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Predesign of Biphenyl Chemical Factory from Benzene with Capacity of 10.000 Ton Per Year

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ABSTRACT

Biphenyl is one of the most important supporting materials needed in the chemical industry as an intermediate. This study aimed to describe the technical review of the biphenyl plant design to be built in Gresik, East Java. The predesign process of the biphenyl plant consists of the analysis of the location of the factory, analysis of the benzene process, and analysis of utility calculations. The factory is designed to operate continuously for 330 days, 24 hours per day, and requires 214 employees. The manufacture of biphenyl begins by reacting benzene in a pipe flow reactor (R-01) at a reactor temperature of 377°C and a pressure of 2 atm. Economic analysis shows that the value of ROI before tax is 50.38%, and the value of ROI after tax is 32.75%. POT before tax is 1.65 years, and POT after tax is 2.34 years. The BEP value is 43.11%, and the SDP value is 23.75%. The interest rate in DCF for 10 years averages 19%. In conclusion, a biphenyl plant from benzene with a capacity of 10,000 tons/year is worth considering from a technical and economic point of view.

1. Introduction

Industrial development in Indonesia is quite developed, especially in the chemical industry. The chemical industry continues to experience improvement in both industries that produce finished materials, semi-finished materials, and even raw materials for other industries. Biphenyls are aromatic hydrogen compounds with the molecular formula $C_{12}H_{10}$.[1,2] Biphenyl is an organic component that is in the form of crystals. Biphenyl is one of the supporting materials that are very important and needed in the chemical industry. In the chemical industry, biphenyl is one of the potential intermediate products to be developed because it has a wide range of uses, including as a raw material for making polymers, emulsifiers, and as a coolant (dowtherm).[4-6]

Given the great demand for these chemicals, the establishment of this biphenyl factory will be profitable and provide benefits for other industries. In addition, it is hoped that the domestic need for biphenyl will be fulfilled, increase the country's foreign exchange, and can create jobs so as to reduce unemployment. The factory capacity is selected based on the minimum productive capacity of the biphenyl factory, which is 10,000 tons/year, with the hope that it can meet domestic demand to reduce import figures and increase foreign exchange by exporting biphenyl products abroad.[5-7] This study aimed to describe the technical review of the biphenyl plant design to be built in Gresik, East Java.

2. Methods

This study was a descriptive study with process modeling and optimization. The study involves using mathematical models and optimization algorithms to design and optimize chemical processes.[8,9] Linear programming, non-linear optimization, and dynamic simulation were used to identify optimal process conditions and improve process performance. The predesign process of the biphenyl plant consists of the analysis of the location of the factory, an analysis of the benzene process, and an analysis of utility calculations. The biphenyl factory will be established in the Gresik industrial area, East Java. Data will be presented in the form of mathematical calculations and narrative explanations.

3. Results and Discussion

Factory location analysis

The biphenyl factory is planned to be established in the Gresik Industrial Area, East Java. The basic considerations for selecting the location for the establishment of the factory are related to the supply of raw materials, marketing, transportation, climate, and utilities needed. Raw materials are the main requirement for the continuity of a factory, so the supply of raw materials must be considered. The factory location is planned in the city of Gresik, East Java, which is quite close to the raw material, namely C_6H_6, in the liquid phase obtained from Trans Pacific Petrochemical Indotama (TPPI) Tuban, distributed via land transportation. Biphenyl products are widely needed by the polymer industry, especially in the field of hard plastics, which are widely used in electronic goods, and also for thermo fluids. The location of the factory in Gresik, East Java, is quite strategic because it is close to the port of Tanjung Perak and industrial areas, as well as other industrial markets spread throughout Indonesia, making it easier for domestic and foreign marketing. Transportation in Gresik, East Java, by land and sea is quite smooth because there are adequate highways, and it is close to the port of Tanjung Perak, making it easier to distribute raw materials to factories and products to consumers.

The provision of a qualified (skilled and educated) workforce to operate industrial equipment must be considered. Qualified workforce can be met from alumni of universities throughout Indonesia and abroad if needed, while those who are less educated can be met by residents of the surrounding area and transmigrants so as to reduce unemployment. In Gresik, East Java is close to several companies (industrial areas) which are complete with utility units so that water and steam supplies can be fulfilled. For this biphenyl factory, buying water from PT. Petrokimia Gresik. Likewise, the need for electricity will not experience difficulties because it obtains supply from PLN and the provision of generator units.

