The prospects for the use of liquefied gas in maritime transport

Romanoz Topuria[1], Mikheil Lezhava[2], Zaza Shubladze[2], Jemal Sharadze[2], Akaki Katsadze[2]

Akaki Tsereteli State University, 59 Tamar Mepe str,Kutaisi 6400, Georgia[1]
Batumi State Maritime Akaademy, Rustaveli Av. 53, Batumi 6010, Georgia[2]
Romtop54@gmail.com, m.lejava@bsma.edu.ge, z.zhubladze@bsma.edu.ge,
j.sharadze@bsma.edu.ge, mr.katsadze@yahoo.com,

Abstract. *If a fuel mixture consisting of a liquefied gas fuel is prepared in the water transport diesel engines, i.e. the gas-diesel process occurs, where methanol is used as an explosive fuel, resulting in the reduction of the self-ignition delay period and fuel combustion duration, the limits of the working mixture combustion are expanded (hybrid combustion), and the mixture formation process is improved, resulting in an increase in the combustion speed, i.e., the complete combustion of the fuel mixture occurs during the active combustion period, and the cycle in the engine is closer to the Otto cycle, which improves the environmental and efficient indicators of diesel engine compared to the gas-diesel engine, where the diesel fuel is used as an explosive fuel.*

Key words: *gaseous fuel; liquefied gas; diesel engine; methanol; explosive fuel, dosing.*

1. Introduction

One hundred years ago, transportation switched from a coal fuel to the petroleum pitch. Another hundred years later, the transition to a new fuel source is increasing, but this time - to gas.

According to stricter international and environmental standards, LNG (liquefied natural gas) is considered to a fuel of the future. According to experts, in the near future it is expected that LNG will be the main fuel in llarge-scale transportation. According to DNV, LNG may be the best option for many ships. The high prices of diesel fuel have led to the development of new technologies for the cost-efficient and environmentally friendly fuels such as liquefied natural gas. LPG is a potential winner in terms of environmental friendliness, safety, reliability and efficiency. Compared to oil, liquefied natural gas has become an important fuel with a significant impact on a global energy. Thanks to its powerful properties, liquefied natural gas is considered the only alternative fuel with a future. Studies have shown that use of liquefied natural gas (LNG) as a fuel has significantly reduced emissions of toxic sulfur or SOx, as well as the emissions of carbon dioxide (CO2) and nitrogen oxides or NOx. The LNG-powered engines can emit almost zero sulfur oxide, which is relevant when the 2015 ECA or ECA regulations come into force. Due to the low carbon content in LNG, harmful carbon dioxide emissions are reduced by almost 25 percent. As is known, the piston internal combustion engines in the modern period are the most economical of all other heat engines, which leads to their wide use in all fields. An important disadvantage of the piston internal combustion engines is that most of them run on liquid fuels of petroleum origin. Prospects for their further development and use directly depend on the complex changes in gaseous fuels (the use of alternative fuels).

2.Preconditions and means for resolving the problem

When ships run on engine powered by non-traditional diesel fuel, a number of difficulties arise related to fuel supply to cylinders, improving the mixture formation process, ensuring the ignition process in the combustion chamber, and the peculiarities of the combustion processes in accordance with the required characteristics. It should also be taken into account the ratio governing of the load carried out in the diesel engine, where the air excess ratio α depending on the load varies over a wide range $\alpha = 5$ and over, at low engine power and in idling conditions, and α=1.35–1.25 at full engine load. The range of admissible change of α depends significantly on the properties of the fuel used. Therefore, converting a diesel engine to run on a gaseous fuel provides a reduction in toxicity and smokiness in exhaust gases, as well as lowers fuel costs. It should be noted that the transport diesel engines run, typically, on compressed natural, as well as liquid natural fuel. When using liquefied gas, fuel costs increase significantly compared to compressed natural gas. Instead, when using the latter, it is possible to fully compensate for the loss of power. So, great importance is attached to the use of liquefied natural gas in the internal combustion engines of water transport. Hydrogen, also belonging to the series of liquid fuels, is the most environmentally friendly fuel in nature with an unlimited supply. It is present in 90% of the components existing in the environment and in more than a third of the components on the earth's surface. One of the disadvantages of using hydrogen as a fuel for an internal combustion engine is the high energy required for its compression and the very low specific energy intensity. There are also problems with its storage, especially in the cryogenic tanks, but the main problem is the high cost of its extraction. It is more promising to use hydrogen in a vehicle as fuel cells, especially using proton exchange membranes. The first cars with fuel cells have already been demonstrated by the companies such as: Toyota, Honda, Volkswagen, BMW, Nissan, Hyundai, but the establishment of their industrial production takes time.

