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LNG/LPG and Alternative Fuel Ships

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LNG/LPG and Alternative Fuels Ships

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LNG Bunker Vessel Design and Operation
K. W. Hutchinson, D. C Dobson, Safinah Group, UK

Worldwide there is a continuing growth in the application of natural gas for electrical power generation etc. for both industrial and domestic consumption, and increasingly now as a substitute for liquid hydrocarbon fuels in marine propulsion etc. Hence, natural gas is increasingly being transhipped in its cooled transitory form of Liquefied Natural Gas (LNG), primarily still transoceanic via conventional sized and larger LNG Carriers (LNGCs) between major production / reception hubs but now increasingly also in coastal waters utilising smaller LNGCs for regional distribution. Consequently, the world fleet of small LNGCs is increasing and the last few years has seen the introduction of a new class of ship namely LNG Bunker Vessels (LNGBVs) / Gas Supply Vessels (GSVs). Previous papers by the authors to RINA International Conferences held in 2016 and also 2017 and 2018 have discussed both large deep-water offshore and small-scale near-shore floating assets respectively. This paper will build upon these papers by turning attention to the emerging LNG bunkering sector.
Drawing on over two decades of experience in the design and evaluation of numerous new-build design, conversion and upgrades of offshore Floating Liquefied Natural Gas (FLNG) FPSOs (Floating, Production, Storage and Offloading), LNG Floating Storage and Offloading (LNG FSOs) reception / distribution vessels, Floating, Storage and Regasification Units (FSRUs), LNG Floating Power Barges (LNGFPBs) etc. together with a decades experience in the design of conventional and highly novel, innovative and ultra-large LNGCs, of all configurations, the authors will briefly discuss the history and development of LNG shipping and offshore and near-shore floating LNG assets over the past half century. The paper will briefly describe the LNG supply and utilisation chain, with a focus on floating assets, before considering the current and future deployment floating LNG bunkering throughout the world in response to the significantly rising demand for LNG as a fuel for both small coastal tonnage and the largest deep-sea ships. The design of LNGBVs will be discussed in detail including the many common, and some unique, but often conflicting and diverse design and operational criteria which must be addressed coherently within the design process in order to generate robust and safe solutions. Finally, the unique operational aspects associated with LNGBVs will be discussed and recent experience shared.

Purpose designed LNG bunkering vessels (LBV): a 2020 update on characteristics and features
R. Tustin, Woo-Jeong Choi, Jose Navarro, Lloyds Register, UK

For ocean going ships where operational endurance, and range, requires large capacity bunker fuel tanks the adoption of LNG as fuel has established a need for new types of dedicated LNG bunkering vessels (LBV) and LNG bunkering barges (LBB) with specialist systems for handling the ship to ship bunkering of LNG.
In 2017 the first three early examples of purpose designed, and built, LNG bunkering vessels (LBV) were put into service to support LNG bunkering operations in European Ports and described in a paper presented for publication by RINA in 2017. In 2018 four more LNG bunkering vessel examples were put into service including a first example of an LNG bunkering barge (LBB) as well as two cases of conversions into LNG bunkering vessels (LBV). These 2018 examples were described in a paper presented for publication by RINA-HIMT in 2018.
Further examples of dedicated LNG bunkering vessels (LBV) and LNG bunkering barges (LBB) have been delivered in 2019 and are on order and under construction for delivery in 2020 and 2021.
Summarizing LNG bunkering fleet development and comparing LNG bunkering vessels (LBV) in service, under construction and on order the paper will offer an update of the authors 2017 and 2018 RINA papers. Finally a comparison will be offered of LNG bunker vessels with receiving LNG fuelled ships from publicly announced agreements for LNG fuel supply.

A study on the performance and emissions of a marine diesel engine fueled with Schizochytrium sp. microalgae oil and its blends
H. M. Attar, Newcastle University, UK

The use of microalgae for purposes of producing biofuels offers many benefits in the ecological and terrestrial preservation domain. The strain selection affects the chemical configuration and hence, the engine's efficiency and exhaust gas emissions. This research investigates the performance and emissions of a marine diesel engine fuelled with marine microalgae (Schizochytrium sp). The engine is fuelled with B20 (20% algae, 80% diesel), B50 (50% algae, 50% diesel) and B100 (100% algae) without any chemical additives. The blends were prepared before each test by heating the algae oil, then blending it with diesel in a stander heating hotplate using a blender machine. The experiments in this project were conducted under various engine speeds and loads.
A drop in power (up to 26%) and BTE (Break Thermal Efficiency) (up to 30%) was observed during the experiments with the three fuels mentioned above at full load, comparing to diesel oil. At lower loads however, the engine performance of B20, B50 and B100 was almost the same as diesel oil in most test conditions. Additionally, the BSFC (Break Specific Fuel Consumption) of algae oil and its blends was higher (up to 38%) than diesel oil in all test conditions while the engine emissions of NOx and NO were much lower (up to 56% and 60% respectively). Noticeably, CO emissions of B100 were up to 60% lower than diesel oil at full load. These findings portray algae oil as the optimum alternative fuel for diesel engines and a promising solution to diesel engine emissions.

