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UTHM Biodiesel Pilot Plant Development

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Abstract:

Biodiesel is an environmental friendly, alternative fuel prepared from domestic resources such as palm oil and *jatropha curcas* that can be used in normal diesel engine cars and buses without any engine modification. It can be used either in the pure form (B100) or as blends on conventional diesel engines and it is biodegradable.

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UTHM being in the state of Johor, where oil palm is in abundance, has embarked on a project to develop a crude palm oil (CPO) based Biodiesel pilot plant for research purposes. This pilot plant will produce 1 MT fuel grade biodiesel per batch with a feed stock of CPO under presence of catalysts.

This paper describes the chronological phases in the UTHM pilot plant development starting from the project initiation to its current implementation stage. The experience shared in this paper would be beneficial for other developers to emulate.

1. Introduction

Biodiesel is a clean burning alternative fuel produced from domestic, renewable resources. It is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics. Chemically, biodiesel is a fuel composed of mono-alkyl ester of long chain fatty acids derived from vegetable oils or animal fats, designated B 100, and meeting the requirements of ASTM (American Society for Testing and Materials) D 6751 or EN (European Norm) 14214.

The state of Johor is fortunate to have a plentiful supply of oil palm and the second largest producer of CPO in the country with around 640,000 ha (18.20 %) of the cultivation area at year 2001 [2], see Figure 1. The availability of the abundant energy sources makes the oil palm truly attractive as a future source of renewable energy. If exploited prudently, it will enhance the sustainability of the oil palm plantation.

UTHM is a state university located in Johor has recently embarked on a project of a biodiesel pilot plant with the feedstock of CPO. It will contribute to the use of sustainable renewable energy source in an efficient manner and is in line with

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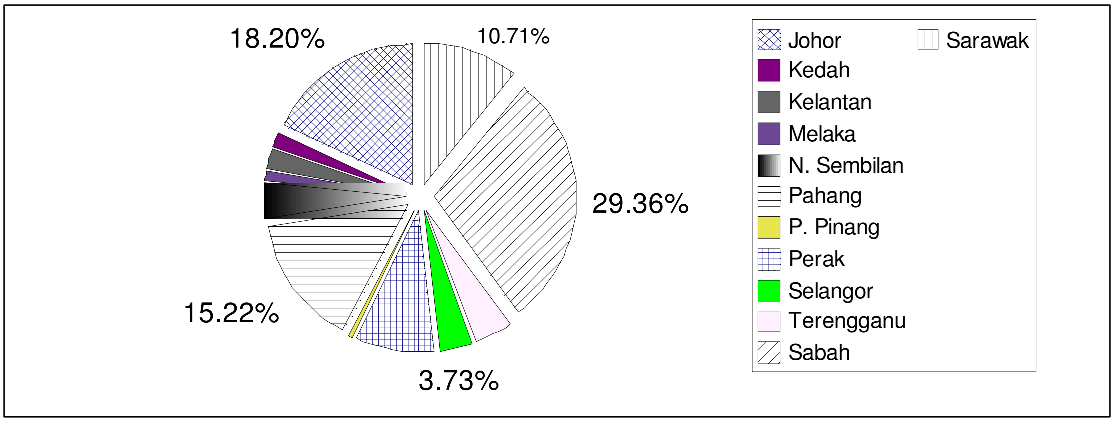

Figure 1: Percentage of Distribution of Oil Palm Area by State

Malaysia's development policy of renewable energy as a fifth fuel [1].

2. CPO, Diesel, and Biodiesel Properties

The oil palm produces two types of oils from the same fruit – palm oil from the outer flesh or mesocarp and palm kernel oil or lauric oil from the seed or kernel inside the hard-shell. The palm oil extracted from the mesocarp is known as crude palm oil (CPO). The kernel also yields residual product known as palm kernel meal, which is mostly used for animal feed.

