International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 11 | Nov 2018 www.irjet.net p-ISSN: 2395-0072

APPLICATIONS OF ALTERNATIVE FUELS IN MARITIME INDUSTRY

Shaik Fayaaz Ahamed[1]

[1]MTech (Naval Architecture and Marine Engineering), Andhra University, Visakhapatnam, India

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Abstract - *Alternative Fuel, means fuels or power sources which serve, at least partly, as a substitute for fossil oil sources in the energy supply to transport and which have the potential to contribute to its decarbonization and enhance the environmental performance of the transport sector. The development and use of alternative fuels as well as appropriate infrastructure in the European territory are essential to meet the requirements of the Directive on Sulphur content in marine fuels and to reduce the dependence of transport on oil. Fossil-based fuels, such as LNG will have limited contribution to greenhouse gas reductions, while biofuels have the potential to lead to drastic reductions. On a technical level, the introduction of alternative fuels will be accompanied by additional complexity, in the areas of fuel supply infrastructure, rules for safe use of fuels on board, and operation of new systems. It is expected that a number of different fuels may become important in different markets around the world, depending on local availability of fuels, which will add to the complexity*

***Key Words*: Alternative Fuels, Marine fuel, Natural gas, Hydrogen, Fuel consumption, Ship emissions**

1. INTRODUCTION

The maritime transportation has been playing a key role in the international supply chain during fast growing international economy. Over 90% of the world trade is carried by the international shipping industry, approximately eight billion *tons* of international trade goods are transported through the sea each year. The increase of the amount of goods transported by ships has caused an increase in the amount of fuel consumed by shipping transport sector through the last decades with the expectation continues of this trend through the next years. Fossil fuel in its forms diesel and heavy fuel oil consider the mainly marine fuel onboard ships. Last years; the marine fuel has been showed tow basic problems, the first one is the continuous increment in fuel prices. Although the prices have fluctuated up and down, it stills at a high level. All expectations indicate that the prices will continue to increases. Accordingly, that has led to a situation where the fuel cost has become even more significant to the total ship's operating cost. The second problem is ships' emissions, over the past decades, air emissions from ships been the subject of increasing attention throughout the industrial world. Although the actual level of marine air pollution is unclear, the contribution of ships to the global emissions can be roughly indicated as being in the following ranges: nitrogen oxides (NOx), 10–20%; carbon dioxide (CO_2), 2–4%; Sulphur oxides (SOx), 4–8%. To comply with the previous problems, many studies were carried out to present practical solutions. One of these solutions is using alternative fuel instead of the fossil fuel. The main alternative marine fuel types may be found in two forms: liquid fuels including ethanol, methanol, bio-liquid fuel, and biodiesel; and gaseous fuels, including propane, hydrogen, and natural gas (NG)

2. LITERATURE SURVEY

The use of alternative fuels is regarded today as a key relevant area of technological development for sustainable transport. In shipping, like in other transport modes, there is today a consistent focus given to the potential application of different cleaner fuel solutions, with some of them posing significant challenges to ship design. The gradual adoption of these fuels, and the example set by first movers has been fundamental in paving the way to a wider use of alternative fuels for the future. Taking into account the large share contribution of shipping to the in the worldwide transport market (accounting for over 80% of world trade by volume, 3% of global greenhouse gas emissions and contributing to air pollution close to coastal areas and ports), the gradual adoption of alternative fuels by shipping would have a significant positive immediate environmental impact.

2.1NATURAL GAS AS AN ALTERNATIVE MARINE FUEL

Natural gas is a gaseous fossil fuel that contains methane as its primary component. It is derived from organic matter that was deposited or buried under the earth, millions of years ago. From the view point of availability; In the last ten years the world production of natural gas shows annual increase of 3.2%, while the world consumption was 3.05%, refers that the sustainability of natural gas is greater than that of traditional liquid fuel (Diesel oil) However, by the beginning of economic crisis the fuel prices showed a rapid drop and reaching its minimum within a few months. According to the present fuel prices, the price of natural gas $/MMBtu which gives the same crude oil energy is nearly equal to half of crude oil price. This means that the use of natural gas as a fuel source for transportation sector, including marine applications will be less costly than the use of traditional crude oil fuel.

2.2 NATURAL GAS AND THE ENVIRONMENT

Natural gas is an extremely important source of energy for reducing pollution and maintaining a clean and healthy environment. The main products of the combustion of natural gas are carbon dioxide and water vapor. Table 1 presents a comparison between Coal, Diesel oil and Natural gas from the point view of emissions.

