Royal Thai Naval Dockyard

# Biodiesel Project in the Royal Thai Navy


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**by**
**R&D Division**
**Royal Thai Naval Dockyard**

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## 1. Motivation and Originality

Petroleum products, especially diesel oil has been the primary source of energy for driving more than 1,000 diesel engines being used in the Royal Thai Navy i.e. all types of ship, marine vehicles and land transportation etc. They need quite a large amount of diesel oil, as much as 37 million litres each year. Nevertheless the rate of energy production of oil and fuel within country is still at low level when compared with the amount of crude oil being imported.

**Fig. 1: Marine vehicles and diesel engine in the Navy**

As long as Thailand still heavily relies on imported energy, we will always be vulnerable to the uncertainties of the global situation as currently experienced worldwide due to the recent oil price shock since the beginning of 2004. Therefore looking for our own new sources of energy within the country e.g. renewable energy, is the best solution to over expense on imported energy and certainly that will help increasing the stability of the national energy supply.

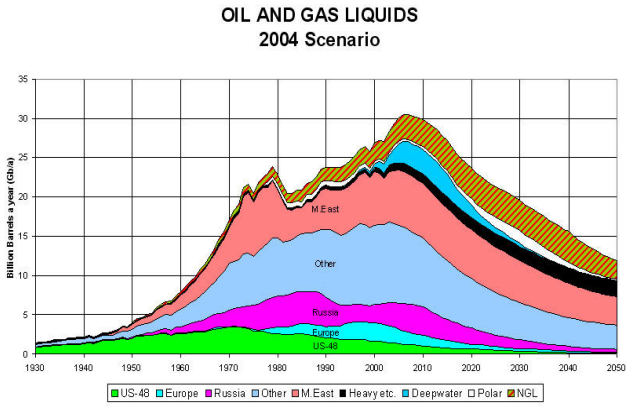


**Fig. 2: Possible trends of energy discovery**

Natural gas and biomass energy such as ethanol and biodiesel possess the strong potential for making become one of promising sustainable energy for Thailand in the near future. Intensive research and development programs, involving renewable energy technology, are very important and they need to be carried out further especially concerning the impacts on automotive engine technology and the environment etc.

### 1.1 Design

The research on biodiesel production and demonstration has started since 2001 at the Naval Dockyard, sponsored by Defence Research and Development Office (DRDO).

Intensive research works and experiments to obtain the most suitable methodology for biodiesel production as well as transesterification reaction have been carried out.

**Fig. 3: Prototype of biodiesel pilot-plant**

After achieving the methodology for biodiesel production, the Naval Dockyard invented a prototype of small biodiesel pilot-plant (Batch type) which had the production capacity of 50 litres/day and was progressed to 2000 litres/days afterwards. The 2,000 litres capacity plant has still been used until nowadays.

**Fig. 4: Biodiesel pilot-plant 2,000 l/d (Semi-continuous batch type)**

Another area of interest in this research project, "Continuous type" biodiesel pilot plant is a more advanced biodiesel production technique which is proved to have higher production capacity. It is smaller and more compact in size and very convenient and suitable for use by local communities in remote area.

**Fig. 5: Continuous type biodiesel plant**

## 1.2 Application

It is very fortunate for Thailand to possess large varieties and abundance in agricultural products, such as palm, coconut, soybean that could be the raw materials for making the ethanol and biodiesel fuel. Used cooking and animal fat can also be used as the biodiesel raw materials. Additional benefit from the ethanol and biodiesel use as fuel substitutes for petroleum diesel, includes air pollution mitigation, foreign currency saving, and good income for farmers.

**Fig. 6: Palm seeds**

Biodiesel is specifically referred to esters produced from vegetable oil or animal fat via chemical processes. Biodiesel is very simple to produce without too costly investment. Biodiesel is also safe for the environment, easy to use and there is no need for engine modifications. Using the renewable energy obtained within the country can save money and reducing the dependence on imported crude oil. Also this can increase agriculturist income as well as the agricultural products.

