LNG/DUAL FUEL POWERED FISHING BOATS

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DEDICATED TO...

MY BELOVED FAMILY AND FRIENDS,

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ABSTRACT

Fisheries are enormously important to the economy and well-being of Malaysian fishermen. Most of the fishermen have a specific route and petrol or diesel is widely used as fuel to power their boats. Gasoline fuels have fluctuating fuel prices and also produces higher emissions. One of the solutions to this problem can be to use a dual fuel engine which uses natural gas as one of the fuel. LNG/CNG is cheaper and greener fuel than diesel or petrol. It has low sulphur content and it also minimizes the NOx emissions when burned compared to gasoline fuels. CNG is not widely used in fishing industry because of lack of awareness about this technology among the fishermen. In this research, a feasibility study of CNG as an alternate fuel for fishing boats in Malaysia was carried out to analyse its cost, fuel storage, stability, power and safety. A small fishing boat (LOA = 6.5m) was selected. The boat was modified using Maxsurf as ship design software by placing two CNG cylinders near the stern of the boat. An analysis was made to check the stability, resistance and power of the boat. The boat passed all stability criteria in the three loading conditions analysed. A detailed economic study was carried out using Net Present Value and Payback period as the performance criteria. A sensitivity analysis was carried out to confirm the effect of changes in Fuel price, Fish price and Fish catch. It was found that fuel cost might drop significantly by 60% if this alternate fuel is used without subsidy and a drop of 57% if the fuel is used with government subsidy which substantially increases the fishermen's income. The results obtained in this research are significant for the growth of fishing industry in Malaysia if used on a large scale.

ABSTRAK

Perikanan adalah bagian terpenting kepada ekonomi dan kesejahteraan nelayan Malaysia. Kebanyakan nelayan mempunyai laluan khusus dan petrol atau diesel digunakan secara meluas sebagai bahan api untuk kuasa bot mereka. Bahan api petrol telah turun naik harga bahan api dan juga menghasilkan pengeluaran yang lebih tinggi. Salah satu penyelesaian untuk masalah ini boleh menggunakan enjin bahan api berkembar yang menggunakan gas asli sebagai salah satu bahan api. LNG / CNG adalah lebih murah dan lebih mesra alam daripada diesel atau petrol. Ia mempunyai kandungan sulfur yang rendah dan ia juga mengurangkan pelepasan NOx apabila dibakar berbanding dengan bahan api petrol. CNG tidak digunakan secara meluas dalam industri perikanan kerana kekurangan kesedaran mengenai teknologi itu di antara nelayan. Dalam kajian ini, satu kajian kebolehlaksanaan CNG sebagai bahan api alternatif untuk bot-bot nelayan di Malaysia telah dijalankan untuk menganalisis dengan kos, penyimpanan bahan api, kestabilan, kuasa dan keselamatan. Sebuah bot nelayan kecil (LOA = 6.5m) telah dipilih. Bot itu diubahsuai menggunakan Maxsurf sebagai perisian reka bentuk kapal dengan meletakkan dua silinder CNG berhampiran dengan tegas bot. Analisis dibuat untuk memeriksa kestabilan, rintangan dan kuasa bot. Bot lulus semua kriteria kestabilan dalam tiga keadaan pembebanan dianalisis. Satu kajian ekonomi terperinci telah dijalankan dengan menggunakan Nilai Kini Bersih dan tempoh Payback sebagai kriteria prestasi. Satu analisis sensitiviti telah dilakukan untuk mengesahkan kesan perubahan dalam harga bahan api, harga ikan dan menangkap ikan. Ia telah mendapati bahawa kos bahan api mungkin drop dengan ketara sebanyak 60% jika bahan api alternatif ini digunakan tanpa subsidi dan penurunan sebanyak 57% jika bahan api itu digunakan dengan subsidi kerajaan yang ketara meningkatkan pendapatan nelayan. Keputusan yang diperolehi dalam kajian ini adalah penting

untuk pertumbuhan industri perikanan di Malaysia jika digunakan secara besar-besaran.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysia is a maritime nation surrounded by sea with a long coastline. The major economy is dominated by shipping and fishing industry. There are different types of fishing boats build in Malaysia from small size to large size. Trawlers contribute at least 50% of the total fishing capacity and the west coast of Malaysia has more fishing activities than the east coast [1]. Most fishing boats still use petrol or kerosene as their fuel. Emissions from fishing fleets contribute to air pollution Significantly [2]. As the IMO regulations are getting stringent in terms of air pollution and emissions from ships and fishing vessels. A solution is needed to provide environmentally friendly shipping.