Table - 1 Fossil fuel emissions level g/KW.h

Pollutant	Coal	Diesel oil (average values)	Natural gas
Carbon Dioxide	322.14	254	181.2
Carbon Monoxide	0.322	0.051	0.618
Nitrogen Oxides	0.707	0.693	0.142
Sulfur Dioxide	4.137	1.791	0.001
Particulates	4.25	0.13	0.01
Mercury	0.00	0.00	Near to zero

2.3 NATURAL GAS AS AN ALTERNATIVE MARINE FUEL

Natural gas can be found in three forms on-board ships: Gas form, Liquid form (liquefied natural gas, LNG); compressed gas form (compressed natural gas). The shipping industry has known LNG decades as a bulk commodity transported by large LNG tankers around the world. Recently a number of forward –looking companies have been paving the way by pioneering the use of LNG as a fuel especially for ships engaged on regular coastal or short sea shipping services. It is believed that in 5- 10 years' time the majority of ship contracted for short sea trades will use LNG as marine fuel oil.

2.4 HYDROGEN AS AN ALTERNATIVE MARINE FUEL

Although hydrogen is the universe most abundant element, it is present in the atmosphere only in concentrations of less than one part per million. Most of The Earth's hydrogen is bound up in chemical compounds. Hydrogen for large-scale use should therefore be extracted from a source such as water, coal, natural gas, or plant matter. A variety of alternative hydrogen energy production technologies are available in practice, including: Steam reforming, Off-gas cleanup, Electrolysis Photo process, Thermo chemical process and Partial oxidation of hydrocarbons

3. EFFECT OF USING ALTERNATIVE MARINE FUELS ON GAS TURBINE PERFORMANCE

One of the marine power plants that very sensitive by fuel type is gas turbines that due to the difference of combustion process from the other plant. To illustrate the possibility of using marine alternative fuels (Natural gas & Hydrogen) as a main fuel for gas turbine power plant instead of diesel oil; a model of LM2500 gas turbine of General Electric. Fig - 1 will used as a case study, while Fig – 2 (b) illustrates the (T-S) diagram for gas turbine system.

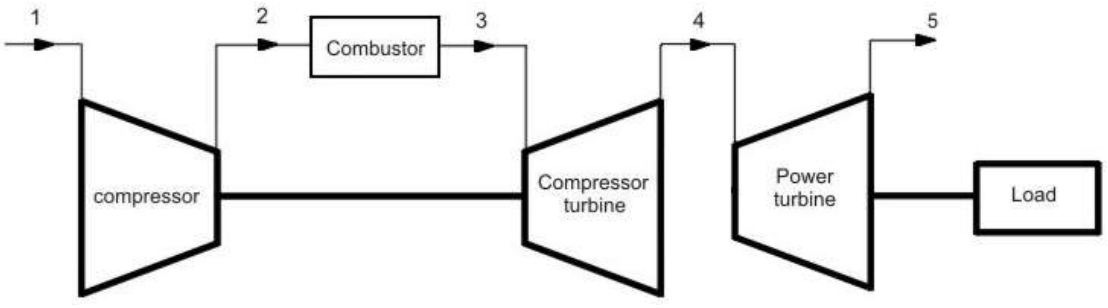

Fig – 1 : The main marine gas turbine components

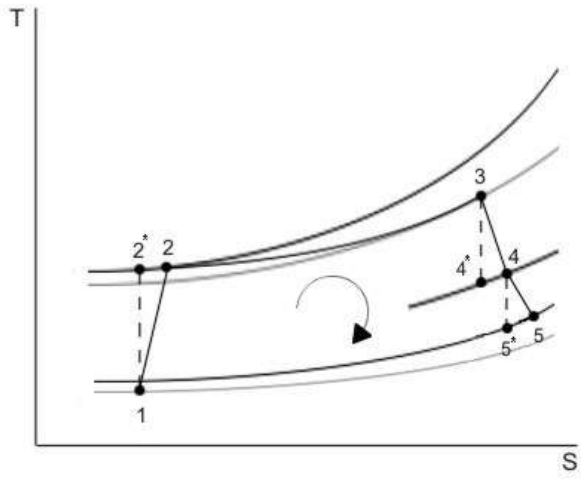

Fig – 2 : Temperature-entropy diagram

3.1 FUEL PROPERTIES

Table – 2 : Fuel Properties

Fuel	Symbol	Calorific value [kJ/kg]	Stoichiometric air fuel ratio	Max. excess air factor
Diesel	$C_{12}H_{26}$	42,800	15.14	3.11
Natural gas	CH_4	50,000	17.39	3.13
Hydrogen	H_2	120,000	34.78	4.03

3.2 CYCLE EFFICIENCY

The cycle efficiency ($_{cycle}$) is the ratio between the output work and the input energy to the engine, this can be expressed in specific form using the specific work of the power turbine (W_{PT}) and the energy content in the fuel (CV_{air}) as follows,

$$\eta_{cycle} = \frac{W_{PT}}{CV_{air}}$$

It has been found from the study that both gaseous fuels give lower efficiency than the original case of diesel for the same power output as shown in Fig. 5. This will be cleared later while discussing the air flow rates for the three cases.