The differences between the feedstock, biodiesel, and petroleum based diesel fuel are important to understand. Table 1 represents selected physical and thermodynamical data of CPO and oils for comparison [3-5]. The kinematic viscosity measures the flow resistance of the fuel. Viscosity is important to diesel and biodiesel because it impacts the operation of components such as the fuel pump. Higher viscosity interferes with injector operation, resulting in poorer atomization of the fuel spray, and has been associated with increased engine deposits. As shown in Table 1, the viscosity of the CPO above 10 times higher than of the diesel specification. Cetane number is a measure of the fuel's ignition delay. Higher cetane number indicates shorter time between the injection of the fuel and its ignition. Based on this number alone, biodiesel would tend to improve the operation of the engine with respect to pure diesel due to its higher cetane number. Flash point measures the lowest temperature at which application of test flame causes the vapor above the sample to

Table 1: CPO, Diesel, and Biodiesel Specification

Oil type	Kinematic viscosity at 40 °C)	Cetane number	Flash point (°C)	Lower heating value (MJ/kg)	Density (kg/l) at 15 °C	Sulfur content (% wt)
CPO	42	> 49	285	39.7	fat	< 0.05
Diesel	4.0	50	84	45	0.85	0.16
Biodiesel	3.5-5.0	51 min	120 min	39 – 41	0.86-0.90	0.001 (max)

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ignite. It is used to assess the overall flammability hazard of the material. Flash point is used in safety regulations to define flammable and combustible materials. Biodiesel would be considered significantly safer with higher temperature. The sulfur content of biodiesel is very low and it reduces significantly particulate emissions in comparison with normal diesel.

According to EN 14214 or ASTM D6751 there are 26 parameters of standard specification for biodiesel fuel oils.

3. Processes of Biodiesel Production

Converting the feedstock of CPO into fuel grade biodiesel will be performed in a pilot plant with a capacity of 1 MT per batch. The batch process has been selected for operational flexibility of equipment, the possibility of a variety of raw materials as well as the plant retrofit for future development.

The pilot plant design is modular – one module for CPO pretreatment which converts CPO into Bleach Palm Oil (BPO), the second one for refining and separating which converts and process the BPO into the end product of biodiesel that meets EN 14214 fuel specifications. The Block Flow Diagram (BFD) of the biodiesel production used in this project is depicted in Figure 2. In the pretreatment module, the process begins with degumming when the CPO is treated with phosphoric acid to remove the natural gums, and followed by bleaching with activated earth under vacuum to remove the coloring matters as well as to adsorbs any metal ions content. Other impurities such as dirt and solid particles are removed using a bleaching earth filter. The objective of the pretreatment section is to prepare the raw materials quality to be fit for the second module. The product of this module is the refined bleached palm oil (BPO).