There are many alternate fuels which can be used to power the ships like bio-fuel, ethanol, methanol, biodiesel, propane, hydrogen, and natural gas (NG). These fuels help in controlling the greenhouse gases which are significant in reducing air pollution. According to IMO there is also a regulation to reduce the NOx and SOx emissions from ships and boats [3]. This can be done by using low sulphur marine diesel oil or using a combination of these alternate fuels with the diesel engine.

Dual fuel engine has the ability to use both petrol/diesel along with alternate fuel. It has been proven to increase efficiency as well as reduce emissions. The dual

fuel engines can also help us save on the operations and maintenance cost because there is a better combustion of gas as it is fully burnt causing less emissions and less sludge formation with little or no leakage of combustion gas so very less unburnt fuel.

Gaseous fuels available for marine use are natural gas and propane (i.e., LPG). Natural gas can be carried in a compressed state called compressed natural gas (CNG) or in a liquid state called liquefied natural gas (LNG). Natural gas is a low-density and low-sulphur content fuel as compared to petroleum products and is practically free from carbon monoxide emission [4]. Natural gas is converted to LNG by cooling it down to -162 degree Celsius at which it becomes a liquid and this process reduces its volume by a factor of more than 600 [5]. While, CNG because of its low energy density is compressed at a pressure of about 200-250 bar and stored in spherical or cylindrical type of storage tanks. Natural gas has been found cost effective when compared to other fuels and can be used as an alternate fuel in the marine industry.

In this research more focus will be given to CNG when compared to LNG because a small fishing boat will not be able to accommodate LNG cylinders with a regasification plant. As LNG is operated at very low temperatures it also requires special cryogenic tanks but as this study is limited to very small fishing boat. A more simple and economical solution will be to use CNG and hence the study will focus on its feasibility.

1.2 Regulations for Emissions

In the previous years, pollution was only meant for water, but since MARPOL annex VI requirements have come into force, It is important to minimize the emissions such as SOx, NOx, CO2, etc. from the marine fuels in order to provide a cleaner environment. According to studies done by Bengtsson,.et,.al,(2011) on life cycle analysis of marine fuels they found that IMO regulations will get even more stringent in the coming years and global shipping has to set determinations to minimize these emissions.

In 2008, the IMO adopted a resolution to update Annex VI of the MARPOL convention on the air emission control for ships. The revised Annex VI came into force on July 1, 2010 reducing the sulphur content in marine fuels from 4.5% to 3.5% maximum. In 2020, that cap will be further reduced to as low as 0.5% worldwide as shown in figure 1.1. The maximum sulphur content in SECA areas is limited to 1% from July 1, 2010 to January 1, 2015, at which date the cap will drop to 0.1%.(Semolinos & Giacosa, 2012).

Also a great concern is to reduce NOx emissions based on IMO tier III requirements. Reducing NOx emissions are another target, and new-build ships are required to reduce by 80% from 2020[3].

Figure 1.1- IMO restrictions on SOx emissions,[3]

There are different methods available for reducing ship emissions in order to comply with the IMO requirements, which have an added cost on the ship as shown by Elgohary,.et,.al, (2014). The table 1.1 shows few methods for reducing emissions.

Table 1.1- Methods of reducing emissions,[4]

Available methods for reducing ship emissions.

Component	Reduction method	Potential reduction
NO_x	Selective catalytic reduction (SCR)	95%
	Emulsification	20%–25%
	Humid air	70%
	Engine tuning	50%–60%
	Exhaust gas recirculation	10%–30%
SO_x	Fuel switching process[a]	60%–90%
	Seawater scrubbing; exhaust below water line	Up to 95%
CO_2	Energy management	1%–10%
PM	Electrostatic filters	Up to 85%

PM: particulate matter.
[a]Switching from residual fuel to distillate fuel.

