

THE APPLICATION OF LNG AS A FUEL FOR MEDIUM AND HIGH SPEED FERRIES

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The shipping industry in Europe is facing increasing pressure from a raft of new environmental regulations, as well as the prospect of higher fuel prices in the near future. The high speed ferry sector has used light weight diesel engines that burn distillate fuels; however the higher installed power required in these vessels coupled with the corresponding higher fuel consumption has further increased pressure on this sector. Austal has been researching new ferry platforms that can combine the advantages of light weight aluminium construction with liquefied natural gas (LNG).

WHAT IS LNG?

LNG is the liquefied form of natural gas. Natural gas consists mainly of methane, with some ethane, propane and butane, which when cooled to -163°C , becomes a liquid and can be stored in insulated IMO type C tanks. Methane contains the highest amount of energy per unit of carbon and has the cleanest burn of any fossil fuel. LNG has an auto-ignition temperature of 580°C compared with 250°C for diesel and 400°C for petrol. Because of this, when LNG is used in a reciprocating engine, an outside source of ignition is required, either in the form of a spark plug or the use of a small amount of diesel.

ENVIRONMENTAL PRESSURES

The International Maritime Organisation (IMO) is in the process of introducing a wide range of regulations

that will control the levels of Nitrous Oxide (NO_x) emissions from ships and Sulphur contained in fuel oils. The IMO has also created Emission Control Areas (ECA's) such as in the Baltic and the English Channel, and vessels operating in these areas are subject to tougher regulations. Worldwide IMO Tier II rules for NO_x emissions came into force in January 2011, and while most diesel engines will be able to comply, Tier III lies not far behind and will become law for vessels built after January 1, 2016, that operate in an ECA. Compliance with the NO_x emission limits can be achieved through the use of off engine solutions such as selective catalytic reduction (SCR) technology. The level of sulphur in fuel will also be subject to control and from July 1, 2011, for vessels operating in an ECA, the sulphur content must be below 1% and will be further reduced to 0.1% from January 1, 2015. The European Union already requires fuel with sulphur content below 0.1% to be used in harbour.

For operators of high speed ferries using distillate fuels, the switch to lower sulphur content fuel can be easily achieved and many operators have already made the move. With the introduction of the Tier III regulations, however, the demand for fuel oil with a sulphur content of less than 0.1% will inevitably drive up cost.

International shipping accounts for about 2.7% of the global emissions of Carbon Dioxide (CO₂) with about 70% of these emissions being produced by ships

operating on coastal and short international routes. The UN Climate Change Conference and individual countries may decide to take action independently on CO₂, by either charging a tax on emissions or passing additional prescriptive regulations. Added pressure comes from the IMO's work in developing an Energy Efficiency Design Index (EEDI) and an Energy Efficiency Operational Index (EEOI) for ships. While initially the EEDI formulae are aimed at ships operating on long haul voyages, there is every indication that the concept may be applied to short sea shipping in the future.

It is estimated that shipping can reduce the level of CO₂ emissions by around 15-20% by utilising a number of strategies such as slowing down; optimising passage plans, weather routing, using more efficient hull shapes and propulsion devices such as improved propeller designs. For high speed craft, the only path to an improved EEDI rating is to slow down, or use another type of fuel that does not generate the same levels of CO₂.

This is where the use of LNG offers a very attractive alternative. LNG offers operators many advantages over conventional diesel fuels, including a reduction in NO_x emissions by 80-90%; a reduction in SO_x emissions to almost zero; and a reduction in CO₂ emissions by 20-30%. The use of LNG also results in very low levels of soot and particles.



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OTHER PRESSURES

The travelling public is increasingly well informed about environmental issues and where there is a choice, will exercise their decision based not wholly on price, but on values including who has the most environmentally friendly vessel.

DESIGN DEVELOPMENT

Over the last 18 months, Austal has been researching the development of several new types of fast ferry. The most promising of these are multi-hulled ferries that comply with the High Speed Craft (HSC) Code, but are significantly slower than the traditional fast ferry.

The development of a slower speed but HSC Code compliant ferry has led to the development of new hull forms that are very efficient at lower Froude numbers. The use of numerical analysis and tank testing has confirmed the excellent performance of these new hull shapes.

