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DUAL FUEL POWERED FISHING BOATS USING NATURAL GAS

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ABSTRACT

Fishing is an occupation in many countries and the demand for fish is widespread. Fishing boats have to be operated in extreme and harsh conditions. Some of the vessels have specific routes while many others go beyond the coastal boundaries to catch fish. Issues related to fuel cost and emission from these boats are of major concern. One of the solutions to this problem is to use a dual fuel engine which uses natural gas (NG) as one of the fuel. Liquefied Natural Gas (LNG)/Compressed Natural Gas (CNG) is cheaper and greener fuel than diesel or petrol. It has less sulphur content and it also minimizes the Nitrogen Oxide (NOx) emissions when burned compared to diesel or petrol. To have a cleaner environment, more emphasis should be done to reduce these emissions. Natural gas is not widely being used in fishing industry because there is a problem related to bunkering and storage. In this research, the feasibility study for natural gas as a fuel for fishing boats in Malaysia has been done to analyze its cost, fuel storage, retrofitting, safety and bunkering so that a safe and cleaner working environment for fishing industry in Malaysia can be created.

Keywords: *Fishing boats, dual fuel engine , natural gas, CNG, feasibility*

1.0 INTRODUCTION

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 west coast of Malaysia has more fishing activities than the east coast [1]. There are many fishing boats which are still using petrol or kerosene as their fuel. As the International Maritime Organization (IMO) regulations are getting stringent in terms of air pollution and emissions from ships we need a solution to provide environmental friendly shipping.

As the resources are fast depleting, using an alternate fuel will be an option when sustainability is a concern. There are many alternative fuels which can be used to power the ships and fishing vessels, some of which may include bio-fuel, ethanol, methanol, biodiesel, propane, hydrogen, and natural gas.

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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 Sulphur Oxide (SOx) emissions from ships and boats [2]. This can be done by using low sulphur marine diesel oil or using a combination of these alternate fuels with the diesel engine.

The reason for choosing natural gas as a fuel for fishing boats is because of the abundant availability, cheap and various other reasons as mentioned in Table 1. Natural gas is a mixture of hydrocarbons such as methane, ethane, propane and butane. It is a low-density and low-sulphur content fuel as compared to petroleum products and is practically free from carbon monoxide emission [3]. Because of the gaseous nature of this fuel, it must be stored on board of a vessel in either a compressed gaseous state (CNG) or in a liquefied state (LNG). Currently, 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 and less emissions. It has been found that nature gas is effective in reducing emissions as it is also widely used in industries and land transport in the form of natural gas vehicles (NGV).

Another major problem related to natural gas is the availability of the bunker. Since it is a new technology not much on its bunkering stations and infrastructure for the facility is known. So it will be a challenge to invest on its bunkering facility. But there is a possibility of making small scale stations, transfer by truck, and ship to ship transfer if the governing body and gas companies operate on mutual understanding and look at the project as environment point of view and future availability of this technology.

Dual fuel engine has the ability to use both petrol/diesel along with alternate fuel. It has been proven to increase efficiency. The dual fuel engines can save the operating and maintenance cost because there is a better combustion causing less emissions.

Table 1: Weighting matrix of alternate marine fuels [4]

	Ethanol	Methanol	Bioliquid 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	excellent	excellent

The DNV innovation project "Fish 2015" introduces the designs of the first LNG fishing ship of the future, "Catchy", for fishing with pelagic trawling and purse seine. It provides flexible operation, energy efficiency and improved and safer working conditions. It shows that LNG can be used as a fuel for fishing ships.

According to Vandebroek and Berghmans [5], safety aspect of using natural gas for marine propulsion is reliable for marine industry. Aspects relating to flammability limits, storage and methane slip were also discussed.

As per the study of Jafarzadeh *et. al.* [6], among various fishing methods, trawling consumed the most energy per kilogram fish caught and also reduced the emission level produced by the fishing vessels. They also proposed an alternative to the conventional fuel used for propulsion with other kinds of fuels with less emission, such as LNG.

According to Thomas *et. al.* [7], four kinds of fishing gear of high catch capability, such as trawl net, fish purse seine, anchovy purse seine and other seine gear form the group of commercial fishing gear, while another 11 kinds of fishing gear of comparatively low catch capability, such as push net, bag net, gill net, fish trap, long line, etc. form the group of traditional fishing gear.