**Fig. 7: Biodiesel from palm**

## 1.3 Approach

While biodiesel has been widely accepted and used in many countries in Europe and several States in U.S. for sometimes, this kind of fuel is still new to most Thais, to fully appreciate the application in their vehicles. One reason being, is the cost which is in general higher than normal petroleum diesel fuel. However since the oil price shock at the beginning of 2004, people have become more aware of the uncertainty of oil price situation and get more interested in biodiesel. A lot of research on biodiesel application as fuel has sprung up everywhere in the country.

In implementing biodiesel use in vehicles, it is best to begin with small blend. A 1-2 % blend of biodiesel in diesel oil raises its lubricity index, particularly if sulfur reduction in diesel is a trend for the future. B20 (20% biodiesel, 80% diesel) is suitable for

environmentally sensitive applications like school and public buses, boats and industrial machinery. The first launched project was the opening of B2 blend (the blend of 2 %biodiesel and 98% petroleum diesel) supply, at the Bang Jak petrol station in Chiang Mai last year, for use in mini-van transport.


**Fig. 8: The opening of B2 biodiesel at the Bang Jak petrol station**

In very near future biodiesel will be one major replacement of the depleting petroleum diesel and the highest priority for the Thai government now is to increase the production of biodiesel raw materials. Palm can provide the highest oil quantity among Thailand's oil-yielding plants and animal oil and used fried oil have also strong possibility. Roughly 42,000 tons of animal oil and used fried oil are recycled and reused in the market each year.

## 2. Environmental and Social Consideration

Using biodiesel as the replacement of diesel fuel can also decrease Greenhouse gas released from exhaust pipe to the atmosphere. These toxic gases e.g. Particulate matters (PM), Carbon monoxide (CO), Hydrocarbon (HC), Sulfur oxide (SO) and Nitrogen oxide (NOx), can cause serious health problems like lung cancers and respiratory symptoms.

| Emissions from Exhaust pipe | 100 % Biodiesel (B100) | 20 % biodiesel (B20) |
|---|---|---|
| 1. $CO_2$ | 43.2 % reduction | 12.6 % reduction |
| 2. HC | 56.3 % reduction | 11.0 % reduction |
| 3. PM | 55.4 % reduction | 18.0 % reduction |
| 4. NOx | 5.8 % reduction | 1.2 % reduction |
| 5. Cancer substances | 80-90 % reduction | 20 % reduction |

**Fig 9: The reduction of emissions when using B100 and B20**

### 2.1 Amount of Emissions

The Thai Naval Dockyard in co-operation with the Department of Alternative Energy Development and Efficiency (DEDE) has further carried out a study on the impacts on

engines when using biodiesel as fuel. The energy department has provided 4 pick-up cars to the Naval Dockyard to proceed with the test program.


**Fig. 10: The vehicles for the test program**

The type of vehicles being tested was pick-up van, 2500cc diesel engines. For the purpose of the accuracy of the test and to keep all engine conditions the same, all vehicles had been overhauled at the same period. Each van was running on different biodiesel blend i.e. B100 (100% biodiesel), B40 (40% biodiesel, 60% diesel), B20 (20% biodiesel, 80% diesel) and D100 (100% diesel) respectively. Regarding the test method, the vehicles was running on chassis dynamometer, as the engine speed increased from 40 km/hr to 110 km/hr, the engine torque was measured, at every 10 km/hr step.