Though, the above mentioned methods are suitable to reduce emissions the pressure for wider and more severe limits on SOx, NOx and particulates will accelerate, especially in developed economies and coastal areas to use some other alternative along with these methods so based on the study of many researchers and companies they suggested to use an alternate fuel like natural gas, propane, hydrogen etc.(Mcgill,.et,.al, 2013) to control the emissions.

Biofuels are liquid fuels; they can be used in internal combustion engines, as a replacement or complement of petrol and diesel which are made from a variety of sources of biomass: plant materials, types of crops, recycled or waste vegetable oils. The energy content of bioethanol is about two-thirds that of petrol and hence consumption is higher in terms of volume and bioethanol is an alcohol which contains oxygen so we need to adjust air/fuel ratio [6].

Hydrogen is considered as a renewable source of energy and has been considered to be the fuel of the future for decades. The energy from hydrogen can be delivered to fuel cells and be converted to generate electricity and heat. Fuel cells are highly efficient energy conversion devices that produce clean, silent, reliable power for as long as a fuel is available with emissions of hot water. It can be stored to produce completely renewable power-on-demand. Hydrogen can also be produced by reforming (separating it from) hydrocarbon fuels like natural gas, propane, or even diesel [7].

Natural gas is a mixture of hydrocarbons such as methane, ethane, propane and butane. It is colorless, non-carcinogenic, non-toxic, inflammable and lighter than air [8]. Thus, widely used in Industry and land transport. It is very cheap compared to petrol and safe in operation.

Among these choices of fuels highest priority is given to natural gas as an alternate fuel. It is because of various qualities like availability, cost and also matching the requirement with IMO regulations [9]. This can be observed from the table 1.2 as shown.

Natural gas is a very clean fuel, which also minimizes the maintenance and operating cost.

Table 1.2- Weighting matrix of alternate marine fuels,[8]

	Ethanol	Methanol	Bio-liquid fuel	Biodiesel	Hydrogen	Propane	NG
Availability	v. Good	v. Good	Excellent	v. Good	Excellent	v. Good	v. Good
Renewability	v. Good	v. Good	Good	Good	Excellent	Fairly good	Fairly good
Safety	Excellent	Excellent	Excellent	Excellent	Fairly good	v. Good	Excellent
Adaptability	v. Good	v. Good	v. Good	Excellent	Good	v. Good	Excellent
IMO compliance	Good	Good	v. Good	Good	Excellent	v. Good	Excellent
Performance	Good	Good	v. Good	v. Good	Good	v. Good	Excellent

Cost	Good	Good	v. Good	v. Good	Fairly good	Excellen t	Excellent

Natural gas is produced, sometimes along with oil, by drilling into the Earth's crust where pockets of natural gas were trapped hundreds of thousands of years ago. Once the gas is brought to the surface, it is refined to remove impurities, like water, other gases, and sand [10]. Then it is transmitted through large pipelines that span the continent. In Malaysia, natural gas is drilled from offshore Terengganu, Sabah and Sarawak while for gas utilization in Peninsular Malaysia, natural gas from offshore Terengganu was piped to Kertih where it was treated in gas processing plants. These processed gases are then piped to the major consuming outlets in Peninsular Malaysia via the Peninsular Gas Utilization (PGU) systems. PGU project which was develop by PETRONAS since 1984, now spans over 1700km comprising main gas transmission pipelines, supply pipelines and laterals [11]. The Figure 1.2 shows the map of peninsular Malaysia which illustrates the natural gas transmission by pipelines.