In liquid form, LNG has 50% of the energy density of diesel oil and therefore, in broad terms, the LNG tanks, piping and other fuel handling equipment require about four times the volume and, together with the heavier LNG engine, result in a propulsion package that is significantly heavier than a conventional diesel engine installation. On the positive side, however, aluminium vessels operating at a slower speed are more tolerant of weight than their high speed cousins

and this characteristic makes them suitable for the application of LNG equipment. Aluminium also does not require any special protection against the spillage of LNG as its physical properties actually improve with a lower temperature. Steel, on the other hand, is subject to brittle fracture.

EXTERNAL CHALLENGES

The regulations covering the design of LNG powered passenger ferries, while well developed and understood in Norway, are still under development elsewhere in Europe and the rest of the world. The development of an LNG powered ferry requires the cooperation of central and local government bodies as well as the support of the flag authority and a high level of understanding of the safety issues associated with the use of LNG.

For the operator, the supply of LNG on a regular basis may be a commercial risk. LNG powered ferries may require re-fuelling once a week or daily depending on the consumption. Outside Norway the distribution network for LNG is poorly developed, and in Europe, hubs that can both import and export LNG are few.

Traditionally the price of LNG has followed the spot price of crude oil, however in recent months there has been a marked shift away from this pattern, with the LNG market price starting to de-couple from the spot price of crude oil. This trend is predicted to continue

as infrastructure and distribution methods to support an LNG sector are developed.

MACHINERY

For an HSC Code compliant vessel operating at speeds above 30-35 knots, dual fuel gas turbines may be an appropriate solution. For operating speeds in the range of 20-30 knots, reciprocating engines are more appropriate.

The range of reciprocating engines suitable for use with LNG fuel is not large; however leading engine manufacturers are developing their range of engines to include dual fuel and pure LNG engines. However, because these engines have generally been developed from an existing range of medium speed diesels, they are heavier than those traditionally used by the high speed craft industry. In broad terms, dual fuel engines may be directly linked to the propulsion unit and pure gas engines are best utilised as generating sets in a diesel-electric installation.

Dual fuel engines are usually started using diesel fuel, use a mix of diesel and gas for low speed manoeuvring and then will switch to an LNG mode at sea, which still uses a small amount of diesel fuel. With modern dual fuel engines, the switching of the ratios between fuels is automatic. The lean burn pure gas engines use spark ignition technology for combustion.

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Lean burn gas engines used as generating sets may be arranged to provide AC or DC power. The final choice as to which type of electric platform is best requires careful study as there are advantages and disadvantages to both systems. There are also a number of additional mechanical features that may be combined with LNG machinery including waste heat recovery and energy recovery units mounted on the main engine exhausts. There are also a number of hybrid propulsion packages available where the engine is connected to the propeller via a gearbox. The gearbox is fitted with a shaft generator that can act as both a generator or as a motor to assist with harbour manoeuvres and, at full speed, used as a source of additional electrical power. The final arbiter may be the vessel type and route profile.

CONCLUSION

The pressures from environmental regulation and the increasing cost of diesel will make LNG an increasingly attractive proposition for operators on routes within ECA's. Other routes that transit areas of special environmental sensitivity may also be suitable for LNG. Aluminium vessels operating both at low speed outside the remit of the HSC Code and at above the HSC Code minimum and 40 knots or more can be powered by LNG machinery. The equipment and rules have been developed to support such vessels and the experience of the Norwegian ferry industry may be used as an example of a successful role model for the introduction of LNG powered vessels.

Ferry operators considering the use of LNG may have to look outside the traditional model when setting up their LNG supply chain and decide whether to develop an LNG hub for themselves only or involve local government and other potential users of LNG so as to share the cost of a larger infrastructure development across several transport sectors such as trucks, busses and other maritime customers.

Austal is currently building its first vessel that will be issued with a "Green Passport" as part of classification certification. It is clear that operators in Europe are under pressure from both the regulatory authorities and from their customers. Operators need to be seen to be proactive in offering environmentally sensitive solutions.