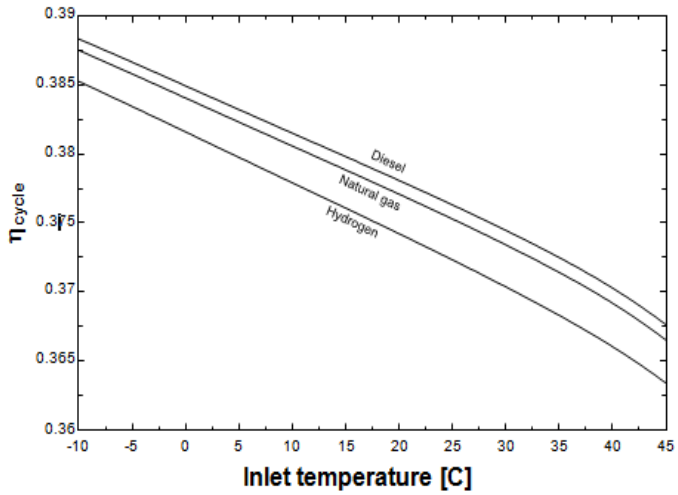

Fig - 3 Cycle efficiency for the different fuels.

3.3 SPECIFIC FUEL CONSUMPTION

The specific fuel consumption is determined by dividing the mass flow rate by the output power.

$$sfc = [power / m_f]$$

The higher calorific value for both natural gas and hydrogen if compared to diesel reduces the quantity of fuel used to give the same heat output. Therefore, it is observed from Fig. 6 that the specific fuel consumption for natural gas and hydrogen is lower than that of diesel. This could be an advantage from the point of view of storage onboard the ships, but the fact is different due to the lower density of these two fuels compared to the diesel.

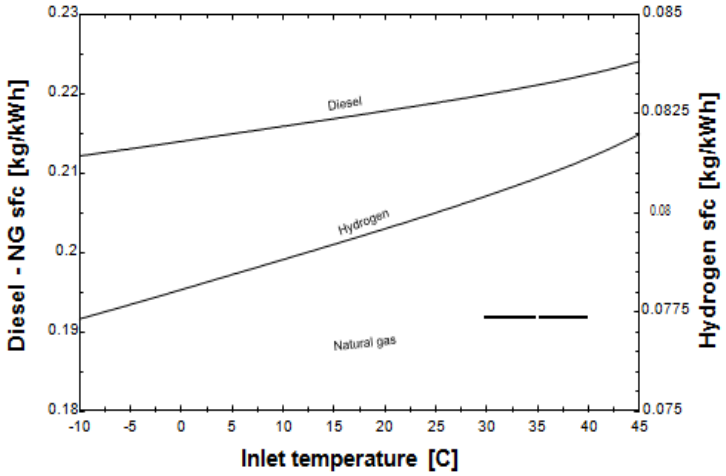

Fig - 4 Specific fuel consumption comparison for the different fuels

4. MAIN STUDY RESULTS FOR THE THREE FUELS AT 15 °C AMBIENT TEMPERATURE

Performance	Diesel	Natural gas	Hydrogen
Efficiency	0.3798	0.3788 (-0.26%)	0.376 (-1%)
Specific fuel consumption [*kg/kWh*]	0.2169	0.1876 (-13.5%)	0.0792 (-63.49%)
Max. temp. [*K*]	1485	1474 (-0.74%)	1444 (-2.76%)
Exhaust temp. [*K*]	812	806 (-0.74%)	788 (-2.96%)
Work ratio	0.443	0.4388 (-0.97%)	0.4269 (-3.72%)
Air flow rate [*kg/s*]	70.84	72.32 (+2.09%)	76.71 (+8.29%)
Exhaust flow rate [*kg/s*]	72.35	73.62 (+1.76%)	77.26 (+6.79%)

5. CONCLUSION

The first conclusion that must be stated first is that the natural gas and hydrogen can be successfully used as alternatives to replace the currently used diesel fuels in the marine gas turbines. For the short-term development, the natural gas provides ideal solution for the marine applications. Also, the thermodynamic performance using the natural gas in the gas turbine cycle was found to be close to the performance when diesel oil is used. With about 0.25% efficiency reduction at the ISO design conditions, the natural gas provides an excellent replacement for diesel. For the hydrogen, it was found that many modifications required to be made to reach the optimum performance. The gas turbine thermal efficiency was found to be 1% less in the case of hydrogen when compared with original case of diesel. The hydrogen application in gas turbines cannot be considered as a near future solution unless the inherent problems of hydrogen are solved by using the proper techniques that are technically and economically feasible. It should be noted that, the natural gas can be used in the marine field confidently to improve the maritime environment and keep the marine power plants performance in its good levels.

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AUTHOR

Ahamed Shaik

MTech (Naval Architecture and Marine Engineering)
Andhra University Free Lance Naval Architect