Научные труды Дальрыбвтуза. 2023. Т. 66, № 4. С. 173–177.
Scientific Journal of the Far Eastern State Technical Fisheries University. 2023. Vol. 66, no 4. P. 173–177.

MARINE POWER PLANTS AND THEIR ELEMENTS (MAIN AND AUXILIARY)

Original article

DOI: https://doi.org/10.48612/dalrybvtuz/2023-66-21

Hybrid power plant for a fishing vessel

Anatolii N. Sobolenko[1], Vladimir V. Manitsin[2]

[1] Marine State University named after Adm. G.I. Nevelsky, Vladivostok, Russia

[2] Far Eastern State Technical Fisheries University, Vladivostok, Russia

[1] sobolenko_a@mail.ru

[2] manitsynv@mail.ru

Abstract. Hybrid power plants of ships with main power units running on gas engine fuel with a propeller driven by an electric motor are considered. A hybrid power plant for a small fishing vessel is proposed, which includes two main diesel generators, current converters, a battery pack, and DC rowing electric motors. The main diesel engines are dual-fuel - they run on both liquid fuel and natural gas.

Keywords: ship power plant, natural gas, hybrid

For citation: Sobolenko A.N., Manitsin V.V. Hybrid power plant for a fishing vessel. *Scientific Journal of the Far Eastern State Technical Fisheries University*. 2023; 66(4):173–177.

СУДОВЫЕ ЭНЕРГЕТИЧЕСКИЕ УСТАНОВКИ И ИХ ЭЛЕМЕНТЫ
(ГЛАВНЫЕ И ВСПОМОГАТЕЛЬНЫЕ)

Научная статья

УДК 621.182.3:629.2-843.9

DOI: https://doi.org/10.48612/dalrybvtuz/2023-66-21

Гибридная силовая установка для рыболовного судна

Анатолий Николаевич Соболенко[1], Владимир Викторович Маницын[2]

[1] Морской государственный университет им. адм. Г.И. Невельского, Владивосток, Россия

[2] Дальневосточный государственный технический рыбохозяйственный университет, Владивосток, Россия

sobolenko_a@mail.ru

manitsynv@mail.ru

Аннотация. Рассмотрены гибридные энергетические установки судов с главными энергоагрегатами, работающими на газомоторном топливе с приводом гребного винта от электромотора. Предложена гибридная энергетическая установка для малого рыболовного судна, включающая в себя два главных дизель-генератора, преобразователи тока, блок аккумуляторов, гребные электромоторы постоянного тока. Главные дизели двухтопливные – работают как на жидком топливе, так и на природном газе.

***Ключевые слова*:** судовая энергетическая установка, природный газ, гибридная

Для цитирования: Соболенко А.Н., Маницын В.В. Гибридная силовая установка для рыболовного судна // Научные труды Дальрыбвтуза. 2023. Т. 66, № 4. С. 173–177.

When developing the fishing in the Arctic Ocean, great attention should be paid to the environmental safety of power plants. That's why, it is preferable to use fuel that does not produce pollutants into the environment, both into the atmosphere and bilge water. Such fuel according to our opinion is natural gas, which is not only environmentally cleaner than liquid fuel, but also many times cheaper than liquid fuel.

In this report it is proposed to consider the project of power plant of a fishing vessel.

Selecting the main engines for the propulsion plant it is necessary to take into account the operating range of modes of operation with such a calculation that their best efficiency was in the range of the highest power. Their size and weight are also taken into account, which is especially important for fishing vessels. In this regard, it is advisable to use medium- and high-speed diesel engines as main engines on these vessels.

For fishing vessels it is characteristic to operate for a long time in alternating modes. The power plant should operate on gas-motor fuel. We know that manufacturers of dual-fuel engines recommend switching to liquid diesel fuel at load less than 80 %. Gas motor fuel can be used only at loads above 80 %. For a fishing vessel this restriction is unacceptable. What is the solution?

The first way out is to use tractor-type engines, for which there are developed fuel supply systems for liquid fuel and gas, with a quick transition from one type of fuel to another. But what do we gain in this case? Our vessel in this case will operate mainly on diesel fuel and in rare cases on gas fuel.

The second way out is to switch to hybrid propulsion system. In this case the engine will work in the mode of constant load on the battery, and the energy consumption for the ship's movement will be from the battery to the electric motors.

A number of companies are working in this direction when designing and manufacturing fishing vessels of the future.

The Norwegian company Liafjord is investing in a new vessel. So far, the first sketches of the new Libas series have been presented. Two hybrids are already under construction and a third is on its way.