Port Design for Small LNG Carriers
A. Crowle, McDermott International, UK

There is an expected increase in ordering of small LNG carriers (less than 50,000 cum) in the near future. Therefore, advances in LNG port design is required to combine facilities for both very large LNG carriers and small LNG Carriers.
LNG ports are traditionally designed for LNG carrier of 125,000 to 266,000 cum capacity. This paper outlines the advances in LNG port design to combine facilities for large LNG carriers and small LNG Carriers between 1,000 cum to 50,000 cum capacity.
These loading operations for small scale LNG ships would take place on existing large scale LNG berths and so the paper identifies any changes to the existing design that would be required in order to have the capability to load to ships of all sizes.
The key elements of LNG ports for all capacity to date show that Small scale LNG carriers are generally equipped with an elevated manifold with 16" presentation flanges to allow standard LNG export loading arms to connect to the ship without any risk of overreach. Additional fenders may be required at the jetty head to allow safe berthing of ships with capacity up to approximately 20,000 m3.
Small scale LNG ships are normally not equipped with a compressor to return the Boil Off Gas (BOG) generated during loading back to shore. Therefore the differential pressure between the ship's tanks and the onshore LNG tanks has to be sufficient to allow the BOG to free flow back to shore.

Conversion of an LNG carrier to Floating Storage and Regasification Unit
R. Bhat, University of Strathclyde, UK

Natural gas is hydrogen rich mixture of light hydrocarbons having the chief composition of methane. While natural gas can be transported through pipelines, the cost of pipeline is between 3- 4 million USD per km (Songhurst et al., 2017) which makes the transportation of natural gas over large distances cost ineffective and hence rest of the natural gas trade is by LNG through LNG carriers. LNG trade volume will increase to 50 % from 2014 to 2020 (Shell-LNG-outlook, 2017). Since the increase in natural gas demand will be sudden, many countries will are required to augment their LNG import infrastructure including regasification units, Storage units like tanks. While the development of import infrastructure can take more money and time, like up to 4 years. A new build FSRU can take upto 36 months and require CAPEX of upto approx 450 million USD (Egashira et al., 2013). This cost of FSRU can further be brought down by carrying out conversion of an LNG carrier, which can take cost up to approx 320 million USD and the time of 12-24 months (Songhurst et al., 2017). This project was on conversion of an LNG carrier to FSRU to provide 2.5 MTPA regasification facility in Jaigarh port, India. After the process design, the equipment layout and conversion was carried in accordance with DNV GL classification rules. Risk assessment was conducted to determine critical subsystems of the FSRU using BBN diagrams and the project was concluded by cost analysis.

A Comparison of Hydrogen and Ammonia for Future Long Distance Shipping Fuels
C. J. McKinlay, S. R. Turnock, D. A. Hudson, University of Southampton, UK

Due to environmental pressures, the shipping industry will likely be required to significantly reduce oil and gas usage in the near future. This paper directly compares two low-emission fuels, hydrogen (H2) and ammonia (NH3), for the application of long distance international shipping. The approach taken was to analyse data from an LNG tanker, considered a typical long distance vessel, to make approximations of energy requirements. A key finding was the maximum energy consumption for a single voyage: 9270 MWh. Based on this figure, calculations were made for the required volume, mass and variable cost for several fuel types. Results showed that H2 required volume was 3930 m3 and 6620 m3 for liquid and pressurised gas storage respectively. H2 is often dismissed for mobile applications due to its low volumetric density, however this study has shown that these volumes are not unrealistic. Ammonia was shown to have several desirable characteristics, but also has low gravitational energy density that would increase the overall ship mass by 0.2 to 2.2 % compared to other fuels, having a negative effect on performance. Also considered were batteries as a power sources, but were shown to be too large, heavy and expensive for long distance applications. Both hydrogen and ammonia have the potential to be solutions for the decarbonisation of long distance shipping, however this study has highlighted a number of key engineering challenges that require further research before either option is to become viable.