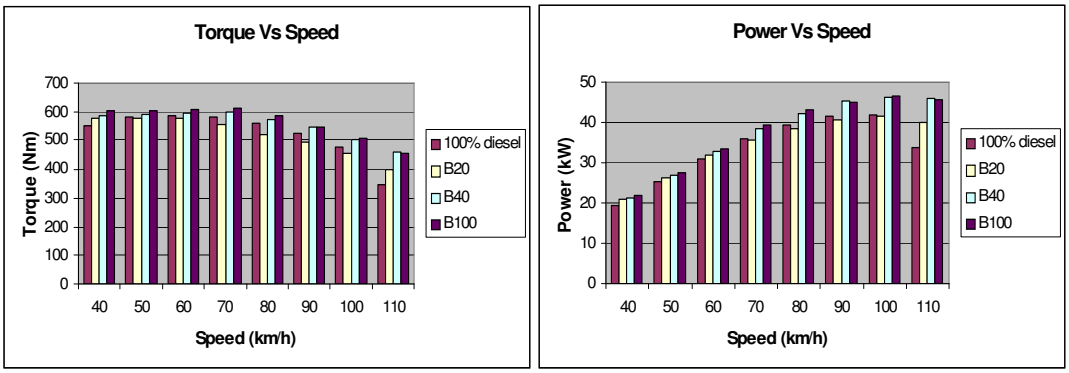


**Fig.11: The comparison of the torque and power of the cars using different blends**

The diagrams shown above is the comparison of the engine power of the 4 vehicles, running on different blend of biodiesel, the vehicle using B100 blend obviously gave the maximum power at every cycle of speed compared with the one using D100. The graph analysis revealed that B100 resulted in the increased in power by 12 % and a rise in the torque by 7.5 % whereas the vehicle using D100 promoted the least power to the engine at the maximum speed. This could likely be due to lower volumetric efficiency at the top speed. There was no significant drop in the power of any vehicles using the fuel which contained biodiesel blends because of better engine combustion, with the help of 10 % oxygen contained within the biodiesel fuel.

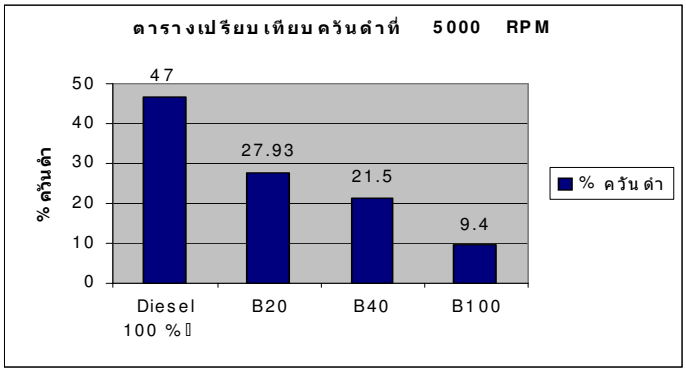


**Fig 12: The reduction of black smoke**

Regarding black smoke reduction, the graph above reveals that the higher volume of biodiesel blend existing in the fuel, the less amount of black smoke and particulate matters being released from exhaust pipe to the atmosphere. As we can see, the black smoke from the pipe was greatly reduced when using 100 % biodiesel.

## 2.2 Community/People Participation

### 2.2.1 Benefit to user

Benefits to users derived from this project are as follows:

- More efficient combustion, as biodiesel contains roughly 10 % by volume of oxygen, which enables air and fuel to be evenly distributed and raises the volumetric ration of air to fuel.

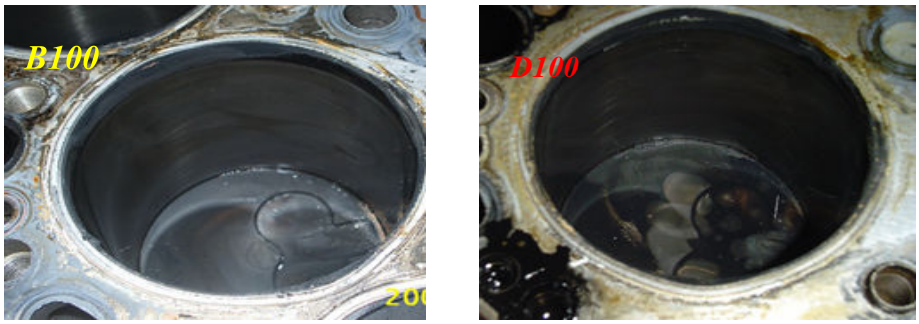


**Fig 13: Comparison of engine combustion chamber of two vehicles using B100 and D100 after 50,000 km of running**

- Biodiesel can be used with current fueling infrastructure and in all diesel vehicles with little or no engine modification.
- Biodiesel's high Cetane number and flash point and increased lubricity mean excellent engine performance, safety and fuel economy.