The automotive diesel engines are converted by a gas diesel cycle, as well as with spark ignition working on a natural fuel. It is technically easy to work with the converted gas-diesel cycle, in addition, it retains the possibility to run on a standard diesel fuel, that is, only on a diesel fuel. In the gas-diesel cycle engines, the ratio governing of load is also used. which ensures that the formation of a highly enriched mixture is avoided, which is associated with a significant increase of C_nH_m in the exhaust, and therefore the formation of a rich mixture leads to the reduction of fuel efficiency [1].

One of the most promising operation processes of the transport diesel engine is a gas-diesel cycle operation. The gas-diesel process has potential advantages over the forced-ignition process. It is known that the highest efficiency of the diesel engine is $\eta_{e=}$0,42-0,44.. In the implementation of the gas-diesel cycle, both external and internal mixings are used. Due to simple design, the external mixing has gained widespread use in transport engines. In this case, the mixer is made in the form of a nozzle installed in the air path. Liquefied gas is supplied to the mixer at a pressure close to atmospheric, in order to exclude gas leakage into the environment and prevent air from entering the gas tube. The good properties of liquefied natural gas fuel for mixing result in the possibility of wide application of internal mixing. Especially the main difficulty is the high self-ignition temperature of natural gas (650-700 ^{0}C), which significantly exceeds the self-ignition temperature of a liquid diesel fuel (320-380 ^{0}C). In terms of the closest approach to this process, we can consider injection of liquid gas fuel individually into the cylinder at the beginning of filling in front of the inlet valve (external mixing), and at the end of the compression process, igniting it with a small dose of diesel fuel or methanol, the amount of which does not exceed 15-20%, which enables us to use the serial diesel engine without changing the compression ratio [2].

When using the gas-diesel cycle, the engine performance is improved by 10-15% compared to standard diesel engine. In order to maintain the power indicator, during the implementation of the gas-diesel process, it is necessary to provide governing ratio of the working mixture in such a way that, accordingly, at any load mode of the engine, such a value of α is selected that ensures power compensation. This would be achieved based on the conditions that we assume that the heat released by combustion at each load mode of a standard engine would be equal to the amount of heat released by combustion of a gas-diesel cycle engine at the same modes. Therefore, the following equality will hold: $Q_{di}=Q_{gi}$ or $H_{di}=H_{gi}$

For a standard diesel engine (α >1), the heat of the working mixture combustion is

$$H_{di} = \frac{H_{ud}}{1+a_{di}l_{do}}$$

while for a gasi-diesel engine (α >1)

$$H_{gi} = \frac{H_{ug}}{1+a_{gi}l_{go}} + \frac{H_{ud}}{1+a_{di}^{2}l_{do}}$$

where

- H_{di} and H_{gi} are the amounts of heat released by the complete combustion of the working mixture of a standard diesel and gas-diesel engines loads, respectively.
- H_{ud} and H_{ug} are the lowest heating capacity of diesel and gas fuels, respectively.
- α_{di} and α_{gi} - values of the air excess ratio according to diesel and gas diesel engines loads.
- l_{do} and l_{go}, respectively, the amounts of air theoretically required for the complete combustion for diesel and gaseous fuel.
- a_{gi} and a'_{di} - values of the air excess ratio caused by the amount of gaseous and explosive fuels in a gas diesel engine.

The influence of the explosive fuel dosage and injection timing angle on a gas-diesel engine performance is also important. .

3. Conclusion

In order to assess the influence of the explosive fuel dosage, we introduce the notion of dynamic factor, which shows how much explosive fuel is required in the working mixture for each mode, and it is expressed as follows

$$K = G_{di}/G_{gi}$$

where G_{di} – the amount of explosive fuel, G_{gi} – the amount of gaseous fuel.

The analysis of the main indicators of the above alternative fuels and the characteristics of the operation of water transport engines shows what a decisive factor is the use of liquefied gases, which determines the prospects for the use of fuel in the piston internal combustion engines for marine purposes, instead of liquid petroleumderived fuels.

4. References

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