The subsequent process is

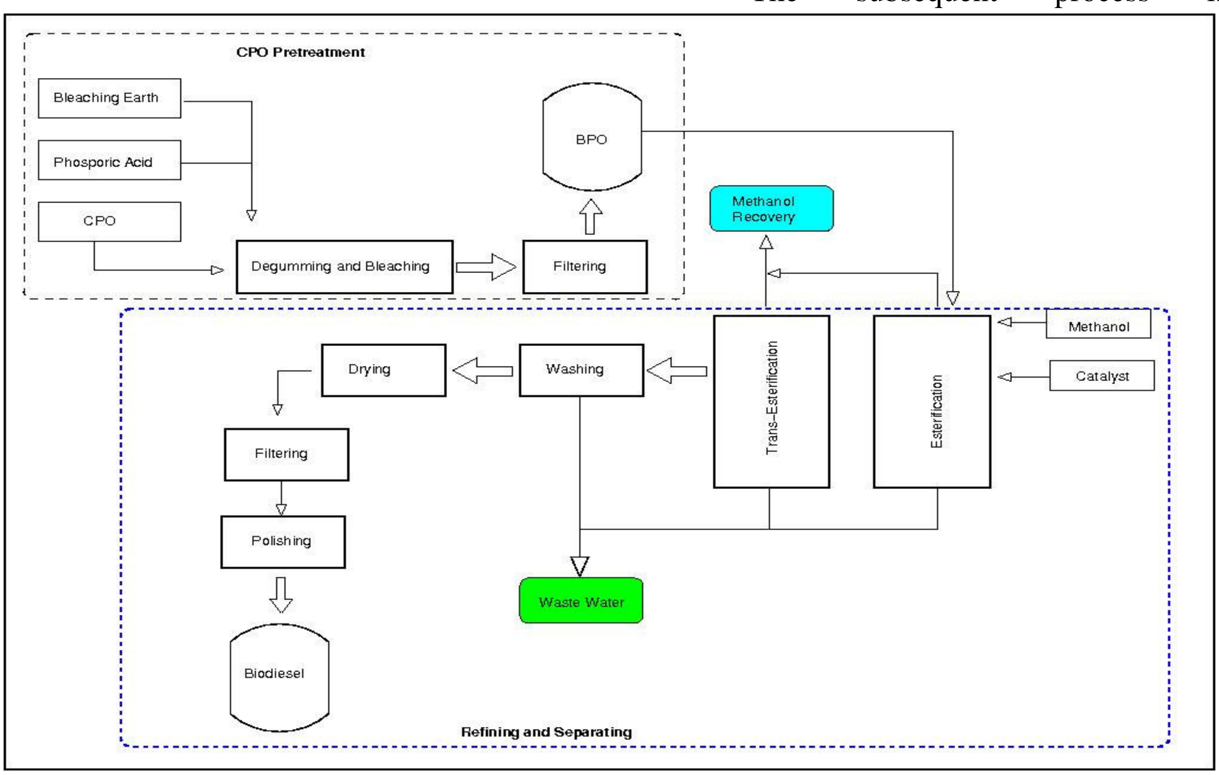

Figure 2: Block Flow Diagram of Biodiesel Production

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esterification and transesterification of the BPO with methanol under presence of acid and base catalyst, respectively. The esterification process converts free fatty acids containing in the BPO to methyl esters under mild conditions. This reaction products are then transferred into the transesterfication reactor with methanol to form fatty acid methyl ester (FAME) or biodiesel. The excess of methanol is recovered for reuse. The methyl esters are then washed, filtered, and vacuum dried before sending to the storage. The waste water resulted by the biodiesel production will be well treated before releasing it to public drainage.

4. Project Development

The project of the pilot plant started at the beginning 2007 and is expected to be fully operational before end of 2008.

Design and construction of the biodiesel plant are complex operations comprising many interrelated activities starting from the feasibility study till the plant handing over. The plant owner and the engineering contractor must work synergistic during the plant development after awarding the contract.

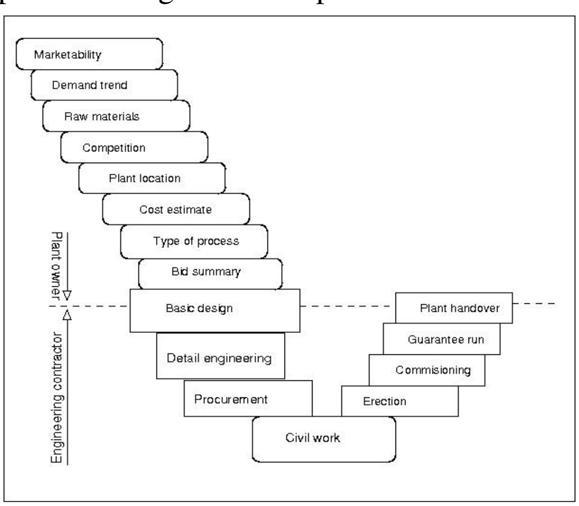

Figure 3: Development of the plant project

The feasibility study performed by the plant owner consists of preliminary design work. Market analyzes are carried out to determine potential benefit, future demand trend in energy conversion technology, availability of raw materials, and competitive situation. The plant capacity and location are specified. Particular attention must be paid hereby to environmental protection. Studies are supplemented by sufficient accurate estimates of capital requirements and profitability.

Once the decision has been made to go ahead with the construction project, the plant owner proceeds with the preparation of an accurate, comprehensive definition of the pilot plant which is used as the basis for inviting bids from competent engineering contractors. The conceptual phase of the project ends when an appropriate engineering firm is chosen and the contract signed.

The implementation phase consists of basic engineering or process design, detail engineering of the pilot plant, procurement of the plant equipment and material, construction, and commissioning. After a successful test run, the plant is handed over to the plant owner. Figure 3 shows a schematic diagram of the development of the UTHM biodiesel pilot plant. Project activity performed by the plant owner is indicated by a rounded square, otherwise by the plant contractor. This article will emphasizes the basic engineering stage when some problems on maintenance aspect and safety concerns have been encountered in the early stage, and the best solution must be searched.

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4.1 Site Location problems and solving

In the beginning of the project, the pilot plant should be located inside the existing laboratory building. This site location is selected to utilize the existing steam boiler for heat supply into the process plant. The environmental impacts such such effluents of methanol vapor and waste water have been included in the feasibility study.