### 2.2.2 Benefit to community

Community could gain the following benefits from biodiesel:

- Compared with diesel fuels, air pollution due to engine combustion of biodiesel fuels drops. The National Biodiesel Board and the US Environmental Protection Agency (USEPA) reported their analytical and experimental work on various biodiesel blends on diesel engines that the B100 and B20 formulas significantly cut combustion exhausts. The experiment at the Naval Dockyard reveals a 60% cut in black smoke through using biodiesel on a 145 Hp diesel engine.
- Since it is derived from plants, biodiesel use reduces greenhouse gas emission.

- Using biodiesel derived from used cooking oil automatically cuts down on the reuse of cooking oil and prevents used cooking oil (which contains carcinogenic dioxin materials) from being used in animal feed preparation.

**2.2.3 Benefit to country**

- Creation of an energy market to support surplus agricultural produce implies more rural jobs.
- Biodiesel use partially reduces crude oil imports. Each year the Kingdom spends more than 400,000 million baht in foreign currency on such imports. This sum exceeds the combined income derived from exporting agricultural goods.
- The use of domestically produced biodiesel enhances national energy security and stability.

## 3. Technical, Economic and Market Consideration

To ensure that the biodiesel quality reaches decent standard and not causing harmful impacts on diesel engines, the biodiesel has been tested on several types of engines e.g. trucks, vans, pick-up trucks, buses and marine diesel engines etc. both short term and long term effects. Then the test results can be further reveal to the public.

### 3.1 Install capacity

The size of biodiesel plant can be varied according to the requirement of users. At the beginning of this research, the prototype of 50 litres/day capacity was constructed to investigate the feasibility of the project. After gaining experience from small plant, the 2000 litres capacity plant was constructed and it was found to be appropriate size for conducting the experiment for this project.

### 3.2 Technical Design

The 2,000 litres capacity plant is semi-continuous batch type. This plant is very simple to construct and the process in making biodiesel is very straightforward.

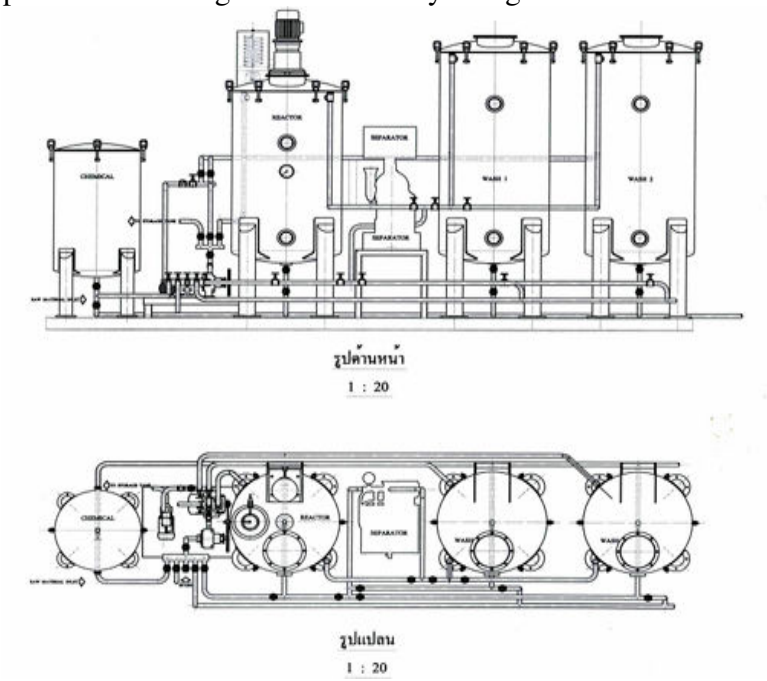


**Fig. 14: The prototype of biodiesel plant**

The necessary equipment for plant system are as following;

- Chemical Mixing Tank
- Reactor Tank ; a 400 litres capacity and made of stainless steel.
- Separator ; Centrifugal type
- Washing Tank no.1 ; a 800 litres capacity made of stainless steel.
- Washing Tank no.2; a 800 litres capacity made of stainless steel.
- Storage Tanks; can store up to 1,000 litres of biodiesel oil.
- Temperature Sensors
- Pumps ; Centrifugal pump
- Etc.