Libas will be the world's first gas and battery powered fishing vessel with a 350 cubic meter liquefied natural gas (LNG) tank on board, according to Salt Ship Design magazine.

An ice-class longships with a hybrid power unit (HPU) is being built in the Norwegian city of Olesund. Thanks to the use of hybrid technology, the vessel will save several dozens of tons of diesel fuel per year. This leads to a powerful reduction in greenhouse gas emissions. The battery, which will be on board the vessel operating in the Atlantic, will primarily supply the main engine so that it can run at more favorable speeds. In addition to the battery pack, the vessel will have a heat recovery system.

Reiarlaget Lie Group in Michigan (USA) has recently awarded a contract for a hybrid-powered vessel using liquefied natural gas and electricity.

The use of LNG with electricity enables a major step towards reducing the climate impact of emissions. Emissions of NOx nitrogen oxides are reduced by 90 percent and emissions of CO_2 carbon dioxide, which creates the greenhouse effect, are reduced by 20 percent.

A hybrid-powered propulsion system includes one or more diesel generators, and a source or series of electrical energy sources, such as batteries.

For a light-tonnage vessel, the hybrid power plant has a weight limit, so the electrical power source must have the highest specific energy and at the same time its power must be sufficient for the peak loads on the shaft of the propulsion motor.

In terms of lowest price, lead-acid or iron-nickel batteries (NiM) should be used. NiM batteries have twice the energy density of the former and are more expensive but less expensive than Li-Ion. When using a hybrid diesel-battery system for recharging ABs, it is advisable to install solar cells on the ship as well.

Successful application of hybrid power units on land vehicles - cars such as Toyota Prius. Honda Civic, Lexus GS 450h, Toyota Alphard, Toyota Harrier and a number of others show the expediency of testing such units on the sea coastal passenger fleet operating with frequent maneuvering modes, which include light-tonnage vessels. Application of combined power plant consisting of several energy sources allows to reduce consumption of fuel and lubricants, to reduce harmful emissions into the atmosphere.

Hybrid power plants, as a rule, consist of a gasoline or diesel engine and a source or sources of alternative energy, which can be chemical or kinetic accumulators, fuel cells or ultra-high-capacity battery

For a light-tonnage vessel, a hybrid electric propulsion system has a weight limitation, so the source must have the highest specific energy and at the same time its power must be sufficient for peak loads on the shaft of the propulsion motor. Li-Ion (Li-Ion) and NiMH (NiMH) batteries are used in the vehicles mentioned. The energy density of the first type of batteries is 60-80 W·h/kg, the second - 100. An electric ship with a 500 kg battery can power a light-tonnage vessel for a day without recharging.

Even greater energy density has air-metallic mechanical rechargeable sources, energy characteristics of which are given in Table 1.

From the data given in the table it is clear that the air-aluminum source (VAIT) has the highest specific energy density.

Parameters of electrochemical batteries
Параметры электрохимических аккумуляторов

Electrochemical batteries	Voltage, kV	Specific energy, W·h/kg
Air-aluminum	1,2 ÷1,3	100 ÷ 500
Air-magnesium	1,4 ÷ 1,5	100 ÷ 500
Lithium-manganese	2,5 ÷ 2, 8	100 ÷ 500

VAIT is charged within several minutes, which are necessary for pouring electrolyte and/or replacing aluminum electrodes. The disadvantages of such sources are rather high internal resistance, low specific power, voltage instability during discharge, voltage dip at switching on. All these disadvantages are eliminated when using a combined current source (CCS) consisting of a VAIT and a battery.

Supercapacitors can also be used in conjunction with VAIT and any selected type of battery, which have the following advantages:

- durability (over 10 years) 100,000 charge/discharge cycles;
- very fast battery charging process - not more than an hour;
- relatively low self-discharge rate - up to 10% per month.

In this case, the first source will be used to charge the capacitor battery, and it, in turn, will supply the load. The disadvantage of these sources is high cost (up to 300 rubles per kilojoule of stored energy) and low energy density at the level of 10 ÷ 20 W·h/kg.

KIT consisting of VAIT and supercapacitor has two important advantages. Firstly, specific energy capacity of such source will be rather high (comparable with the same indicator of Li-Ion and Ag-Zn batteries), secondly, specific power will be higher than when using any type of AB (for supercapacitors this indicator is equal to 2000÷15 000 W/kg). Besides, such combination allows to get rid of disadvantages inherent in VAIT.

Supercapacitors can fulfill the role of conventional capacitors: improvement of power quality - compensation of current peaks in transient modes, generation of reactive power. In case of regeneration, braking energy (even of high power) can be used to recharge supercapacitors.

