will increasing the production of oil rig.

Several methods of upgrading light naphtha to be HOMC will be explained below. Direct blending is the most convenient method for upgrading light naphtha that doesn't need more equipment but only needs a blending unit [2]. The second one is a Continuous Catalytic Reformer (CCR). CCR unit will produce aromatics compounds and hydrogen in large numbers in producing gasoline. The principle is naphtha, after hydrotreating, is a contact with an outlet from the stacked reactor to maximize the heat transfer before it goes to the reactor again for the next production [3]. Then, supercritical fluid is often used to upgrade all types of oil. The main principle of this process is divided into partial oxidation as pre-treatment, and the main process is hydrogenation using a water gas shift reaction to destroy the C-C bond [4]. If we have a large amount of alcohol, methaformer is the most suitable process. Its main principle is for naphtha to react with methanol to convert the paraffin into aromatic and other cyclic components with higher RON [5]. Isomerization is the last process. It is possible to raise the RON by isomerizing paraffinic components (alkanes) to create iso-paraffin (iso-alkanes) or other branch components. Chlorinated alumina is the catalyst in use [6]. In order to maximize the result, isomerization is combined with Pressure Swing Adsorption (PSA) to separate the unbranched paraffinic component which will reduce the number of RON [7]. This study will use the isomerization and PSA combined process because it is graded as the most efficient process.

Many studies on PSA and upgrading chemical products, including naphtha, have been discussed. Anugraha et al. [8] increased the quality of naphtha to become a useful fuel with qualifying performance that is High Optimum Mogas Component (HOMC) by employing the PSA method and Aspen Adsorption simulations to determine the ideal combination of zeolite adsorbents (Beta and 5A) to utilize in the procedure. Hinkov et al. studied the PSA techniques that have been modified and adapted for removing CO_2 from gas streams [9]. Furthermore, Pratiwi et al. used Aspen Adsorption V.7.0 to simulate the Pressure Swing Adsorption method of hydrogen purification [10]. Anugraha et al. studied the potential of utilizing light naphtha as raw materials to create commercial fuels using a blending method [11]. In order to analyze the technical efficiency study, it is used ASPEN HYSYS is one of the software used in simulating the process that will be implemented, and the economic research is based on the calculation of economic parameters such as Net Present Value (NPV), Internal Rate of Return (IRR), Pay Out Time (POT), Break Even Point (BEP), and IRR Sensitivity.

EXPERIMENTAL

Data Collection

Specifying the raw material specification that will be used to simulate the process is needed. Table 1 is obtained from the assay in Sanipah Condensate.

Schematic Main Process

After we define the raw material, the next step describes the main flow process as shown in Fig.1.

Also, this block diagram can be used as the baseline in simulating the process with ASPEN HYSYS. The production capacity is 15,548 barrels per day of gasoline from 10,000 barrels per day of light naphtha.

Simulating Process using ASPEN HYSYS and ASPEN Adsorption

ASPEN HYSYS is the software that will be used in simulating the process. In configuring ASPEN HYSYS, there are several ways to do. First is configuring the

Table 1**.** Specification of Light Naphtha. [12]

Propertie*s*	Amount	Component	Composition (mol)
Density (kg/m^3)	664.6	n-Pentane	0.414
Molecular Weight	78.68	cyclopentane	0.136
RON	73.61	40 – 50 °C	0.036
Sulfur Content (%wt)	0.00	51 – 60 °C	0.127
Nitrogen Content (%wt)	0.00	61 – 70 °C	0.181
Aromatic By Volume (%wt)	1.306	71 – 80 °C	0.105
Watson UOP K-Factor	12.752		

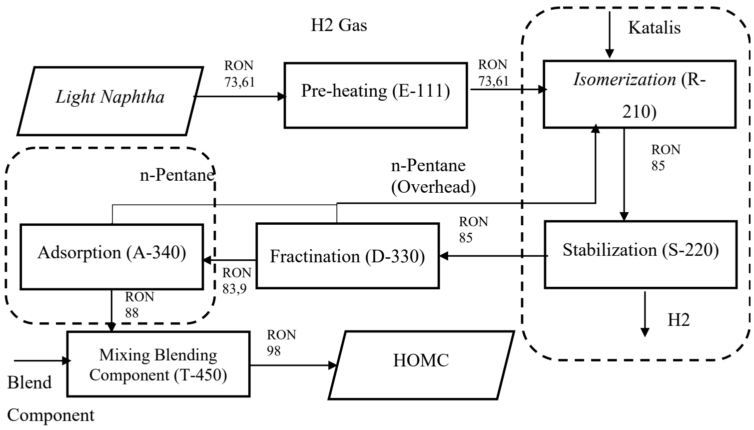

Fig. 1. Scheme of the proposed process.