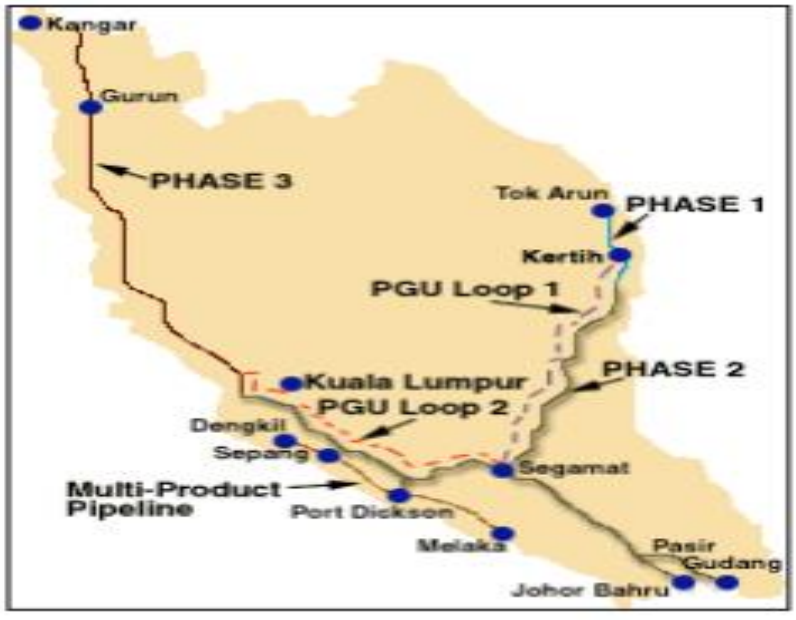

Figure 1.2- Peninsular Gas Utilization (PGU) project,[10]

1.3 Problem Statement

Malaysia is a country surrounded by sea on all sides, and fishing is an occupation for most of the people. Among these fishing boats there are many boats which use petrol or kerosene as their fuel for propulsion. These fishing boats make regular trips in search of fish. Since the demand for fishing is increasing so is the demand for more fishing boats this is causing an increase in emissions all across Malaysia. Now the fishing industry in Malaysia needs a solution to overcome the problem of emissions and IMO requirements for emission control.

Currently, using an alternate fuel seems to be a possible solution to overcome this problem. Natural gas is a good option as it is clean and environmentally friendly but the biggest problem is its storage on fishing boats. If we use it on small fishing boats we have to consider its weight and location because in fishing boats there is storage space only for fishing net and fish. But with slight modifications it is possible to apply CNG cylinders of small size which can power the fishing boats with much cheaper cost and fewer emissions.

CNG as a fuel has never been used on small fishing boats. It is widely used in land but not in sea. So it is hard to know how exactly it behaves when we change the environment. For data collection, all factors should be closely investigated before implementing this technology on fishing boats. The fishermen are also not aware of this technology. Hence, in this research all these critical factors will be focused to get a solution whether CNG acts as a user friendly fuel for fishing boat

1.4 Objective

In this research the following objectives will be obtained

a. To conduct a feasibility study of natural gas (LNG/CNG) as an alternate fuel for fishing boats.

b. To propose a preliminary design by using CNG on a fishing boat.

1.5 Research Questions

To understand the importance of using natural gas on fishing boats a few research questions can be formed and solutions to address these questions will be further discussed in the results obtained from the study.

- Can LNG/CNG be used to power small fishing boats?
- What safety precautions to be considered before installation?
- How will the refuelling and bunkering done?
- Is it cheap or expensive?
- How is the natural gas market in Malaysia?
- How big is the storage tank?
- Will it affect the stability of fishing boat?

1.6 Significance and Scope of study

Natural gas is one of the cheapest and cleaner fuels than diesel or petrol. If this is used as an alternate fuel it can have heavy savings on fuel cost as well as emissions. The scope of this research is to analyze if this alternate fuel is more feasible for Malaysian fishing boats, including specific aspects of retrofitting, Fuel supply and storage, Safety(on-board or onshore), classification and find solutions to address potential risks.

In this research, these three concepts of fishing boats, alternate fuel and dual fuel engines will be merged to form a solution for Malaysian fishing industry to provide sustainable and cleaner environment. In this a feasibility study will be done mainly on natural gas to understand its safety and cost of operation so that it will help us analyze if using an alternate fuel is more economical in fishing boats in Malaysia.

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