The following problems have emerged during the basic engineering stage:

- Maintenance problem
  The space between the highest point of the equipment and the ceiling is only 30 cm left. It will be difficult for an operator to conduct the maintenance duty, see Figure 4.
- Lack of data of the floor structure
  Even though the building has been used to store 8 CNC machines and each machine has at least 3 Tones in weight, this previous data is not enough to convince the personnel from the civil engineering group. Because of unavailability of the original data regarding to the floor structure strength of the building, it brings to uncertainty whether the building structure is able to withstand the total load of the plant. The plant equipments are skid mounted on the steel frames and distributed in three floors. The maximum load in a section is estimated 20 MT.
- Ventilation systems
  The pilot plant is exposed to the potential hazard of the methanol vapor. This hazard is controlled by the proper natural ventilation systems within the building. To get the natural ventilation, the height of the building roof must be increased by 2.5 m, it brings to very expensive for the civil work.

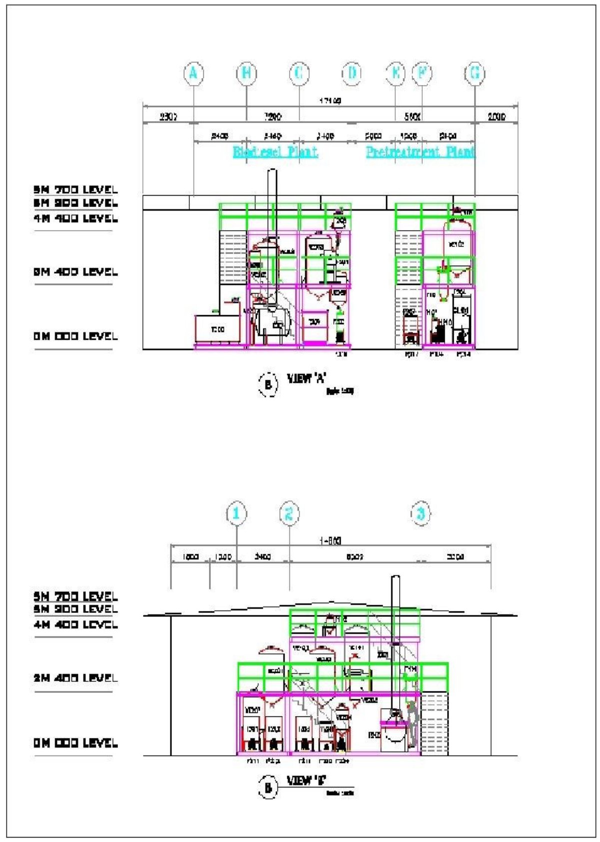

Figure 4: Plant layout inside the building

Additionally, the Occupational Safety and Health Administration (OSHA) recommended for double layer and fire walls for the building walls next to the other laboratories. The cost for the removing the old walls and replace with the new ones will be very high.

To resolve that problems, a technical solution has been proposed in which the pilot plant should be redesigned to overcome such of difficulties and must be suitable for installation inside the building. This approach has failed due to the cost incurred for the building restructuring and setting up a new construction site doesn't differ significantly.

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The final site location has been then recommended by the civil engineering team for a new building that is isolated with other laboratories and the pilot plant will be installed near to the university waste water treatment pool.

4.2 Basic engineering

With a new building for the pilot plant, a significant change in spaces for process area and utility has caused the change in the plant layout and the utility arrangement along with the budget and the project schedule. Activities in the basic engineering phase remains the same except an adaption in piping and and plant layout. The current stage of the project is in the development of the basic engineering that is described below.

Basic engineering includes the process flow diagram, the piping and instrumentation diagram, plant layout, equipment list, utility distribution, process engineering data, electrical equipment list, data sheet for control equipment and instrumentation, and the maximum load distribution. The process flow diagram is extracted from the block flow diagram as explained in section 3. This diagram contains the bulk of input and output streams necessary for the design of the process engineering. The Piping and Instrumentation Diagram (P & ID) or mechanical flow diagram describes the whole plant in detail It contains all essential information including:

- Operating data and dimensions of equipment including the bleaching vessel, the reactors, the filters, the degumming vessel, methanol

