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CHOSEN PROBLEMS OF TRANSPORT AND VESSEL'S FUELLING BY LIQUEFIED NATURAL GAS

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Abstract

It was presented the possibilities and ways of methane transport by sea. They are still searched new better possibilities of methane transport especially when the gas mining is at the sea. The advantages of using methane as marine fuel are discussed because it seems to be ecological and cheaper one. The lack of LNG bunkering network for vessels is the biggest problem to share methane as a marine fuel. Only a few ports inside the Baltic Sea area give such possibility. Of course, the network is under construction but the development goes too slowly to fulfil the International Maritime Organization (IMO) requirements on 2020 year. A challenge is to prevent failure during cargo operations, loading hose failure, pipe rupture, manifold leak, tank overflowing, or rupture etc. The risk of failure is increased due to very low temperature of liquid methane and the quick temperature change of all elements of cargo system during operations. The aim of the work was to show the indicated problems of vessel's fuelling by LNG. It was discussed the methane slip during cargo operations and fuelling. The misfires during burning processes into the engines are the biggest problem due to very narrow window of methane self-ignition. It happens the misfiring or knocking cycles. It disturbs the correct work of the engine, resulting in quick engine malfunction or damage.

Keywords: *natural gas, LNG fuelled vessel, dual fuel engine, LNG, boil-off gas*

1. Introduction

Natural gas (NG) as an energetic medium has time for prosperity. Due to necessity of transport by sea, the possibilities are as follows:
- as liquefied natural gas (LNG),
- as compressed natural gas (CNG),
- as methane hydrates (MH).

Liquefied natural gas (LNG) is transported by sea by specialized vessels (LNG gas tankers) which are ready to carry cargo in cryogenic tanks in temperature about -161.5°C and a little over ambient pressure [1, 8, 10, 12]. Due to the boil-off, the LNG vapour is used as a fuel in dual-fuel diesel engines and boilers. The LNG is more and more used as marine fuel for other vessels. Based on the lower heating value the combustion of methane causes about 25% less CO_2 compared to diesel fuel (methane has higher LHV and smaller carbon content) [9-11, 27].

Compressed natural gas (CNG) is transported in pressurized tanks in gas state (because the critical temperature of methane is -82.56°C) [12]:
- at ambient temperature and 22-30 MPa of pressure,
- at about 0°C and 14-16 MPa of pressure,
- at -29°C and 12.7 MPa of pressure.

There is no problem with gas leakage and slip to the atmosphere. The cargo tanks are hermetic until the gas pressure inside the tanks is below the relief valve setting (the pressure of the gas in closed tanks depends only on its temperature).

The next method for methane transport is in form of palletisation the methane hydrates (MH) deposits [12, 20, 21, 26].

The required parameters of transport the pellets of MH are rather simple for fulfilment. It needs the temperature of about -20°C (248-255 K) (see Fig. 1) at ambient pressure.

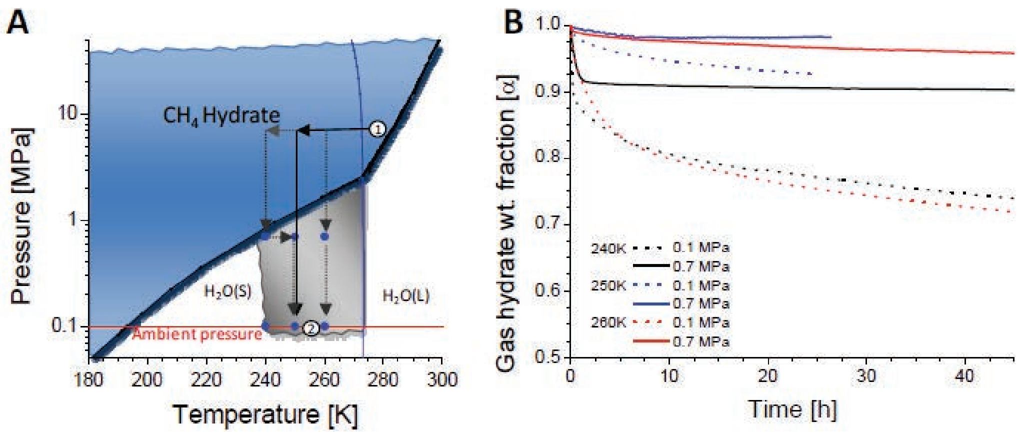

Fig. 1. A – The needed temperature for methane hydrates transport at ambient pressure; B – The needed time for palletisation process in terms of pressure [21]

