ETHYL ALCOHOL FROM MOLASSES PLANT DESIGN WITH CAPACITY 40,000 TON/YEAR

Submitted to fulfill the requirement of
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Surakarta 14 August 2017

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ABSTRAK

Etil alkohol adalah jenis alkohol utama pada minuman beralkohol. Etil alkohol banyak diproduksi melalui proses fermentasi gula menggunakan *yeast* atau melalui proses petrokima. Etil alkohol adalah produk kimia utama yang digunakan untuk antiseptik, anti racun, pelarut medis, keperluan konsumsi, bahan bakar (bahan bakar mesin, bahan bakar roket, dan bahan bakar sel), pemanas dalam keperluan rumah tangga, bahan baku, pelarut, dan cairan bertemperatur rendah (digunakan dlam laboratorium dengan *dry ice* atau pendingin lain). Pabrik etil alkohol dari tetes tebu sebagai bahan baku utama ini akan didirikan di Sukoharjo, Jawa Tengah dengan kapasitas 40.000 ton/tahun dan dibangun pada tahun 2020. Bahan baku tetes tebu diperoleh dari pemasok yang berada di sekitar Solo – Semarang, Jawa Tengah. Produksi etil alkohol ini masing-masing berlangsung dalam fermentor dengan kondisi operasi isotermal pada suhu 35°C dan tekanan 1 atm.Utilitas yang dibutuhkan untuk mendukung prosesnya adalah air sebanyak 187.154,6378 kg/h yang diperoleh dari air sungai. Udara dan udra tekan yang dibutuhkan sebanyak50 m^3/hjuga dibutuhkan untuk membantu berlangsungnya proses.*Steam* juga dibutuhkan untuk membantu proses, sebesar 66,767,052.8459 kg/h digunakan disertai dengan kebutuhan listrik sebesar 350 kw/h.Pabrik etil alkohol ini beroperasi selama 330 hari dengan nilai FixedCapitalsebanyak Rp74.261.326.185,2297 dan diketahui nilai Working CapitalRp45.472.670.854,7867. Dari evaluasi ekonomi yang telah dilakukan menunjukkan Profit before taxsenilaiRp 25.002.027.285,4679 diiringiProfit after tax sejumlahRp 17.501.419.099,8275. Dari perhitungan yang dilakukan dapat diketahui bahwa ReturnOnInvestment before taxsenilai 33,6676%, dimanaReturn OnInvestment after taxmenunjukkan nilai 23,5673%. Pay Out Time before tax menunjukkan angka 2,2900tahun dengan Pay Out Time after tax 2,9791tahun. Break Event Point bernilai 53,8313% dan Shut Down Pointsebesar 41,2793%, andDiscounted Cash Flow sebesar 30,2125%. Dari hasil evaluasi ekonomi, pabrik etil alkohol ini layak untuk dibangun dan beroperasi.

Kata kunci : Etil alkohol, Etanol, Tetes tebu, Proses fermentasi

ABSTRACT

Ethyl alcohol is the principal type of alcohol in alcoholic beverages. Ethyl alcohol is mostly produced by the fermentation of sugar by yeast or by petrochemical processes. Ethyl alcohol is a chemical product primarily used for antiseptic, antidote, medical solvent, recreational, fuel (engine fuel, rocket fuel, fuel cells), household heating, feedstock, solvent, and low temperature liquid(used in laboratories with dry ice or other coolants). The plant of ethyl alcohol from molasses as raw material will be established in Sukoharjo, Central Java with capacity 40,000 tons/year and built in year 2020. The raw of molasses is obtained from some suppliers around Solo – Semarang, Central Java. The production of ethyl alcohol is carried out in a fermenter where the operating condition of