A Flexible LNG Bunkering Vessel
R. Sevastre, ICE, Isle of Man

In 2019, the authors' organisation ("ICE") was challenged by a major player in the LNG supply market to design an oceangoing medium-speed, manoeuvrable LNG Bunkering Vessel, capable of bunkering LNG in ports worldwide.
The vessel is designed to transport approximately 8,000 m3 of LNG and will be able to supply multiple vessels during the same voyage ("milk run" operation mode), carrying different partial loads in two (2) x 4,000 m3 independent type C bi-lobe cargo tanks.
A wide range of transfer rate (up to 1,000 m^3/hour) is achievable by a combination of four cargo pumps, considering that the customers may have highly different receiving capacities for LNG and the fact that for some vessels - including ferries, cruise and container ships - the time available for fuelling is limited by a strict timetable. Maritime "pit stop" bunkering can be carried out in parallel with unloading and loading operations for cargo or passengers.
The vessel is equipped with two electrically driven 2,600 kW azimuth thrusters plus a 450 kW bow thruster. Power is generated by three pure gas engine generators for which two fuel gas supply operation modes are possible:
• Fuel supply with the accumulated Boil-off Gas (BOG) from the cargo tanks, used mainly when sailing from one port to another, and
• Fuel supply from a dedicated LNG storage tank used for during port area operation (stand-by/navigation/cargo offloading). This system is also a back-up to the BOG fuel supply.
The special, innovative features related to bunkering operation include:
• Aft loading / unloading manifolds, in addition to the conventional port and starboard midships manifolds, to enable load and offload at any of the current LNG terminals and various sizes of vessels;
• Electric-hydraulic manifold crane located midships with a capacity of 3.5 - 4 tons SWL at 17 - 21 m outreach, dedicated to LNG / vapour hoses and fenders handling;
• Electric-hydraulic manifold crane aft (5 tons SWL at 15 m);
• Pneumatic Fenders designed for offshore ship-to-ship transfers.

Numerical Investigation on Coupling Dynamic Performance of FLNG and LNG Carrier duringn Side-By-Side Offloading Operation
A. Nair, Houlder, UK
Z. Hu, Newcastle University, UK

FLNG (Floating Liquefied Natural Gas) is a relatively new concept, moored offshore to produce and storage liquid natural gas, and offload it to LNC carrier. The side by side offloading operation of FLNG and LNGC is a challenging task due to the complicated dynamic coupling responses and the extremely strict safety requirement on liquid cargo in -163-degree temperature. Hence the reliability of side-by-side offloading operation must be guaranteed regarding vessels motion and the loads induced on the connecting system. This paper addresses a numerical study on the coupled hydrodynamic characters of the side-by-side FLNG, LNGC and connecting system, through frequency-domain and time-domain analysis methods. The numerical analysis is carried out with the state-of-the-art software code. The frequency domain analysis was conducted for the single body and multibody respectively, with various loading conditions. The multibody analysis investigated hydrodynamic interaction and gap resonance. A comparison analysis is carried out to calibrate the numerical models with the experimental results.
It is shown that the time series of vessel motion bring concern on low-frequency motion in the collinear environment, and the large relative low frequency motion of vessels can be detrimental to the hawser lines. The comparison analysis shows that the direction of environment loads plays an obvious role in the accuracy of numerical analysis results. It is also indicated that decrease in the gap between vessels can lead to an increased hydrodynamic interaction amplitude. Consequently, the researcher could effectively analyse the behaviour of vessels in a variable environment heading for different loading condition to evaluate load on the connection system thus to aid the designers and operators.

Future fuels for commercial shipping
J. Buckingham, BMT, UK

By 2050, each ship will need to emit GHG at 25% the 2008 reference to meet the requirement to halve GHG emissions from shipping by 2050, and if shipping doubles by then. The required 75% reduction cannot be achieved through the use of energy saving technologies alone, but they do have a role to play in reducing the 40% reduction in energy intensity to meet putative IMO 2030 targets.
Worldwide speed limits policed by AIS-type technology also cannot make the meaningful saving, even if slower ships speeds greatly increase the potential benefits from wind propulsion.
Alternative zero-carbon fuel will be used to provide a large part of the solution to meet the 2050 target. This paper examines individual low-carbon sourced fuels such as methanol, ammonia, biofuels and others. The paper explores their production and supply chain both now and speculates how they may change in future years to address the likely bunker demands. This examination will take place in the context of shipping in the world's energy consuming sector and the way in which it may become one of the largest global consumers of liquid fuel as other sectors case to use it.
A possible future trajectory in low-carbon infrastructure will include example case studies to indicate how the future energy mix may affect the production of shipping fuels.
The paper draws together and analyses published material from a wide range of sources and seeks to create a context of how future energy for shipping bunkers will evolve.

Practical lessons learned from the use of LNG over the past decade
G. Plevrakis, ABS, Greece

Given the IMO initial greenhouse gas strategy including targets established for 2030 and 2050, there is increased focus on the fuels being used in the marine sector. LNG, which can be considered to have a carbon intensity reduction from traditional fuels in the region of 20%, has been identified in many studies as a potential transition fuel, to serve as a bridge from today until future application. With LNG having been used in the industry for many years there is good practical experience which has been obtained. This presentation will address the practical lessons learned from the use of LNG over the past decade.

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