The new one natural gas hydrate (NGH) formation and palletisation is still during research but there are some concepts how to do it and how to transport the pellets. It needs a lot of fresh water besides methane in gas state. It is after the process of methane hydrates formation under pressurization (again to that state) and dewatering (the excess of water) through palletisation process and cooling to about -20°C (253 K) with decompression to storage. This method is the safest for transport and storage [26]. How safe is methane ice it may be seen in Fig. 2.

The regasification of methane from pellets of NGH and compression to about a 10 MPa (100 bar) may be done on a vessel or onshore facilities. If we do it on a vessel, we will unload about 110 kg of methane gas from each 1 m^3 of cargo and will leave on-board about 0.8 m^3 of water to once more use.

Fig. 2. Methane hydrates: as an ice and burning ice [20]

2. Methane slip during transport

2.1. The reasons of methane slip

Escaping methane leakage from any system or equipment is called slip. It goes from an extracting well, during cleaning and liquefaction processes, during transport and re-loading processes, any leakages from cargo systems, vessel bunkering operations, during engine misfire, emergency situations during methane transport, etc. [6, 7, 17, 18]. It means that we always have problems with hermetisation during methane operations.

2.2. Reasons of reducing necessity the methane slip

There are many reasons for reducing the methane slip [13-16, 22]:

– gaseous methane goes to the atmosphere increasing the greenhouse effect;
– gaseous methane is a contaminant gas in the atmosphere and into the sea and oceans,
– it wastes a lot of ecological fuel and in the end – energy,
– it makes dangerous situations due to the mixtures of air and methane are flammable and explosive (risk of fire or explosion),
– using methane as a fuel decreasing the carbon dioxide emission to the atmosphere but after taking into consideration involved the methane slip the accumulative effect decreased the ecological profit and may be greater than used liquid fuels (liquid hydrocarbons) or coal depending on the quantity of methane slip
– and others.

2.3. Problems of vessel fuelling by the methane

There are about 500 vessels fuelled LNG in operation in 2017 (on January 2014 was 387) (the total number of vessels over 500 GT is about 100 thousand in the world). The number of such vessels will be increased especially when they sail on Emission Control Areas (ECAs) like Baltic Sea area. The existing and possible future ECAs are presented in Fig. 3.

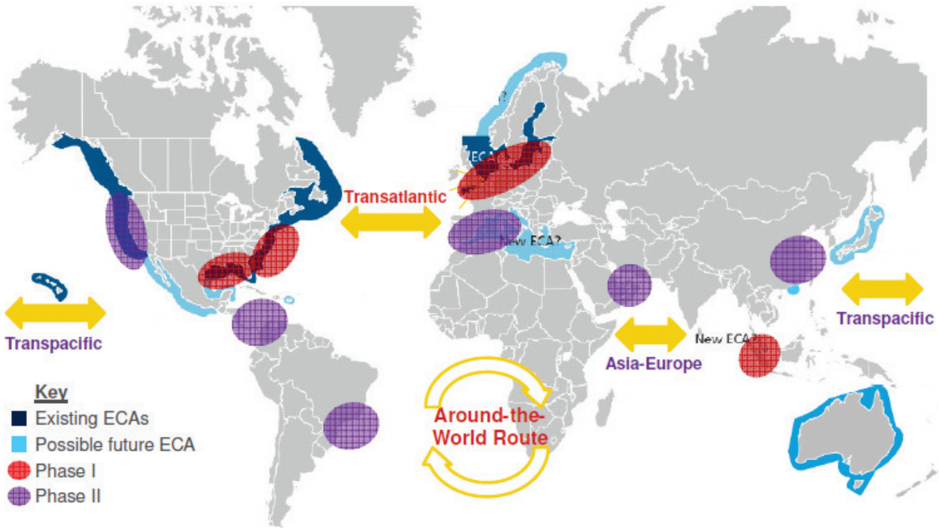

Fig. 3. Existing and possible future emission control areas (ECAs) [16]