pressure and temperature are 1 atm and isothermally at 35°C, respectively. Utility needs to support the process. Used water as much as 187,154.6378 kg/h which is obtained from river water. Air and compressed air as much as 50 m^3/h also needs to suport the process. The other utilities needs is steam 66,767,052.8459 kg/hand electricity 350 kw/h.This ethyl alcohol plant has 330 operational days withFixedCapitalas much as Rp74,261,326,185.2297and known theWorking Capitalas much as Rp45,472,670,854.7867. From the economic evaluation that had been calculated before showed that the Profit before tax isaboutRp 25,002,027,285.4679, while theProfit after tax aboutRp 17,501,419,099.8275. From the calculation also known that the ReturnOnInvestment before tax isabout 33.6676%, whileReturn OnInvestment after tax isabout 23.5673%. The Pay Out Time before tax shown the number of 2.2900 years with Pay Out Time after tax are 2.9791 years. Break Event Point is 53.8313% and Shut Down Point isabout 41.2793%, and Discounted Cash Flow as much as 30.2125%. From the results of economic evaluationthis Ethyl alcohol plant is feasibly established and operated.

Keyword : Ethyl Alcohol, Ethanol, Molasses, Fermentation Process

1. INTRODUCTION

1.1. Background

The increasing of petroleum price since 2003 caused by decreasing of petroleum production. Most people said that decreasing caused by American invension to Iraq where Iraq is the highest petroleum source number tree after Saudi Arabia and Iran. But the more influential factor is the increasing of petroleum request from big country and developing country where the consumption of energy relatively increase every year like a lifestyle (Pimentel D et al, 2009). The increasing of fossil energy consumption which relatively high especialy in transportation also can increase green house gas emision too (Amela A & R Haasp, 2010)

Inspite of increased price of fossil fuel, Indonesian petroleum consumption still high. The increasing of petroleum consumption make Indonesians government want to handle this case relate to globlal petroleum price which always increase. The step that take by the government is give a subsidy (International Institute for Sustainable Development). But for a long time the petroleum price increase uncontrolly and the amount goes to rare. The rare of petroleum will make the scientist search the renewable energy source for the future (Austin G. T, 1984)

Alternative energy that usually used in some country are bioethanol. Bioethanol can be produced from source that consist of sugar, carbohydrate, and cellulose, for example flour $(C_6H_{10}O_5)_n$ which hydrolize become a glucose then fermented using *Saccharomyces cerevisiae* and purified by distillation (Fessenden and Fessenden, 1999)

Bioethanol is a biofuel which consist of ethyl alcohol. In some condition and amount ethyl alcohol can mixed with gasoline for transportation energy. Biofuel become more interesting after oil crisis as liquidfossil fuel changer.the increasing of biofuel interest in las decade is contribute to the popularity of biofuel as alternative fuel (Karel J et al, 2012)

Currently, biofuel global production still low but continuously increasing following the needs of energy. This increasing based on some country that want to change some part fossil fuel with biofuel. Some country in Europe have the rule that 5.75 percent of transportation energy must use biofuel as alternative fuel (European Parliament and Council, 2003).

With developing of ethyl alcohol plant, so hopely can :

1. Decreasing the consumption of fossil fuel in Indonesia.
2. Decreasing the dependence of fossil fuel in Indonesia.
3. Comply with a request of ethyl alcohol in Indonesia.
4. Increase the country devizen by ethyl alcohol export.
5. Decreasing the amount of unemployee with adding a job vacancy.
6. Help the government program about petroleum using (Perpres Number 5 year of 2006 about National Energy Sublety and President Instruction Number 1 year of 2006 about stock and Utilization of Natural Fuel (Biofuel) as alternative energy)

1.2. Design Capacity

The selection of ethyl alcohol plant design capacity is consider with some reason, that is:

1.2.1 The needs of ethyl alcohol in the country

The data of ethyl alcohol needs in the country can shown on table behind in column of import volume :

Table 1. Ethanol (Ethyl Alcohol) Product Data

Comodity Kind	2006	2007	2008	2009	2010
Production capacity (Ton)	990,000.00	990,000.00	990,000.00	990,00.00	660,000.00
Production volume (Ton)	920,000.00	947,823.55	641,852.00	621,535.00	620,000.00
Import volume (Ton)	31,026.78	30,095.98	64,148.00	76,937.00	20,000.00
Export volume (Ton)	524,814.20	543,182.70	400,000.00	414,000.00	420,000.00
Utillity (%)	93	96	65	63	94

(BPS, 2012)

1.2.2 The roadmap of biofuel utillization

Currently the utilization of biofuel in Indonesia increase. For 2011-2015 need about 2.78 million KL of bioethanol as a mixture of 10% gasoline (Kementrian ESDM).

