Prospects for utilizng natural gas as fuel in small-capacity maritime transport assets

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Abstract: *Normally, maritime, air and surface transport assets powered by internal combustion engines are the major sources of chemical, biological and physical pollution of the environment. In the meantime, oil shortage and world oil prices are rising every year, which raises questions on the use of alternative energy sources that are not fossil fuels.*
At the present time, natural gas as one of the types of fuel is widely and successfully used in surface transport owing to the availability of their sufficient reserves and good thermophysical characteristics. The article deals with the prospects for natural gas production in the sea and the possibilities of utilizing its energy source in small-capacity marine and river transport equipment in both diesel-cycle and directly converted to natural gas-powered diesel engines.
KEY WORDS: *DIESEL ENJINE, HIDROGEN SYLFIDE, METHANE, MEMBRANE TECHNOLOGY.*

1. Introduction

At the present time, the energy-environmental parameters of the internal combustion engines of vehicles depend to a great extent on fuel type used, because the maritime, air and surface transport assets that are the consumers of oil obtained from oil processing are the major sources of chemical, biological and physical pollution of the environment. In the meantime, oil shortage and world oil prices are rising every year, which raises questions on the use of alternative energy sources that are not fuels obtained from oil processing.

An important direction for the development of maritime transport is increasing fuel efficiency, energy efficiency and environmental safety of its energy equipment. Typically, these parameters in internal combustion engines are determined by the organization of the work process and the type and composition of fuel used. Therefore, it is important to convert the energy equipment of small-capacity naval vessels to the gas-diesel cycle or directly to the natural gas cycle.

1. Preconditions and means for resolving the problem

Depending on primary raw materials, alternative fuels are of various types, of which at the present stage natural gas, as one of the forms of fuel, is widely and successfully used in road transport, which is due to its reserves and good thermophysical characteristics. In particular, the use of this type of fuel has the following advantages:

- High-octane rating allows to increase the degree of compression, which increases the capacity and saves fuel;
- Toxicity and acoustic performance of combustion products are reduced, which significantly improves the state of the environment;
- It is possible to use the principle of quality regulation, which allows us to increase fuel efficiency;

The significant amount of methane in the deep waters of the Black Sea leads to an increase in the percentage of its use as an alternative energy source in transport power equipment, since natural gas (CHn) is more environmentally friendly than traditional fuel, because carbon mass fraction is 74 ÷ 75%, while the same indicator for gasoline is 85,6% and for diesel fuel - 86%, which leads to a decrease in the CO and CO_2 concentrations in combustion products.

The question arises: how can methane be obtained from the deep-sea waters? To solve this problem, we used the method of membrane separation of the gaseous mixtures based on the use of porous, non-porous and composite selective-penetrating membranes. The advantages of the membrane separation processes are continuity, low energy consumption, process control, and compatibility with other separation processes. At present, importance among the various methods of cleaning the gaseous systems, the adsorption methods are becoming increasingly important, as they provide practically complete capture of waste and cleaning of several components simultaneously.

- High-octane rating ensures efficient and fault-free performance of gas diesel at high compression degree. It should be noted that in this case smoke opacity is reduced by 2-3 times (which is typical for diesels) and almost no soot particles are formed;
- It is possible to convert diesel directly to compressed natural gas. From an environmental perspective, such an engine is more efficient than the base diesel and gas diesel variants, because no solid particles are produced in the form of soot and the smoke opacity is reduced to zero;
- The degree of wear of the piston cylinder parts decreases and the service life of the oil increases.

Thus, natural gas as an energy source can be successfully used in small-capacity maritime and river transport, as well as in gas-diesel cycle power equipment and diesel converted directly to natural gas.

The question is: why have we brought this problem to the forefront and conducted studies?

Georgia is known to be a country with limited reserves of fuel and energy resources, but the energy potential of the Black Sea can be widely used in transport energy equipment and primarily in low-capacity maritime transport.

Hydrogen sulfide and methane existing in the deep waters of the Black Sea attracted the attention of scientists immediately after their discovery as a virtually inexhaustible raw material for the production of alternative energy and with a view to addressing the lack of fuel and energy raw materials.

One of the main problems in determining the environmental status of the Black Sea today is the presence of methane and hydrogen sulfide in the lower water layers, the content of which is increasing every year due to pollution. Studies conducted at the end of the last century revealed that the main source of methane dissolved in water (75%) is the shallow (700 m) sedimentary volcanic layers, where the existing thermobaric conditions are favorable for the formation of solid methane carbohydrates, which decompose with an increase in sea-water with emission of large quantities of methane.

To extract a mixture of hydrogen sulfide, methane and other components from the deep waters of the Black Sea, a technological scheme of the device was developed, which is designed to ensure the processes of separation the gaseous mixtures extracted from the depths of the sea, as well as their decomposition through the use of the membrane technologies and sorption methods. In particular, in our case, the membrane-zeolite module for methane adsorption was studied.