The lack of LNG bunkering network for vessels is the biggest problem to share methane as a marine fuel. Only a few ports inside the Baltic Sea area give such possibility. Of course, the network is under construction but the development goes too slowly to fulfil the International Maritime Organization (IMO) requirements on 2020 year. The next challenges of LNG bunkering are as follows [2-5, 25]:

– the equivalent energy LNG to diesel oils needs bigger volume of fuel tanks – about 1.8 times but taking into account the necessity of LNG fuel tanks thermic insulation it increases to 2.1-2.3 times;
– bigger volume of fuel tanks decreases the accessible volume for cargo;
– there is a need of LNG standard as a marine fuel, the quantity of nitrogen in LNG is the most important one;
– engine manufacturers use Methane Number where the gas industry uses Wobb Index and High Heat Value or Low Heat Value (HHV/LHV);

- the price of LNG is independent to diesel and heavy fuels, strongly depends on the bunkering area. The price of equivalent energy in fuels gives the advantage to LNG nowadays but it needs long term commitments between vessel operators and bunkering companies, minimum take-off (scale of LNG bunkering), maybe oil to LNG indexed price formulas;
- there are no LNG terminal business models. It is needed the LNG stores, new operations and customers to handle, smaller vessels interfering with current services, the LNG business is not adapted to small scale etc.;
- on a start-up phase – commitment for ship operators to ensure LNG availability for small volumes, on the other hand the necessity of vessel route change or to pass over the ports without the possibility of LNG bunkering;
- demand for LNG bunker will remain low for some time. The forecasts are as follows: from 11 million tons per annum (Mtpa) in 2020 – it should be about 3% of LNG market and about 5% of overall marine fuel market to 33 Mtpa in 2030 – it should be about 5% of LNG market and about 10% of overall marine fuel market;
- the port procedures for LNG bunkering. There is no coordination among ports in LNG bunkering regulations. The differences will disturb to prepare the bunkering procedures for vessels.

3. Ways of methane slip limitation

3.1. Ways of methane slip limitation during cargo operations

The transport of methane by sea during normal operation causes very small leakage to the atmosphere. Transport system was proper prepared on vessels [7-9]. During LNG, carrying the boil-off gas (BOG) is reliquefied again or used as a fuel in DF engines and boilers [10, 23, 24].

A little bigger problem makes cargo operations between terminal LNG to vessel (gas tanker), vessel to LNG terminal, ship to ship or cistern to ship is showing in Fig. 4 [25, 28]. The prepared procedures of LNG reloading or bunkering decreased the risk of spillage. The connections pipelines after trans-shipment should be purged by nitrogen after that the pipes disconnection is possible. During LNG, operation when the liquid gas goes in one direction the methane vapour goes other pipe back to that tank to maintain a little overpressure into the tank and prevent to form under pressure inside and air suction from atmosphere through opened vacuum valves. The unsolved properly procedure and operation possibility is the loading of gas tanker. If any problem occurs with the vapour sending back to the terminal the reliquefaction system capacity is too small so the pressure inside membrane tank system (which is designed for a maximum of 700 mbarg) increases and the pressure or safety relief valves may stay opened (the gas releases directly to the atmosphere). If the pressure reaches the 600 mbarg in cargo tank the excess boil-off gas will be directed to the boiler (as a gas combusting unit) for incineration.

To prevent a failure during cargo operations, loading hose failure, pipe rupture, manifold leak, tank overflowing, or rupture etc. is a challenge [5]. The risk of failure is increased due to very low temperature of liquid methane and the quick temperature change of all elements of cargo system during operations. The potential effects of LNG hazards are as the following:
- cryogenic exposure,
- asphyxiation,
- fire and explosion.