For the production process, firstly the refined palm oil which has been finely filtered is fed via centrifugal pump into reactor tank where the oil will be stirred slowly by the mixer blades, while the temperature will be kept at 60°C inside the reactor. After that the solution of Potassiam hydroxide + methanol will be fed into the reactor to mix with the readily heated palm oil. The mixing continues further for one hour to fully complete transesterification process. After the process has completed the separation between biodiesel and glycerine takes place. The glycerine will settle to the bottom due to the higher density, and the biodiesel will stay at the top. The glycerine then will be romoved and stored for further chemical process, such as for making soap and cleaning agent. The biodiesel will be pumped to tower tanks to start the washing process. This process will discard any remains of chemical substance such as KOH and methanol. Washing process can be done a few times as necessary. However the washing process can take a while to finish, at least 3 hours per batch. The washing process will help to purify biodiesel and make it cleaner to use as diesel fuel replacement.

For continuous pilot plant, inside the pipe consist of series of orifice plates attached inside a very long and narrow pipe (1-2 inch in diameter) which is bent around to look like U shape. The orifice plates inside the pipe will cause extreme turbulence to the mixing liquid leading to very effective and more perfect of transesterification process, achieving good quality and purer biodiesel oil. It is estimated that this plant could produce at least 10,000 litres of biodiesel per day. This smaller plant is really suitable for local communities because it is very compact in size and great mobility.

**3.3 Technical Performance**

The biodiesel plant at the Naval Dockyard has been running since 2001. Good quality of biodiesel oil has been produced for use in more than 20 tested vehicles in the dockyard and the plant is still operating very well.

**3.4 Investment Cost**

In fact the cost for building the biodiesel plant is not too expensive. It is really depends on what size of the plant capacity is needed and the type of material used for construction. For small local communities that require a compact set of biodiesel plant e.g. 2,000 litres/day capacity, the expense is approximately 2 Million baht (when using good quality of reactor tanks and equipments). The plant can be easily designed and built by our own engineer.

To calculate raw materials cost, there are a few elements to consider. The raw materials for the research project i.e. refined palm oil, were given without any charges by the Thai Custom Department in Songkla province. However the transportation cost was

approximately 1-2 baht/litre, Methanol costs around 18-20 baht/litre. The Catalyst, KOH, costs about 40-45 baht/kilogram. The cost in details can be summarized as following;

| | | |
|---|---|---|
| 1. Raw materials cost | | |
| 1.1 Transportation cost | 1-2 | baht/litre |
| 1.2 Mathanol cost | 18-20 | baht/litre |
| 1.3 Catalyst cost | 40-45 | baht/kilogram |
| 2. Labour cost | 336 | baht/day |
| Total of raw materials+labour cost | 2,336-2,916 | baht/400 litres |
| 3. Electricity and water supply cost | 233.60 – 291.60 | baht/400 litres |
| Total cost | 2,569.60 – 3,207.60 | baht/400 litres |

**The total biodiesel production cost (excluding palm oil price) 6.42-8.02 baht/litre**

### 3.5 Market size

The biodiesel fuel is becoming more attracted to the Thai government and the Thai people as the oil price is rising continuously. It is very certain that there will be more the biodiesel plants and more biodiesel user in the near future. Now the Navy has successfully established two biodiesel production plants, one is situated at the Royal Chitralada Palace as the demonstration plant. The other plant, sponsored by DEDE, is in Chiang Mai as the demonstration site for people to visit and to obtain the basic knowledge of biodiesel production for local communities. The model biodiesel plants, designed by the Royal Thai Navy will be the prototype for the next plants, especially intended for local communities in Southern and Eastern part of the country.

### 3.6 Local Manufacturing / Content of System

As previously mentioned the plants can easily be constructed and the materials for construction can be obtained within the country, there is no need to import any equipment from abroad.

### 3.7 Amount of energy avoided

Diesel consumption in Thailand far exceeds gasoline consumption and the diesel market is worth twice the gasoline market. It is therefore possible that refineries may not be able to produce enough diesel to meet the domestic demand. Biodiesel use could ease this problem.