Table 2. Economical and Material Costs Assumptions.

No.	Parameters	Assumptions	No.	Materials	Costs
1.	Private Capital	40 %	1.	Light Naphtha	\$ 0.37/liter
2.	Loan Capital	60 %	2.	Reformate	\$ 0.022/liter
3.	Bank Interest	8 %/year	3.	Benzene	\$ 0.48/liter
4.	Inflation Rate	3.55 %/year	4.	Methanol	\$ 1.72/liter
5.	Income Tax	35 % for income > \$ 33.33	5.	Ethanol	\$ 0.014/liter
6.	Plant Lifetime	20 years	6.	Butanol	\$ 0.023/liter
7.	Construction Period	2 years	7.	Chlorinated Al Catalyst	\$ 61/tonnes

component list by Petroleum Assay. The Petroleum assay describes the crude oil that will be used in this simulation. It will give data on the petroleum properties and hypo components. It is needed to specify which well will be used. The Fluid package that will be used is Peng Robinson. ASPEN Adsorption is used to simulate PSA. It is needed to specify the Langmuir constant of the adsorbent used and its reaction with light naphtha. The assumption in the adsorption process is non-isothermal with no conduction as energy balance, using the Ergun equation as material balance and solid lumped resistance kinetic models. The calculations of mass and energy balance will be based on the result of this simulation.

Economical Basis Assumption

The economic feasibility analysis parameters include NPV, IRR, POT, BEP, and IRR Sensitivity. Economic analysis is carried out using the discounted cash flow method, whose value is projected at present. It is also needed to assume the cost of the required material. The basis of material cost and the economic basis assumptions are used in Table 2.

The capital costs of equipment will be calculated based on equipment cost prediction in 2014 by Matche. To calculate the cost in 2024 (projected as the year of buying equipment), it is necessary to analyse the Chemical Engineering Plant Cost Index (CEPCI) of 2024 as the additional calculation factor. CEPCI 2024 will be obtained from extrapolation data of CEPCI from 1989 to 2020 by Chemical Engineering Magazine, 2022. The CEPCI of 2024 is 674.316, while the CEPCI of 2014 is 576.1 [13].

RESULTS AND DISCUSSION

In this section are discussed the simulation and evaluation results of the light naphtha refinery. The results include plant conceptual designs, performance analysis, and economic analysis.

Integrated Light Naphtha Refinery Plant Conceptual Designs

Based on the selection process that has been carried out, the isomerization and PSA processes are selected. The isomerization used in this study is the isomerization process with the addition of depentanizer fractionation because this process configuration is the most compatible with the available assay content to separate n-pentane. Fig. 1, presents the planned combined isomerization and PSA process flow diagram for the light naphtha refinery plant. Based on the major process, there are several steps. First, pre-heating or heating the flow of raw materials to a temperature of 150 °C before the main process aims to improve the efficiency of the isomerization process so that it reaches optimal conditions and produces a maximum RON output of 80 - 85 [6]. Second step is tthe isomerization of C5 / C6 into iso-paraffin with the help of a chlorinated alumina catalyst. The product of this isomerization is called isomerate with a higher RON value than before. Third step includes stabilization of naphtha through release of hydrocarbon gases that are lighter than C5, such as separating hydrogen gases that are not used in the isomerization process. Fourth, it is depentanizer with the aims to release the remaining and non-polymerized n-pentane based on its boiling point by using distillation column units. The operating conditions applied to this process are 100 °C for the overhead product and 128 °C for the reformate or the resulting product. Fifth - PSA that uses zeolite as its adsorbent is installed in a vessel usually known as an adsorber. In this process, light naphtha is compressed until the pressure reaches 10 bar, and the temperature is raised to 0 ^{o}C to maximize the adsorption process at high temperatures. Finally, the addition of several additives is also adjusted to maximize the value of RON, with the rampant use of the Euro-type fuel itself, which focuses on the use of butanol compounds. In addition, to distinguish the fuel by color, specific dyes need to be added.