1.2.3 The raw material available

In this plant design used mollasses as a raw material which got from sugar industry around Surakarta and Semarang area with the amount industry is about 13 units with the capacity of mollasses about 99,580 ton.

1.2.3 Bioethanol plant data operate

Table2. Data of Ethyl Alcohol plant

Plant Name	Location	Capacity (KL/Year)
Salim Group	South Sumatra	70,000
PT. Indo Acidatama Tbk	Central Java	61,875
Molindo Raya	East Java	50,000
PT. PS Madukismo	Yogyakarta	18,480
Anugrah Kurnia Abadi	Lampung	2,500

Depend on four consideration before, in this ethyl alcohol plant design choose the rate of ethyl alcohol need, the feedstock, and the other ethyl alcohol

plant before, the number of capacity product choose about 50,000 KL per year or 40,000 ton/year.

2. METHODOLOGY

2.1 Process Selection

There are some processes of ethyl alcohol manufacturer, namely:

2.1.1 Ethylene hidration

Synthesis ethyl alcohol can be produced from ethylene absorption in sulphuric acid which produce ethyl sulphate that hydrolized become ethyl alcohol and sulphuric acid. (Faith et all, 1975). Ethanol for industrial stock is usually made from petro chemical by acid catalyzed hydration of ethylene (Roberts et all, 1977). The catalyst most commonly use phosporic acid that adsorbed onto a porous support like silica or diatomaceus earth (Naim et all 2005).

2.1.2 Ethylene catalytic hidration

Synthesis ethyl alcohol generally processes from direct ethylenen hydration using sulphuric acid as catalyst (Faith et all, 1975). The current process of involves the ethylene dirrect hydration with the amount of catalytic agent of sulphuric acid. The temperature is around 300^oC to 400^o C with pressure 1000 Psi.

2.1.3 Fermentation

This is the process that choosen in this preliminary design plant. When the yeast reduced in oxygen produce ethyl alcohol and carbon dioxide. The chemical equation can be written to summarize the convertion behind (Morias et all, 1996).

$C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2$

$C_{12}H_{22}O_8 + H_2O \rightarrow 4\ CH_3CH_2OH + 4\ CO_2$

Fermentation here is yeast culturization process under favorable thermal condition to make an ethyl alcohol. The process happen on temperature around $35^oC - 40^o$ C.

2.2. The Use of the Product

There are some using of ethyl alcohol, that is important raw material industry and has wide spread use as a raw chemical material for other organic compound, medical wipes and most common antibacterial hand sanitizer gels at a

concentration of about 62% v/v as an antiseptic, treatment for poisoning by other alcohol, good general purpose solvent, and used as fuel.

2.3. Plant Location

With some consideration, the plant location placed in Sukoharjo, Central Java. The place are directly effect the main production which is near the raw materials and easy of the distribution of the product.

2.4 The Step of Process

Basicly the step of producing ethyl alcohol from molasses is:

2.4.1 Molasses process

Molasses processing is make optimum condition for yeast growth. The important thing at this process is pH controling by adding sulphuric acid and sugar concentration by adding water (M-01). To make unwanted contaminant disappear is heating the molasses (F-01) until temperature of 75^{o}C using steam with temperature about 100^{o}C then cooled to 35^{o}C (E-100).