The study revealed that methane practically does not adsorb on undried zeolites, but the study of methane adsorption was carried out on locally produced pre-dried natural clinoptilolite and synthetic zeolites of Khekordzula (CaA, cationite KY-2-8) modified with Ni. The experiment studied the adsorption rate of CH_4 on zeolites with

dependence on the delay time (Fig. 1).

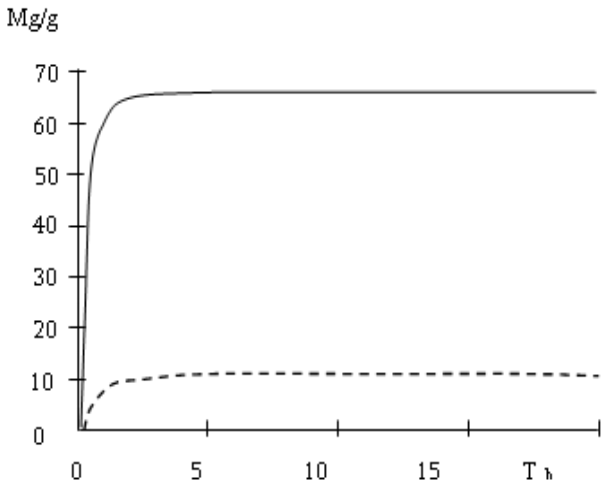

Fig. 1. *The adsorption rate of CH_4 on zeolites.*
---------- CaA
- - - - modified with Ni.

The study revealed that synthetic zeolite CaA is characterized by high adsorption capacity towards methane. Productivity of Khekordzula's zeolite modified with Ni is much smaller, while methane KY-2-8 is not adsorbed at all on cationite, although the rate of adsorption in both cases is almost not dependent on the delay time, that is, natural zeolites and synthetic CaA can be used as highly-efficient adsorbents towards CH_4 in the deep waters of the Black Sea.

In the case of gas diesel, it differs from the base engine in terms of both the mixture production and mixture ignition. In particular, in this type of engine, the mixture of air and fuel gas is compressed, the self-ignition of which at the end of the compression is not carried out due to the high self-heating temperature of natural gas (680-750 ^{0}C) and the so-called "ignition dose" of diesel fuel (the diesel fuel self-ignition temperature – 320^0 – 380 ^{0}C) is used to generate a combustion source at the end of the compression. In modern engines, the value of the ignition dose is 15-20% of fuel cyclic supply of the base diesel engine and depends on the load mode. In this type of engines, the fuel mixture is prepared and delivered to the cylinder in the fuel supply system of gas-powered vehicle, while the ignition dose of diesel fuel is injected at the end of the compression from the base diesel nozzle. In our case, the study covers a four-stroke two-cylinder diesel engine (9.5 / 11) with combustion chamber in the piston. The data of the pilot studies for both base diesel and gas-diesel cycle engines in nominal conditions are given in Table 1, while Figure 1 illustrates the external service indicators.

Table 1. *Characteristics of the diesel and gas-diesel engines operating cycle*

Characteristics	Type of engine	
	Gas-diesel	Diesel
Effective power, kW	9,78	10,1
Mean effective pressure, MPa	0,486	0,502
Effective torque, n.m.	58,6	60,2
Diesel fuel consumption per hour, kg/h	0,651	2,322
Gaseous fuel consumption per hour, kg/h	0,409	-
Diesel fuel effective consumption, g/kWh	0,74	225
Gaseous fuel effective consumption, g/kWh	46,5	-

2. Conclusion

Studies have demonstrated that the effective power and torque of the gas-diesel and its base diesel engines are practically are substantially the same. However, in the case of diesel engine, the cost-effectiveness of diesel fuel is reduced by almost 3 times. It should be also noted that the gasoline-diesel engine has better environmental performance than the base engine. In particular, smokiness of combustion products decreases by 2-3 times and the noise level - by 3-8 dB. At the same time the reduction in carbon oxides and hydrocarbons is observed in the combustion products, but nitrogen oxides are increased. Studies in this direction are ongoing on the engine operating in load mode. Work is underway to convert the diesel engine directly to natural compressed gas. This type of engine is an engine operating by carburation and forced ignition that is more economically and environmentally efficient than the base diesel and gas-diesel engines.

The next stage of the research involves exploring the possibilities of using methane as an energy source in the low-power gas-diesel-cycle engines, as well as in the diesel engines directly converted to natural gas.

Based on the results of the conducted studies, we can implement in practice the conversion of the small-power diesel engines to natural gas, which will allow us to successfully use methane extracted from the Black Sea basin as fuel in small cargo ships. This will contribute to the creation of small-capacity ports within the country's territorial sea and further intensification of small and medium-sized businesses.

3. References

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