Refinery Performance Analysis

In this study, plant production calculations such as mass and energy balances are performed by simulation using Aspen HYSYS software and validated using excel calculations to confirm the calculations further. The simulated process follows the process described previously. This technical analysis considers the specified production process, operating conditions, and production that can take place well.

The Light Naphtha Refinery plant requires or processes up to 10,000 barrels of light naphtha per day, or 3,600,000 barrels per year, based on mass balance calculations on the preliminary design process, assuming it operates 24 hours per day, 365 days per year. The facility's other materials and utilities are listed in Tables 3 and 4.

This factory produces high gasoline with 98 RON as much as 893,520,000 liter year^{-1} or 103,417 liter hr^{-1}. The product of this factory will be sold as mixed materials or more commonly known as HOMC, that can improve fuel performance.

Economic Analysis

In this study for a light naphtha refinery project, economic analysis is one of the parameters of whether a factory is feasible. The economic aspects will be considered using several economic feasibility parameters such as NPV, IRR, POT, and BEP [13]. Cash inflow is derived from the proceeds from product sales by the refinery. This plant's products are gasoline RON 98 with an estimated selling price of $ 804,168,000/year.

The amount of Capital Expenditure (CAPEX) is equal to the amount of Total Capital Investment

Table 3. Annual materials required for the proposed plant capacity.

No	Materials	Annual Requirement (tonnes/year)
1.	Reformate	114,318,000
2.	Benzene	117,559,200
3.	Methanol	40,734,000
4.	Ethanol	33,349,320
5.	Butanol	23,476,800
6.	Chlorinated Al Catalyst	867
7.	Downtherm A	4,079
8.	Zeolite Adsorbent	3

Table 4. Annual utility requirement for the proposed plant capacity.

No	Utility	Units	Annual Requirement
1.	Electricity	kWh	94,511
2.	Fuel Gas	MMBTU hr^{-1}	24
3.	Refrigerant	liter hr^{-1}	21,008,710

(TCI) without considering the cost of workers in the construction of the factory, so the value of CAPEX is the same as the value of Fixed Investment (FCI). Meanwhile, OPEX (Operation Expenditure) consists of purchasing electricity, water, chemicals, labor, supply management needed per day, administration costs, research, and development costs. Based on the calculations, this plant has a CAPEX value of $ 83,199,565 and an OPEX value of $ 749,773,909. So, Total Annual Cost (TAC) can be calculated and obtained with $ 0.848 per liter HOMC.

Economic analysis is carried out using the discounted cash flow method, whose value is projected into the NPV, an analysis that compares the investment value at present, with the investment value in the future with Eq. 1, where *CFt* is cash flow in year *t*; CF_0 is present investment value, *i* stands discounted rate, *t* is calculated year, and *n* is investment time.

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+i)^t} - CF_0 . \quad (1)$$

The calculated NPV value is $ 138,247,252, where the NPV is positive (NPV > 0), indicating that the projected income generated or invested exceeds the projected costs incurred. This shows that this plant is feasible to be built. IRR based on discounted cash flow is a specific interest rate at which all receipts will exactly cover all capital expenditures. IRR is the value of the discounted rate causing the difference in NPV to be 0. Discounted rate is a value that expresses changes in the value of the value in the future. The calculated IRR is 29.38 % per year, greater than the loan interest, which is 9.75 % per year [9]. POT is the time to return the investment capital from the sale of products that make a profit. It was found that the payback period is 3 years and 5 months, less than the plant's estimated age. BEP analysis determines the amount of production capacity where the total production costs are the same as sales results. Fixed costs, variable costs, semi-variable costs, and total costs are not affected by the production capacity. The fixed costs include depreciation, taxes, insurance, and loan. The variable costs include raw material, utility, and royalty. The semi variable costs include labor, maintenance, laboratory, general expenses, and plant overhead cost. Based on the calculations, the BEP obtained 49 % of the proposed production capacity. So, based on the calculations above, this plant is feasible to be built.

CONCLUSIONS

According to the technical analysis, the plant is successful in producing High Octane Mogas Component (HOMC) with RON 98, so it is worthy to be built. In an economical aspect, based on the analysis has been done it is also feasible to be built.

Acknowledgements

The authors gratefully acknowledge financial support from the Institut Teknologi Sepuluh Nopember for this work, under the project scheme of the Publication Writing and IPR Incentive Program (PPHKI) 2022.

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