Figure 1 shows the relation between the fish demand and total catch from the year 1970-2010. It shows that the demand for fish has always been rising but the amount of fish catch varies and hence the fisherman income changes subsequently so it is vital to introduce energy saving techniques and help generate an increased fisherman income.

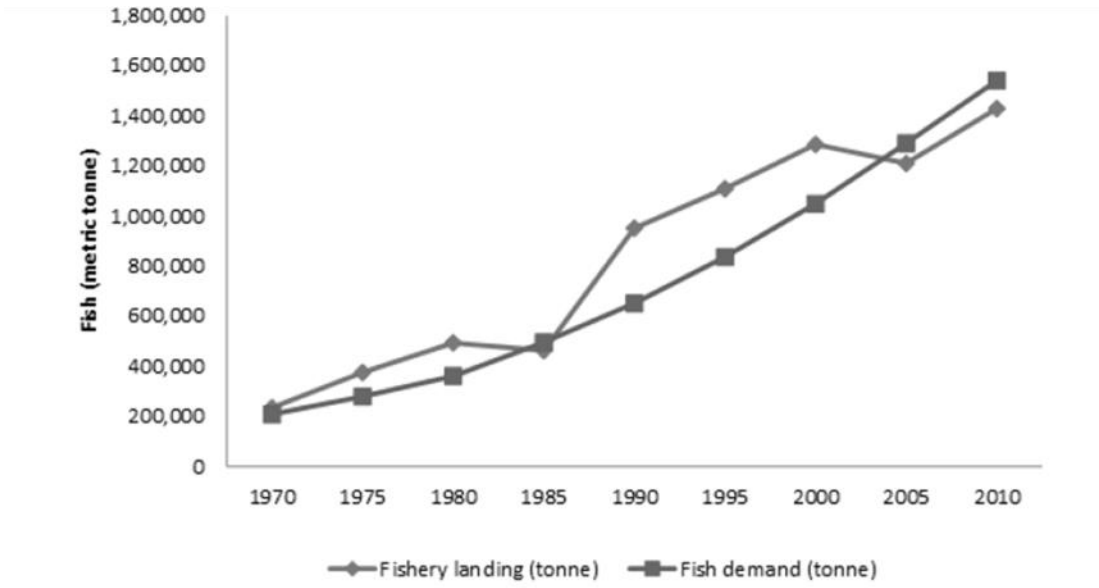

Figure 1: Fish demand vs Marine fish landing in Malaysia [8]

2.0 METHODOLOGY

The literature review was first done on natural gas as a fuel for both land and sea transport, then the kind of fishing boats that are widely used in coastal waters of Malaysia was analyzed after which a fishing boat was selected. In the selection process for a boat, a field visit was carried out at a few locations in Johor and Terengganu, Malaysia to understand the types of fishing boats which operate in coastal zones of Malaysia. A study on how dual fuel engines work was also done. The results of the study were compared for both land and sea transport and also to further understand the operation of fishing boat using dual fuel.

To continue with the research, it was decided that a small boat operated in Pontian region was selected and modified by using CNG as an alternative fuel. The same approach can be used to help fishermen who have limited income instead of using petrol or diesel engines to power their small fishing boats. The fuel prices for diesel and petrol are always on the increasing trend and also there is a concern of emissions.

Nevertheless, the CNG cylinders cannot be installed directly on the boat as any additional weight can have adverse effects on its stability.

2.1 Stability of Small Fishing Boat using CNG

The stability of the vessel is an important aspect to be determined as it is a measurement of the ability of the vessel to resist the overturning forces encountered during the course of its operations. The stability calculations are usually performed to determine the intact and damaged states of the vessels to ensure its compliance with the stability requirement. The measurements of the stability performance include the range of heel angles, maximum value of the righting arm and area under the righting arm curve which then will be compared with the IMO standard on safety recommendations for small fishing vessels. The stability of boat was done by considering different loading and unloading conditions using *Maxsurf* stability program. The three loading conditions to be considered in assessing the performance of the boat include the followings:

- Departure for fishing grounds with full fuel, ice, fishing gear, etc.
- Departure from fishing grounds with full catch, 30% fuel, etc.
- Arrival at home port with full catch and 10% fuel, etc.