2.4.2 Yeast culturization

Grow the cells before used in fermentation process done as long as 24 hours at temperature around 32-35^{o}C and atmospheric pressure 1 atm (F-101). Molasses pumped to culturization tank (R-01) with capacity about 5% from reactor capacity (R-02) as long as 24 hours. In this process needs an adjuvant like (NH4)2HPO4 (give phospate needs), urea (give carbon needs), ammonia (give nitrogen needs), air (give oxygen needs), and antifoam (anticipate the foam form).

2.4.3 Fermentation

Fermentation done on fermenter reactor (R-02) with operation condition 35^{o}C of temperature, atmospheric pressure 1 atm, and pH around 4.5-5. Molasses are mixed with the product of culturization tank (R-01) and add some ammonia to give a nitrogen needs, antifoam to restrain the foam found along fermentation process, and also added a buffer solution to make the pH of media still stable.

2.4.4 Filtering

Separation process between the solid from ethyl alcohol and the other fluid before the purification process. The fermented ethyl alcohol pumped to the filter (H-01), from this separation process still consist a small other fluid. Its thrown to

Waste Management Unit while the filtrate pumped to separator (D-01) through heat exchanger (E-200).

1. Purification process

Purification process from another fluid make the ethyl alcohol purification reach 95% mass of ethyl alcohol, 5% consist of water mass and small amount of aldehyde. From the separator (D-01), the top product still consist the other fluid like acetic acid, glycerol, and penthanol. To get the ethyl alcohol 95% need the purification process again. Top product of separator pumped to first distillation column (D-02) which before through the heat exchanger (E-103). While the bottom product pumped to Waste Management Unit. From first distillation column (D-02) get aldehyde, water, and ethyl alcohol as top product while the bottom product as acetic acid, glycerol, and penthanol.Ethyl alcohol will store in storage tank (F-103) through cooler (E-105) while the bottom product pumped to Waste Management Unit before through the cooler (E-106).

2.5. The Concept of the Process

2.5.1 Basic reaction

Ethyl alcohol production from molasses using a fermentation process by yeast. The reaction happen is exotherm reaction. The fermentation process run on fermenter reactor at temperature of 35^{o}C, atmospheric pressure 1 atm, pH around 4.8-5 with 48 hours fermentation process. After fermentation process found an ethyl alcohol, CO_2, and another material as slurry. After the process finish then doing a destillation process until reach a concentration around 95-95.6% of mass.

2.5.2 Thermodynamic View

The reaction of forming ethyl alcohol by fermentation doing on exotherm condition, this can be happen because the value ofΔH are a negative value, that is:

$C_6H_{12}O_{6Zymase}\rightarrow 2C_2H_5OH + 2CO_2$ ΔH= -130 kJ

It can be seen from the negative value ofΔH_{298}make the reaction become an isotherm reaction. After that calculate the equilibrium constant :

$\Delta G_o = RT \ln K$

$$\ln K = \frac{\Delta G^o}{-RT}$$

$\Delta G = \Sigma\Delta G_{298 \text{ of product}} - \Sigma\Delta G_{298 \text{ of reactant}}$

$= (-788.82 + -335.7) - (-909.4)$ kJ/mol

$= -215.12$ kJ/mol

$= -51{,}378.07$ cal/mol

$$\text{In K} = \frac{\Delta G}{-RT}$$

$$\text{In K} = \frac{-51378{,}07\ kal/mol}{-1{,}987\ cal/moL.K\ x\ 298\ K}$$

In K = 86.77216

$K_{298} = 4{,}46329 \times 10^{37}$

From the calculation get an equilibrium constant value more than one so the reaction is irreversible reaction.

$2C_6H_{12}O_6 + H_2O \rightarrow C_2H_5OH + CH_3COOH + 2CO_2 + 2C_3H_8O_3$

2.5.3 Kynetic View

Ethanol has been made since ancient times by the fermentation of sugars. Simple sugar are the raw material. Zymase is an enzyme from yeast that change the simple sugar into an ethanol and carbon dioxide. The fermentation reaction represented by the simple equation behind :

$C_6H_{12}O_6 \xrightarrow{Zymase} 2C_2H_5OH + 2CO_2$

$\mu = 0.6$/hour with μ is the biomas growth speed.