Austal's success is centred in designing and building vessels that are customised to the operator's particular route requirements and believes that being in a position to offer LNG as an alternative solution, along with other environmental features, will provide operators greater flexibility in deciding what type of vessel they require in these challenging times.

CASE STUDIES

Austal has studied the capabilities of LNG in three different vessel types: a 102m trimaran ferry; a 72m catamaran; and a 127m trimaran. These studies are 'snap shots' of what is possible with LNG. Within each vessel, there exists the capability to alter the specification to provide higher and lower speeds, deadweight and range.

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VESSEL ONE: The first platform is based on the Austal 102m trimaran ferry, the outline specification of this vessel is shown below.



Length Overall	102.0m
Length Waterline	101.4m
Beam Moulded	26.8m
Hull Depth Moulded	7.6m
Vehicles	190 truck lane metres & 145 cars
Passengers	1165
Main engines	3 x Wartsila 9L34DF Dual fuel (4,050kW each)
Propulsion.....	3 x CP propellers
Speed	26 knots
1 x cryogenic tank	120,000m ³
1 x diesel tank.....	40m ³
Range	450 nm (on LNG)
Deadweight	600 tonnes

The trimaran hull form is an ideal platform to develop an LNG powered vessel. The central hull can be designed to house all of the LNG machinery, thus simplifying the layout and reducing piping runs. The centre hull is also large enough to house the cryogenic tank and comply with the B/5 regulations, this double bottom can also be designed as the diesel tank. The

trimaran will be powered by dual fuel engines, thus providing the redundancy required by the HSC Code for the fuel supply. Propulsion is by propellers due to the moderate speed, with rudders and bow thrusters to give the vessel excellent in harbour manoeuvring capabilities. Larger dual fuel engines can offer speeds up to around 30-32 knots.

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VESSEL TWO: The second vessel is a 72m catamaran; the outline specification of the vessel is shown below.



Length Overall	72m
Length Waterline	61.8m
Beam Moulded	17.60m
Vehicles	110 truck lane metres and 48 cars
Passengers	650
Main engines	4 x Bergen C26:33L9AG (2,310ekW each)
Propulsion.....	4 x CP propellers
1 x cryogenic tank	2 x 50.0m3
Range	600 nm
Speed	24 knots
Deadweight	258 tonnes

This vessel is equipped with four lean burn pure gas engines arranged as generator sets, sized to provide the power required for the hotel load and propulsion. The vessel will be fitted with two cryogenic tanks, one in each hull or on the superstructure so that there is redundancy in the fuel supply. The vessel will be equipped with two propellers on each hull each with a high lift rudder to provide the required low speed

manoeuvrability in harbour. The lightship weight of this vessel will be higher than for the equivalent direct drive LNG powered vessel due to the weight of the electrical equipment, however for operators requiring a pure gas solution, this vessel offers an attractive solution. For domestic routes where aluminium non-HSC Code vessels may be permitted to operate this vessel could be designed to operate at lower speeds.

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VESSEL THREE: The third vessel is based on a 127m trimaran.



Length Overall	127m
Length Waterline	117m
Beam Moulded	30.4m
Vehicles	450 truck lane metres and 123 cars
Passengers	1,300
Main engines	2 x GE LM 2500 PE dual fuel
Propulsion	4 x waterjets
1 x cryogenic tank	1 x 125,000m ³
Diesel tank.....	1 x 60m ³
Speed	42 knots
Range	450 nm (on LNG)
Deadweight	1000 tonnes

The concept of this vessel is very similar to Vessel One, where the machinery and cryogenic tank are located in the centre hull. The gas turbines may be arranged to drive one large waterjet through a suitable reduction gearbox or drive two waterjets from a gearbox that splits the drive into two output shafts. This latter solution may be lighter and cheaper than the former. This vessel is fitted with one cryogenic tank located in the centre hull. Diesel fuel tanks will also be fitted as the turbine us a dual fuel unit. The turbine is started on diesel fuel and once up to temperature

uses the waste heat from the turbine to evaporate the LNG. The drawback to this concept is the low operating range due to the high LNG consumption of the gas turbines. This vessel will require re-fuelling on a daily basis, depending on the route. The re-fuelling strategy may require additional work to investigate how to minimise its impact on the vessels working day.