Table 2 shows a stability assessment for departure from the fishing ground.

Table 2 Stability assessment for departure from the fishing ground

Load Case: Departure from the Fishing Ground				
Criteria	**Limit Value**	**Units**	**Actual**	**Status**
Area from 0 to 30 degree (shall not be less than (>=)	3.151	m.deg	8.560	Pass
Area from 0 to 40 degree (shall be greater than (>)	5.157	m.deg	8.560	Pass
Area from 30 to 40 degree or Angle of Flooding z (shall be greater than (>)	1.719	m.deg	6.592	Pass
Maximum GZ at the angle of heel equal to or greater than 30 (shall be greater than (>)	0.200	M	1.143	Pass
Angle of maximum GZ (shall not be less than (>=)	25.0	Deg	87.30	Pass
Initial GMt (shall not be less than (>=)	0.350	M	1.299	Pass

2.2 Resistance Analysis of Fishing Boat with CNG

In assessing the resistance performance of small fishing boats, a *Maxsurf* resistance software has been used as shown in Figure 2. There are different methods to determine the resistance. Holtrop and Van Oortmerssen methods are used as they are ideal for small ships like trawlers and tugs, fishing vessels, etc.. The required speed limits have to be known for the boat operation and based on this knowledge, it can be determined the maximum power to run the boat at desired speed. Comparing the results between normal boat and boat with CNG, it has been found that the weight of the boat with CNG has increased and hence it requires more power at similar speeds.

