Power control of the engine operating on the fixed pitch propeller

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As the main engine on transport ships, effective low-speed engines operating on a fixed-pitch propeller (FPP) with variable speed are most prevalent. The power of the main engine during its work on the propeller curve depends on the external operating conditions and the mode of operation of the propeller. Operational regulation of the power of the main engine during its operation at the FPP is performed by changing the rotational speed (figure 2). In this case, the power produced by the main engine is determined by the consumer of mechanical energy - the propeller screw. Fixed pitch propellers are characterized by high hydrodynamic performance in the design mode. When the operating conditions change, their efficiency decreases significantly (figure 1), which affects the power consumption of the main engine. The mutual arrangement of the propeller curves of the engine load (figure 2) is formed depending on the design features and the technical condition of the propeller and the hull, the mode of operation of the vessel, the sailing conditions (changes in draft, depth under the keel, weather conditions). This pattern forms the dependence of the parameters of thermal and mechanical tension of the engine on the operating conditions and significantly limits the operational envelope of diesel engine. In modern studies, insufficient attention is paid to the ability to change the power of the engine at a constant frequency of rotation of the FPP. Analysis of the scientific literature and patent developments showed a significant interest of researchers to the design of the propeller. However, most of the proposed designs have a permanent, unregulated effect on the main engine and cannot be used to control its power at a constant frequency of rotation of the FPP.

**Figure 1.** Screw propeller open water diagram: 1 - the coefficient of thrust \((K_1)\); 2 - moment coefficient \((K_2)\); 3 – efficiency \((\eta)\).

**Figure 2.** Propeller curves of the engine load: 1 - design condition; 2 - heavy condition; 3 - light condition.
It should be noted that to control the ambient flow in the adjacent area - aerodynamics, jetting of additional medium is successfully used in order to change the mode of operation of the blade devices. The installation of a slit nozzle on the fixed blades of the FPP (see figure 3) and the jet supply of additional water through it allows to realize the effect on the fluid flow interacting with the blades. The supply of additional water to the suction surface of the propeller blade in the vicinity of the inlet edge allows changing the flow parameters of the fluid flowing around the surface. This allows to change the nature of the interaction of the blade with water, depending on the parameters of the supplied water. Inkjet supply of additional fluid leads to a decrease in the heterogeneity of local speeds on the propeller blades and the flow of the blade. When this happens, the absolute increment of the flow velocity over the entire plane of the suction (sucking) surface of the blade. Additionally, a reduction in the influence of the incident flow, depending on the hull of the vessel, on the mode of operation of the propeller is achieved. There is a decrease in the effect of cavitation on the mode of operation of the propeller and an increase in the cavitation margin.

Due to this, it is possible to change the hydrodynamic parameters of the propeller (such as torque, power consumption, efficiency), regardless of the speed and operating conditions. By changing the power consumption and the hydrodynamic moment of resistance to rotation, the required thermal performance of the main engine without overload is ensured.

The use of jet impact has a positive effect on the dynamics of the propeller, which allows to improve its coefficients for open water diagram. Due to the targeted change in the parameters of the water supplied at a constant rotational speed, the power consumed by the propeller is regulated. Let us analyse the propeller load curves of the typical modes of operation of the main engine in changing sailing conditions. The optimal parameters of water supply to the propeller were found, at which an increase in the efficiency of the FPP allowed us to reduce the input (consumed) power by 10% at a constant speed of the vessel.

Figure 3. The arrangement of the slit nozzle on the propeller: $V_{\text{flow}}$ - is the free-stream velocity vector; $V_{\text{jet}}$ - the velocity vector of the additional jet action of the supplied water; 1 - hub; 2 - blade profile; 3 - slit nozzle; 4 – blade.
Figure 4 shows in logarithmic scales the mutual arrangement of the propeller load curves for optimal operating conditions of the main engine, and additional water supply to the FPP blades. Vessel operation “in ballast”, during transfer to the port of loading, under favourable weather conditions - line 3. When transitioning “in load” and favourable weather conditions - line 2, with deterioration of hydro meteorological factors - line 4. During operation of the vessel and towing resistance (due to fouling of the hull of the vessel) mode of operation of the vessel "in ballast", when the vessel is transferred to the port of loading, under favourable weather conditions - line 5. When the vessel is "loaded" and favourable weather conditions - line 1 (corresponds to with a nominal propeller curve with a reduced "sea margin"), with the deterioration of hydro meteorological factors - line 6.

When mounted on the propeller blades of the slit nozzles for supplying additional water, the design conditions of operation of the main propulsion plant are preserved. As a result, when the water supply to the slot nozzles is turned off, the propeller load curve of the main engine corresponds to the nominal one - line 1 (see figure 4). During the operation of the main propulsion plant of the vessel in the initial period of operation or in the ballast, due to the jet water supply, the engine is not overloaded by speed. In case of unfavourable changes in the external operating conditions, the increase in power consumption is compensated by the jet supply of additional water to the FPP blade.

Due to the use of jet impact of water on the propeller blades, such additional operating modes of the main engine can be obtained, such as:
- heavy running propeller curve under favourable weather conditions in the ballast (line 3’);
- light running propeller curve “in load” under adverse operating conditions (line 4’);
- light running propeller curve “in ballast” with significant fouling of the hull of the vessel and favourable weather conditions (line 5’);
- light running propeller curve “in load” with significant fouling of the hull of the vessel and adverse weather conditions (line 6’).

On the basis of the obtained results, it is of interest to further study the effect of controlling the power of the main engine, with a constant rotation frequency on the thermal and mechanical tension of the main engine, as well as the rationality of choosing the rated power of the main engine.