## 4. Operating and Maintenance Scheme

### 4.1 Operational hours

The 2,000 litres capacity biodiesel plant can operate 24 hours producing 400 litres of biodiesel per one batch at every 5 hours. The plant usually was not operated everyday but it depends on the amount of biodiesel needed for running the test each day.

### 4.2 Maintenance Scheme

The project officers are in charge of preparing weekly or monthly maintenance schedules. They have to examine the operation of motors and pumps and the flow of the system etc. and get them fixed or replaced when any parts of the machinery broken down. Otherwise, they must make sure that the process is running smoothly at all times.

### 4.3 Local service content

From the experience, the biodiesel plant at the Naval Dockyard has almost never found the problem with any machinery equipment, probably because there are not many moving parts in the plant. However if any equipment or machine are not in the condition of

working, they will be repaired by Naval Dockyard technical staff or hiring the local companies for any serious cases.

## 5. Replicability

### 5.1 Replicability project

#### 5.1.1 Biodiesel Pilot Plants for Royal Chitralada Projects

During April 2004 last year the Royal Thai Navy involved in designing and building the prototype of biodiesel pilot-plant, 2,000 litres/day capacity for the Royal Chitralada projects. This building was made possible by several parties. The Thailand Tobacco Monopoly, Department of Naval Dockyards, Royal Thai Navy and Sang Som group of companies assisted with the design and construction supervision while Raja Biodiesel Company secured biodiesel production equipment. The building will be used by RCP to conduct experiments on applications of biofuels as fuels and in future production of various other products related to biofuels.

**Fig. 15: The opening of biodiesel pilot- plant at Chitralada Palace**

The raw materials that are used for making biodiesel are from used cooking oil remaining from the canteen of the Royal Chitralada palace. The 99.5 % ethanol and Sodium Hydroxide as a catalyst are used for the chemical reaction. The quality of biodiesel fuel obtained is very high standard which equal ASTM level of America. And this plant will be a fine example for demonstration of biodiesel production from used cooking oil. The remaining glycerine will be further transform to others useful items such as soap bars, facial and body cream and lotion etc.

#### 5.1.2 The Biodiesel Pilot Plant in Chiang Mai

Apart from building the biodiesel pilot-plant for the Royal project at Chitralada, at the moment the Navy and the Department of Energy is constructing another biodiesel pilot-plant in Chiang Mai. This plant is a semi-continuous type that has the capacity of 6,000 litres/day.

**Fig.16: Biodiesel Pilot- Plant in Chiang Mai**

This biodiesel site will be the second demonstration model of the biodiesel production process and this plant will also supply biodiesel fuel for the public and local people to use as the replacement of diesel fuel.

### 5.1.3 The Application of Biodiesel for Duel Fuel

In this research project, the Navy has successfully modified a conventional diesel engine into duel fuel diesel engine, using the mixture of compressed natural gas which is in abundance and widely used in the country, and biodiesel, used as the pilot injection in diesel engine.


**Fig. 17: Prototype duel fuel vehicle using NGV-Biodiesel**

This type of modified engine still mainly consisted of conventional basic engine parts like normal diesel engine i.e. cooling system and fuel tank etc. However there were some additional parts such as compressed natural gas tank (CNG) together with connecting pipes and a regulator which was used to control the pressure of the injected natural gas to the inlet pipe of the engine. While the vehicles are running the natural gas will be sucked into the engine combustion chamber via the inlet valve during the suction stroke. Then the B100 Biodiesel fuel will be injected into the combustion chamber via fuel injector as normally happen to the conventional diesel engine. The ignition will go on like so. Both biodiesel and natural gas will be used at the ratio of 30:70 (30% biodiesel and 70% natural gas).

There is a switch at the driver panel of which can alternate the mode of fuel usage. If one wishes to use normal diesel or 100 % biodiesel fuel, one can push the switch to normal mode that will stop the supply of natural gas to the engine. The vehicle will now be running on only diesel or biodiesel fuel only. It needs mentioning that for this duel modification, it is not suitable to use normal diesel fuel as the pilot injector with natural

gas. It is best to use biodiesel fuel with natural gas since they will promote much more complete combustion of the engine.