Lead-acid and iron-nickel accumulator batteries are one of the cheapest and widely spread power sources with energy density of about 30 W·h/kg The advantage of alkaline accumulators of TNJK type in comparison with lead accumulators is low dependence of capacity on discharge mode. Therefore, the power supply with such a battery will be greater than in case of application of other batteries with the same capacity. In comparison with acid alkaline batteries require less careful maintenance, are not subject to sulfation, have higher explosion and fire safety, greater mechanical strength, are not afraid of shocks, shaking, vibration, well withstand short circuits.

Thus, we can conclude the following. The use of hybrid power units on light-tonnage ships is possible and expedient. All of the considered current sources, except for the kinetic accumulator, work practically silently. A coastal navigation vessel with fuel cells and the necessary hydrogen reserve can have only this power source.

If we want to have lowest cost, lead-acid or iron-nickel ABs should be used. NiM batteries have twice the energy density of the former, and they cost more but are cheaper than Li-Ion. When using a hybrid diesel-battery system for recharging ABs, it is advisable to install solar cells on the vessel.

For the proposed project of the vessel it is possible to accept the main hybrid diesel-electric installation with two diesel generators with diesel engines 12GZhCh15/18 produced by JSC "Barnaultransmash", Barnaul with capacity of 330 kW each. The diesels are produced for operation on gas motor fuel [1]. The output power of each diesel generator will be 300 kW.

As a rowing motor we take a DC electric motor. To convert AC to DC, we accept special converters for installation.

The flexible scheme allows to summarize the energy produced by DG and VDG at the control room in order to increase the speed of the ship, or to replace VDG with the main diesel generator in order to save energy.

We accept to install nickel-iron alkaline batteries 36TNZhK-1000 according to GOST 22492-77 in quantity of 10 pieces connected in series. This allows to obtain an output voltage of about 400 V. Such batteries are produced for non-rail transportation. Specific energy of TNJK series batteries is 31÷36 W·h/kg, resource 7 000 h 10 batteries will weigh 660 kg and occupy a volume of 0.6 m^3.

Batteries are installed in a special room outside the engine room. The room is made of non-combustible materials. Entrance to the battery room should be through a vestibule.

The temperature of the battery room at the level of the batteries should not be lower than +15 °C. Heating and ventilation are carried out by a special caloriferous device located outside the battery room and supplying warm air into the ventilation duct.

Batteries should have aisles for maintenance with a width of not less than 1 m in case of double-sided arrangement of batteries and not less than 0.8 m in case of single-sided arrangement. The distance between walls and vessels should be not less than 150 mm.

As a rowing electric motor we take ultra-compact DC traction motors TED 18-300 with power of 330 kW each [2]. The mass of TED 18-300 is not more than 80 kg. It is a revision of the traction motor for the project of the fuel cell car "Lada ANTEL-2".

Structurally, the TED 18-300 consists of three parts: the housing, the ultra-light rotor, which is mounted on the shaft in bearing supports and the stator module, which is attached to the housing. Inside the stator module there are windings, magneto-wires and rotor position sensor. The windings

are directly liquid cooled with transformer oil. To limit the value of the power voltage, the windings of the 18-80 TED are six-phase.

Commercial firms in Russia have worked out the technology of conversion of automobile engines to natural gas. There are a lot of commercial offers to convert engines with the cost within 100 thousands rubles. Russian factories already produce dual-fuel diesel engines of small capacity quite suitable for installation on small ships. In this regard, the project of dual-fuel power plant for a tugboat seems to be very relevant.

References

1. [Electronic resource] URL: http:/www/rosavtodiesel.ru.
2. [Electronic resource] URL:http:/nild/narod/ru/gibrid_korabel.html.

Список источников

1. [Электронный ресурс] URL: http:/www/rosavtodiesel.ru.
2. [Электронный ресурс] URL:http:/nild/narod/ru/gibrid_korabel.html.

Information about the authors

A.N. Sobolenko – Doctor of Technical Sciences, Professor;
V.V. Manitsin – PhD in Technical Sciences, Associate Professor of the Department of Ship Power Plants.

Информация об авторах

А.Н. Соболенко – доктор технических наук, профессор кафедры судовых двигателей внутреннего сгорания;
В.В. Маницын – кандидат технических наук, доцент кафедры «Судовые энергетические установки».

The article was submitted 27.11.2023; approved after reviewing 28.11.2023; accepted for publication 30.11.2023.

Статья поступила в редакцию 27.11.2023; одобрена после рецензирования 28.11.2023; принята к публикации 30.11.2023.