3.2. Ways of methane slip limitation during operations on LNG

DF engines may work on diesel fuels and natural gas. The window of self-ignition the methane-air mixture is very narrow [1]. It happens the misfiring or knocking cycles. It disturbs the correct work of the engine, resulting in quick engine malfunction or damage. If the misfire does not occur or occur very rarely the methane slip may be low below 1%. In the Fig. 5 it is shown the cross-section of fuel delivering system to dual fuel four-stroke engine made by Wartsila.

During maintenance of DF engines, it should be done according to the engine manual [3, 15, 17, 19] to avoid possible methane leakages or to minimise the volume of purged pipelines.

Fig. 4. Mv. Ostfriesland bunkering from LNG cistern [4]

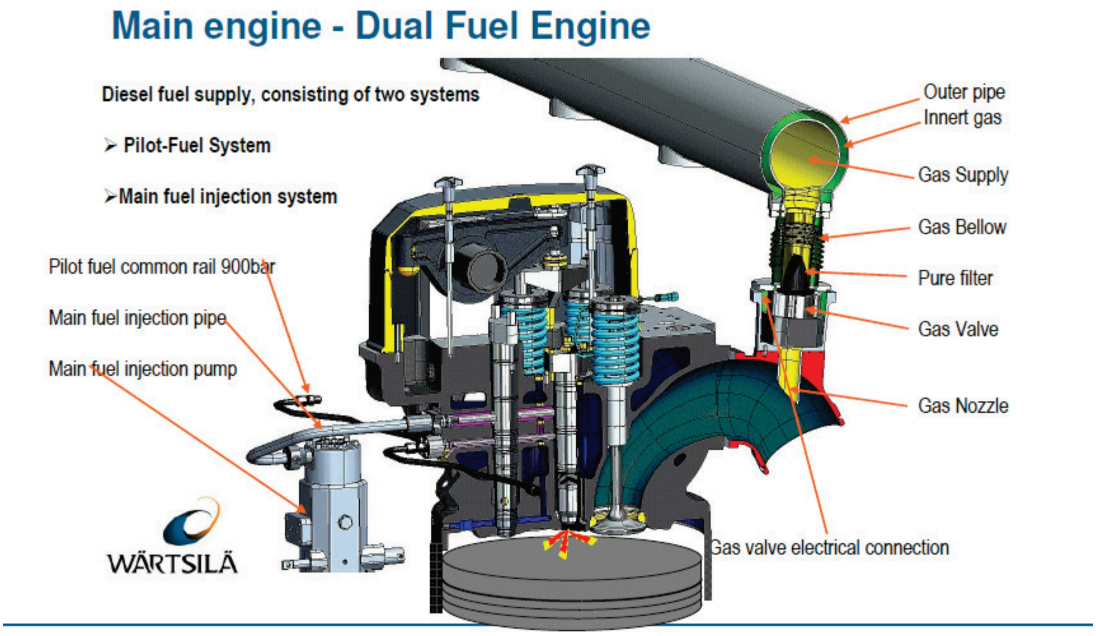

Fig. 5. Cross-section of the upper part of dual fuel four-stroke diesel engine [15]

6. Final remarks

Natural gas seems to be a good solution as an ecological marine fuel especially on ECA areas. Many problems of preparing diesel engine on LNG fuel were solved. It was obtained experience in operation on vessels. The next decisions are easier to undertake.

The most important challenge for sharing LNG as marine fuel is the limitation of methane slip to keep the ecological advantage.

It is possible quick sharing of LNG as fuel on vessels.

The limitations of methane slip are a challenge to overcome.

Sea transport may be ecological and friendlier for environment.

The future price of LNG as fuel is unknown. This is very important to shipping especially in comparison to other marine fuels (mainly to HFO and MDO) (the fuel cost makes about 70-90% of all vessel operation costs). LNG has the potential to be economical competitive to fuel oils.

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