Its actualy very complex and impure cultures of yeast produce varying amount of other substance including glycerine and various organic acid.

$C_6H_{12}O_6 \rightarrow C_3H_8O_3 + CH_3CHO + CO_2$

$2C_6H_{12}O_6 + H_2O \rightarrow 2C_3H_8O_3 + CH_3COOH + C_2H_5OH + 2CO_2$

3. RESULT AND DESCRIPTION

3.1 Main Equipment Review

Fermentor R – 02 specification

Function = Fermentation process placed using *Saccharomyces cereviciae*

Operation = Batch operation

Amount	= 15 pieces (Run with schedule)
Temperature	= 35ºC
Pressure	= 1 atm
Diameter	= 6.0960 m
High	= 14.9535 m
Volume	= 355.6596 m^3
Type	= Flow reactor tank with stirrer
Head type	= Teorispherical head
Material	= Stainless steel SA-167 type 304
Stirrer type	= Turbine
Stirrer speed	= 50 rpm
Stirrer diameter	= 2.0117 m
Stirrer motor	= Variable-speed belt
Stirrer power motor	= 50 hp
Cooler type	= Coil
Cooler diameter	= 0.125 in
Coller high	= 3.0951 m
Cooler coil amount	= 8,800 coil
Cooler media	= Cooling water
Cooler utility	- Reactor stirrer usedelectrical source fromutility - Cooling water

3.2. Utility

Process supporting unit is often called the utility unit that is an important part to support the production process in the plant. Process supporting unit contained within the plant of ethyl alcohol are:

1. Water management and supply unit

   Manage and suply water for the production process.

2. Steam generator unit

   Supply the steam for heating for process.

3. Compressed air provider unit

Provide pressure air for instrumentation to support production process.

4. Power generator unit

   Power production process and lighting.

5. Fuel provider unit

   Supply fuel needs of boiler and generator.

6. Waste water management unit

   Manage plant waste water.

3.3. Plant Management

Corperate form : Limited liability company (PT)

Status of the company : Private company

Production capacity : 40.000 ton/year

Plant location : Sukoharjo, Central Java

Consideration of the selection of companies based on several factors, are:

1. Easier to get funding, by selling company shares.
2. Limited responsibilities of shareholders
3. Shareholder can chose and pay commissioner member and company executive that already gad experience and capable for it works.
4. Wider business area, a company can get funding from society so it can expand it business.
5. Company form that own its own wealth that separated from personal wealth.
6. Easier to get funding from bank with it's own company as it assurance.
7. Easier to move in capital market.

3.4. Economic Evaluation

The economic evaluation is used to determine are the plant can be profitable and feasible. The estimation of equipment cost and other cost is important to be calculated. The figrure bellow show the result of the economic evaluation consist, Rate of Investment (ROI), profitm Pay out Time (POT), and Break Even Poin (BEP).