Process review analysis

Biphenyls are aromatic hydrogen compounds with the molecular formula $C_{12}H_{10}$. Biphenyl is an organic component that is in the form of crystals. Biphenyl is one of the most important supporting materials needed in the chemical industry as an intermediate.[10-13]

Biphenyl production can be done in 2 ways, namely benzene dehydrogenation and benzene dimerization. Making biphenyl by dehydrogenation of benzene runs optimally at a temperature of 375 – 400°C and a pressure of 2 atm without using a catalyst. The benzene dehydrogenation reaction is as follows;

$$C_6H_{6(g)}\ 1/2\ C_{12}H_{10(g)} + 1/2\ H_{2(g)}$$

The process is carried out in the gas phase using a pipe flow reactor. Products in the form of biphenyl and hydrogen are separated in a separator, and then the biphenyl is purified in a distillation tower.[14,15] The reaction with the catalyst ($PdCl_2$) takes place at a temperature of 165-185°C at a pressure of 10 atm in a stirred tank flow reactor (RATB). Making biphenyl by benzene dimerization can be done by the following reaction;

$$C_6H_{6(l)}\ 1/2\ C_{12}H_{10(l)} + 1/2\ H_{2(l)}$$

Process selection analysis

Process selection refers to technical and economic advantages. The economic aspect can be viewed from the calculation of economic potential. The economic potential of the above process is as follows;

$$PE = (BM\ C_{12}H_{10}\ .\ Price\ C_{12}H_{10}) + (BM\ H_2\ .\ Price\ H_2) - (BM\ C_6H_6\ .\ Price\ C_6H_6)$$

$$=(154\ kg/kgmol\ .\ US\$\ 2{,}83/kg) + (2\ kg/kgmol.\ US\$\ 0/kg) - (78\ kg/kmol\ .\ US\$\ 1{,}5/kg)$$

$$= US\$\ 435{,}82/kmol - US\$\ 117/kmol = US\$\ 318{,}82/kmol$$

Based on these mathematical calculations, an alternative for the dehydrogenation of benzene was chosen with the consideration that this reaction does not use a catalyst and takes place in the gaseous phase at temperatures and pressures that are not too high.

Raw material preparation modeling

Benzene is stored in a storage tank (T-01) at 1 atm and 30°C. Benzene 99.8% is pumped up to 2 atm, then heated and evaporated with a vaporizer (V-01) to change the phase from liquid benzene to gas. In order to make the separation more perfect, after the vaporizer (V-01), the benzene flowed to the separator-01 (SP-01). Benzene gas released by separator-01 (SP-01) is heated using heater-01 (HE-01) until it reaches a temperature of 650°K, then fed into the pipe flow reactor. Inside the reactor, benzene reacts to form biphenyl and hydrogen. The reaction in the reactor (R-01) took place in the gas phase with a pressure of 2 atm and a temperature of 376.85-376.76°C and is endothermic, so a heating medium is needed so that the operating temperature in the reactor is not too low. The product that comes out of the reactor is a mixture of benzene, toluene, hydrogen, and biphenyl.[16]

The gas mixture leaving the reactor (R-01) is cooled and condensed in a partial condenser (CD-01) until it reaches a temperature of 89.39°C, then enters the Separator-01 (SP-02) to separate the vapor gas based on the phase difference. The top product in the form of hydrogen, benzene, toluene, and biphenyl in the gas phase has flowed to the advanced processing unit. In comparison, the bottom product in the form of benzene, toluene, and biphenyl in the liquid phase is pumped and put into the distillation tower (MD-01). In the distillation tower (MD-01), benzene, toluene, and biphenyl are separated. The bottom product is biphenyl with a purity of 99.3% with a little benzene and toluene, while the top product is benzene with a purity of 99.8% and toluene. The bottom product in the form of biphenyl is the desired product, and then the product is fed into the prilling tower to make the product into solid granules and then stored in a silo (SL-01). The top yield is 99.8% benzene, and toluene is recycled to feed into the reactor.

Utility analysis

Utilities are supporting units for the continuity of the production process at the factory.[8-12] So, apart from raw materials and auxiliary materials, infrastructure needs, especially utilities, are needed. This unit plays an important role in production because, without this unit, the production process cannot work. The biphenyl plant utility unit with a production capacity of 10,000 tons/year includes water treatment, steam generation, electricity supply, compressed air supply, and fuel supply.

The water needed for the biphenyl plant includes cooling water, water for the cooling process in the reactor, water for steam, water for office and household needs, and other needs. Water needs are met by purchasing from PT. Petrokimia Gresik, which is located close to the factory location. The water requirement in the factory as a whole is 81314.26 kg/hour.

The steam required for this biphenyl plant is saturated steam at a temperature of 257.17°C and a pressure of 44.2 atm. Steam is produced from the boiler (B-01), then used in heat exchangers, namely vaporizers and reboilers. The steam requirement for V-01 is 2,660.68 kg/hour, and RB-01 is 4,637.88 kg/hour, so the total steam requirement in the biphenyl plant is 7298.56 kg/hour.

As for the electricity needs of this factory, it is used for lighting, a source of power for process equipment, and a source of utility power. Based on the calculation results, the total electricity demand is 44.04 kWatt. Electricity needs of this magnitude are met from PLN of 80 kWatt. But if there is a blackout by the National Electric Company or other matters, a 100 kW backup generator powered by diesel oil is used. The need for diesel fuel to drive the generator as a power plant is 2730 kg/year. The need for fuel oil for boiler fuel is 4,277,988 kg/year. The need for furnace fuel is 1,089,396 kg/hour. The need for compressed air is used to drive the control devices. The air is distributed in a clean and dry state. To increase the air pressure, a compressor is used. The compressed air requirement for this plant is estimated at 28.8 m^3/hour.

4. Conclusion

A biphenyl from a benzene plant with a capacity of 10,000 tons/year is worth considering from a technical and economic point of view.

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