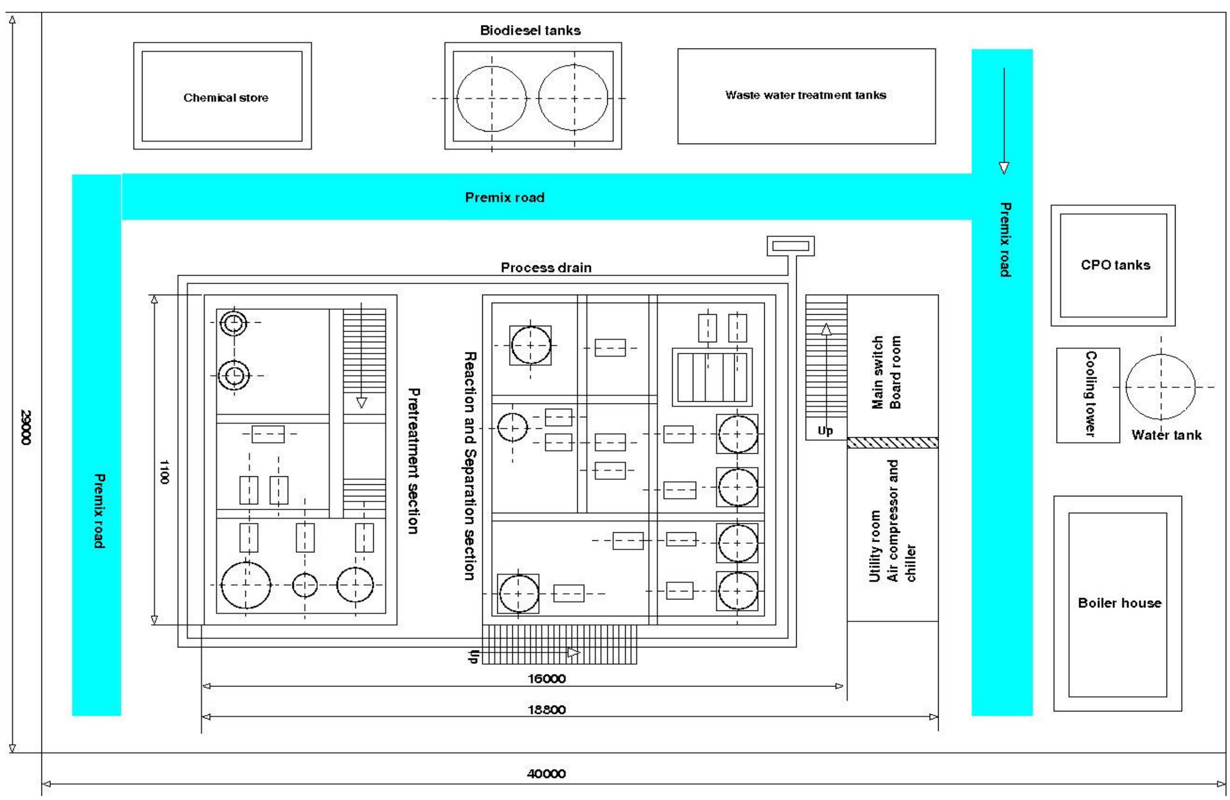

Figure 5: Overall plant layout plan (unscaled)

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recovery.

- Design data for pumps, data on insulation and heating of equipment as well as piping.
- Codes for fittings and equipment nozzles
- Detailed information on electrical and dedicated control systems

Plant layout includes approximate data on the positions and sizes of the pretreatment section, the reactors and separating section, the storage areas for chemical, raw materials, end products, a control room, a boiler house, and the compressed air and nitrogen storages. Figure 5 shows the overall pilot plant layout plan.

4. Utilization

The biodiesel pilot plant is a significant platform especially for conducting research and development in area of alternative energy resources that are plentiful available in Johor. This pilot plant represents the real commercial biodiesel plant however in smaller scale. The batch technology of the pilot plant enables us to study the performance of each unit operation or a plant revamping if necessary without interfering the production processes, test the operability of a control system, obtain kinetic data, determine the economic feasibility or new process, gain the design data, screen catalysts, prove areas of advanced technology, and provide data for solutions to scale-up problems along with technical support to an existing process or product. The environmental impact studies such as toxic dispersion model, waste water, and assessing process hazards are interesting areas of choices. Additionally, the pilot plant may give better impression and inspiration to the students during experimental activities.

Furthermore, with a production capacity of 1 MT per batch, the biodiesel product can be utilized as fuel for university buses, trucks, and process heating such as boilers.

5. Summary

Project development of the biodiesel plant is a complex task comprising many interrelated activities starting from the feasibility study till the plant handing over. The plant owner and the engineering contractor must work synergistic during the plant development stages after awarding the contract.

Some problems encountered in the stage of basic engineering regarding to the site locations have been solved after thorough considerations on maintenance problems, safety issues, and potential future development.

The biodiesel pilot plant planned ready for operation before end of 2008 will give us more opportunities to conduct research and development in area of alternative energy resources and other related disciplines that are in line with the Malaysia's development policy of renewable energy as a fifth fuel.

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