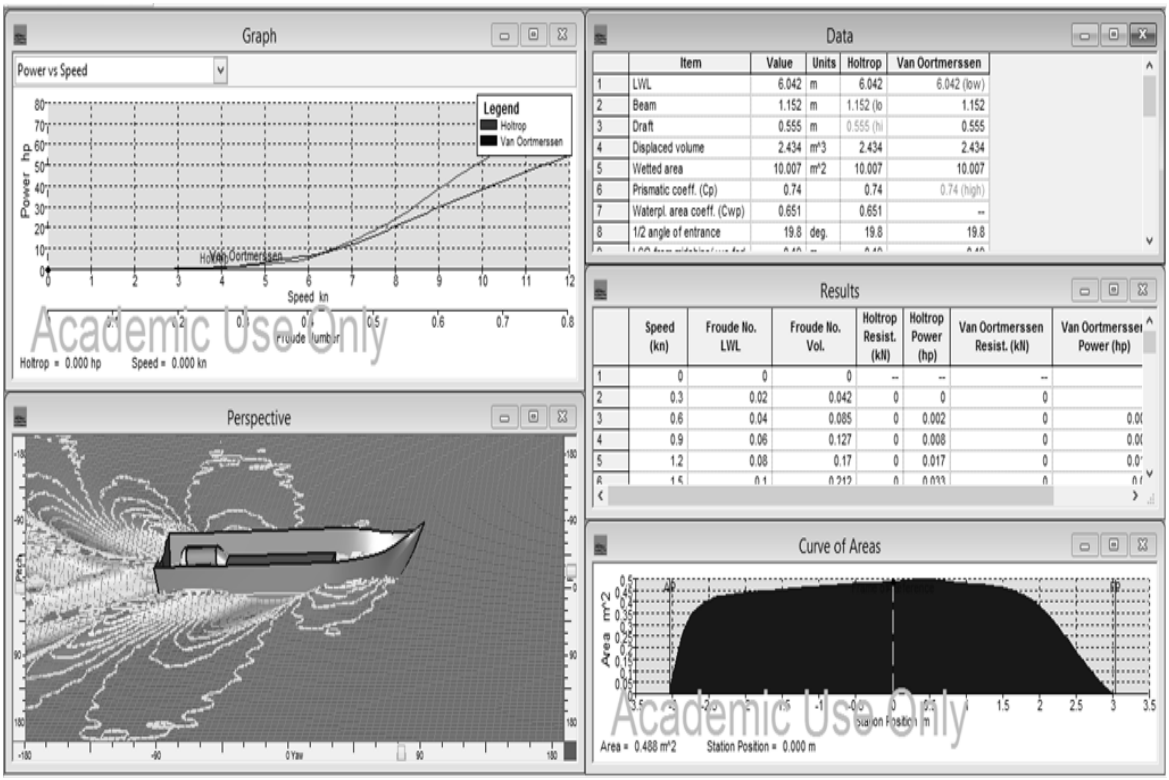

Figure 2: Resistance analysis using *Maxsurf*

2.3 Economic Analysis

Currently, all alternative fuelled vehicles have a price premium over traditional fuelled vehicles (unless manufacturers have special promotional prices that they subsidized). The natural gas used on the boat has high potential economic value in the future. A study on the operation costs indicated that natural gas can have a fuel cost saving of 54% when compared to traditional method if the fuel consumption per hour and total distance is assumed to be constant for a period of one year at a fixed fuel cost. The current price of petrol is RM

2.30/litre while CNG price is RM 0.68/litre. The initial investment is high as the cylinders have varied prices based on the material use. In this project, a cylinder of type-3 fibre was used as it is light in weight. A sensitivity analysis was also performed for different scenarios based on fuel cost, fish catch and fish price.

2.4 Environmental and Safety Aspect of Natural Gas

Vehicles that run on clean burning natural gas are as safe as vehicles operating on traditional fuels such as petrol. The low density of methane coupled with a high auto-ignition temperature (540 °C compared with 227-500 °C for petrol and 257 °C for diesel fuel) and higher flammability limits give the gas a high dispersal rate and make the likelihood of ignition in the event of gas leakage less than for petrol or diesel. Additionally, natural gas is not toxic. Figure 3 depicts the ideal CO exhaust emission rate of land vehicle.

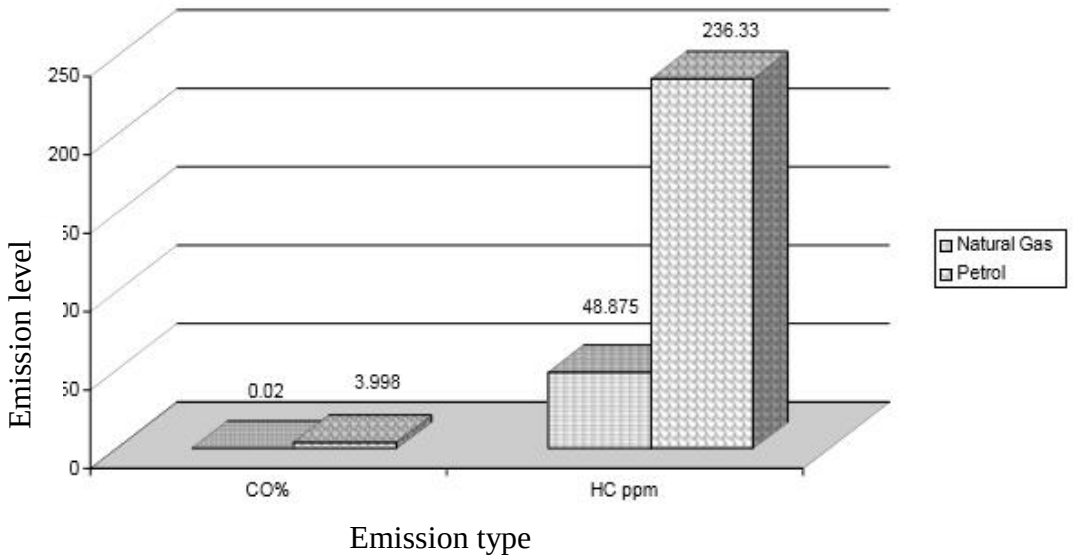

Figure 3: Ideal CO exhaust emission rate of land vehicle [9]

3.0 CONCLUSION

Natural gas large reserve base lends itself to opportunities for exploration of the resources not only to generate foreign exchange earnings through the export of LNG and piped gas but also fuel nation demand energy for industrialization and to spawn other ancillary and related industries, including the development of the natural gas vehicles especially for fishing boats. Natural gas powered fishing boats totally eliminate nitrogen oxides and give a significant decrease on CO and HC emission. It has a higher installation cost but over the years, it yields a short payback period. It is one of the solutions for the fishermen to generate a better income and control the emission.

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