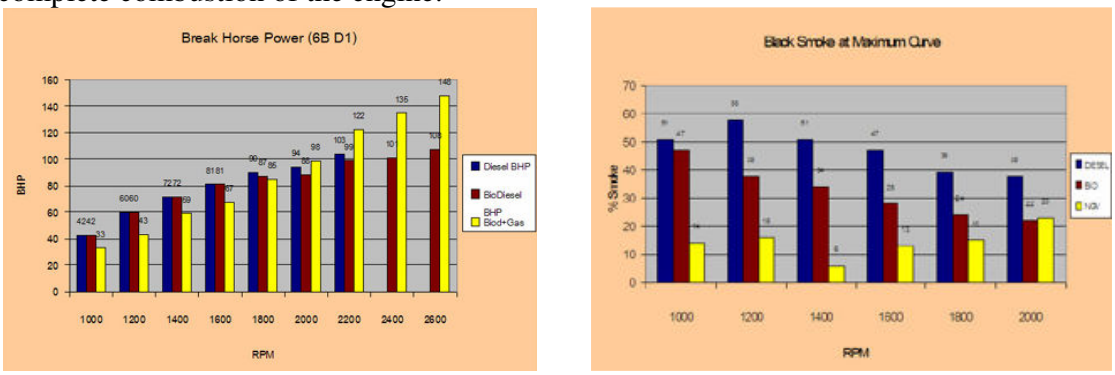


**Fig. 18: Comparison of engine power and amount of black smoke using different fuel**

The graphs above show that the mixture between natural gas and biodiesel, that can significantly increase the engine power especially at higher speed. Also black smoke being released from the engine can be greatly cut down by as much as 60 % using this duel fuel technology.

### 5.2 Life of Project

Although the Royal Thai Navy has successfully developed complete biodiesel plant technology and gathered a great deal of knowledge on impact of biodiesel onto engine and environment, there are plenty of works to be done on biodiesel quality optimization and the utilization of by-product i.e. glycerine. The research project on biodiesel will still continue to further develop methodology to gain the most benefit from by-product e.g. extraction of vitamin A and E from glycerine.

### 5.3 Cost Effectiveness

As mention in section 3.4, the total biodiesel cost is oil price + 6-8 baht per 1 litre. Currently the price of used cooking oil in the market is about 10 baht/litre, net total cost of the used cooking oil will be approximately 16-18 baht/litre, which is about the same as petroleam diesel cost these day.

The price of current refined palm oil is still very high, however in the future, when there are more raw materials grown and the government put more supports on biofuel application and use, surely the cost will drop. Besides the by-product such as glycerine is much more valuable than biodiesel product itself. With the right technology, it can be transform to other chemical product like washing and cleaning agents, ladies cosmetics, body and face cream etc. which can lower the cost of biodiesel production down.

### 5.4 Sustainability of project

It is undeniable that the World energy resources have been depleting dramatically especially crude oil and natural gas. Many countries now have realized the importance and the urgency of finding the new source of energy i.e. renewable energy. Most countries in Europe have already started to utilize this renewable energy long time ago. Wind energy, Solar energy and Biomass energy paid quite remarkable contribution to their national electricity energy supply. For Thailand, still, a lot of promotion and education on renewable energy needs to be carried on so that people will realize the importance of current world energy situation and the conservation of energy. An intensive R&D on renewable energy such as Biomass, Biogas, Solar energy, Hydro

energy, Wave energy and fuel cell technology, is really a must, since they do concern the stability of the Armed forces and the nation. The biodiesel and ethanol project should be one answer to the self-sufficient economy and growth that the Thai Government are looking for. The Royal Thai Navy has realised the importance of having our own energy supply and R&D on biodiesel fuel has been done intensively so far. The biodiesel will hopefully maintain the national stability and increasingly gain popularity as a fuel. But above all, domestic development of the fuel can truly be regarded as a self-help means toward self-sufficiency as advised by HM the King.

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