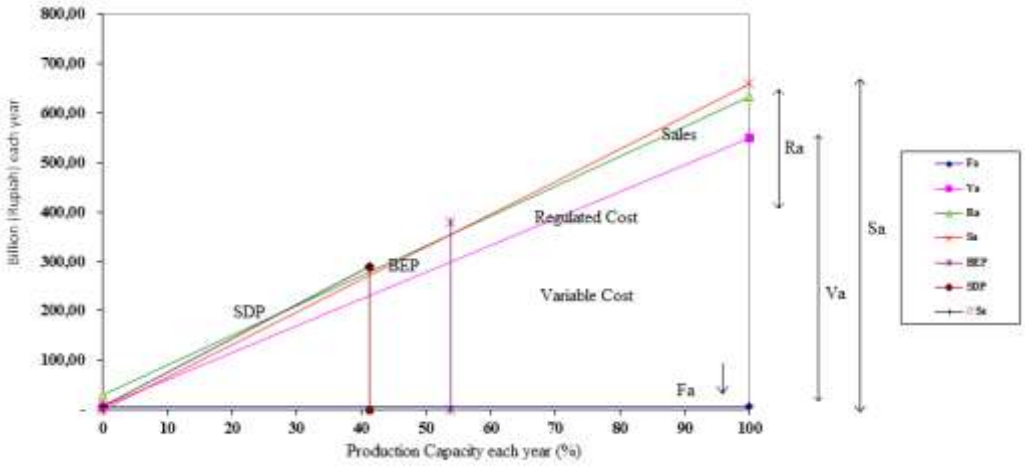

Figure1. Economicevaluation

4. CONCLUSION

From the economic evaluation figure before showed that the Profit before tax isaboutRp 25,002,027,285.4679, while theProfit after tax aboutRp 17,501,419,099.8275. From the calculation also known that the ReturnOnInvestment before tax isabout 33.6676%, whileReturn OnInvestment after tax isabout 23.5673%. The Pay Out Time before tax shown the number of 2.2900 years with Pay Out Time after tax are 2.9791 years. Break Event Point is 53.8313% and Shut Down Point isabout 41.2793%, andDiscounted Cash Flow as much as 30.2125%. From the results of economic evaluationthis Ethyl alcohol plant is feasibly established and operated.

REFERENCE

Amela, Ajanovic and R, Haas, 2010, Echonomic Chalenges for the Future Relevance of Biofuels in Transport in EU countries, Energy 35 (8), 3340-3348, 2010

Austin, George T, 1984, Shreve's Chemicl Process Industries, McGraw Hill, Inc, New York.

Badan Pusat Statistik, 2012, Ethyl Alcohol Product Data

Brown, G.G., 1950, Unit Operations, John Wiley and Sons, Inc., New York.

Brownell, L.E. and Young, E.H., 1979, Process Equipment Design, John Wiley and Sons, Inc., New York.

Coulson, J.M. and Richardson, J.F., 1983, Chemical Engineering, Vol.6, Pergamon Press, Oxford.

European Parliament and Council, 2003

Faith, Keyes and Clark, 1961, Industrial Chemical, Fourth edition. John Wiley and Sons, Inc, New York.

Fogler, H. S,andNihat.M, 2006, Elements of Chemical Reaction Engineering, 4th edition, University of Michigen.

Karel, J., Ladislav, K., and David, Z., 2012, Biofuels : Policies and Impacts, Agric. Econ. – Czech, 58, 2012 (8): 372-386.

Kementrian Energi dan Sumber Daya Mineral Republik Indonesia, Pusat Data dan Informasi Energi dan Sumber Daya Mineral, 2012, Kajian Supply Demand Energy.

Kern, D.Q., 1950, Process Heat Transfer, McGraw-Hill International Book Company Inc., New York.

Kirk,R.E,andOthmer,D.F., 1965, Encyclopedia of Chemical Technology, Vol 10, 1st, Interscience Encyclopedia, Inc., New York.

Naim Kosaric, Zdravko Duvnjak, Adalbert Farkas, Herman Sahm, Stephanie Bringer-Meyer, Otto Goebel, and Dieter Mayer, 2011, Ethanol Ullmann's Encyclopedia of Industrial Chemistry. Wiley-VCH, Weinheim.

P.B. Morias, C.A. Rosa, Linardi, V.R. Carazza, E.A. Nonato, 1996, Production of Fuel Alcohol by *Saccharomyces* strains from tropical habitats. Biotechnology Letters, 18 (11) (1996) pp. 1351-1356.

Peraturan Pemerintah No 79, 2014,Kebijakan Energi Nasional

Pimentel, D., Gardner,. J.B., Bonnifield, A. J., Garcia, X., Grufferman, J. B., Hran, C. M., Rochon, E. T., Schenkler, J. L., and Walling, E. E., 2009, Energy Efficiency and Conservation for Individual Americans. Environment, Development and Sustainability.

Roberts, John F, Caserio, Marjorie C. 1997. Basic Principles of Organic Chemistry. W. A. Benjamin, Inc.