10.31653/smf50.2025.160-166

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USE OF NANOMATERIALS – A WAY TO INCREASE THE RESOURCE OF MARINE MECHANISMS

Formulation of the problem

Improving the reliability and durability of ship mechanisms is one of the main tasks of modern shipbuilding and fleet operation. A promising direction for solving this problem is the application of nanotechnologies [1] – a field of science and technology aimed at obtaining materials formed by elements with sizes in the range of 1-100 nanometers.

Analysis of current research.

The physical and chemical properties of nanoscale particles significantly differ from their corresponding macroscopic particles [2], which is related to size effects. It should be noted that the fraction of surface atoms in a spherical particle with a size of 10 nm is 30% [3], which determines its increased chemical activity. 1 g of a substance formed by such particles has a surface area of ~100 m^2. Excess surface energy leads to significant non-equilibrium of nanoparticles [4]. Therefore, nanoparticles provide materials made from them with an increase in hardness by 2-7 times, strength by 1.5-8 times, and fluidity by 2-3 times compared to traditional materials [5,6].

Setting the task.

This work examines the prospects of using nanomaterials from the companies "XADO" and "NanoVit" to effectively increase the lifespan of ship mechanisms by introducing them into lubricating materials.

Research material

Nano additives to Lubricants

The homogeneity and stability of the lubricating substance into which nanoparticles have been introduced determine its ability to work reliably. The settling velocity is an important parameter determining colloidal stability and can be calculated using Stokes' law:

$$v = \frac{2(\rho_н - \rho_p)gr^2}{g\mu}$$

where v - steady settling velocity, ρ_H - density of the nanoparticle, ρ_p - density of the liquid, g - acceleration due to gravity, r - radius of the nanoparticle, and μ - dynamic viscosity of the liquid.

Previously, micron-sized particles were used as additives to lubricants, for which achieving homogeneity was a difficult task. When using nanoparticles, the settling velocity decreases by 100-1000 times, which significantly improves the stability of nanoparticle dispersion.

"XADO" Nanomaterial

"XADO" is a Ukrainian company [7] founded in 1991 in Kharkiv, which is a manufacturer of revitalizant – a high-molecular lubricating material containing a very active carboxyl group (COOH), as well as a mixture of nanoscale oxides Al_2O_3, SiO_2, Fe_2O_3 and their hydrates/ The nanoparticles of this substance have a shape close to spherical. Introducing [8] revitalizant into lubricating materials leads to the formation of a protective coating on the metal parts of mechanisms that rub against each other, directly during their operation

The process of forming a protective coating, called revitalization, is based on the physico-chemical interaction of friction surfaces in the presence of revitalizant under boundary or mixed lubrication regimes. The mechanism of protectiv

Figure 1. Stages of revitalization in the "metal-metal" friction zone and formation of a protective film [7]

As a result of the process, a metal-ceramic gradient coating is formed. A feature of the process is the strengthening of the coating with its simultaneous "growth," which has high contact strength and plasticity, good thermal conductivity, and at low speeds increases the actual contact area, reduces the coefficient of friction and wear, and also protects surfaces from scuffing and welding. Revitalizant exhibits unique properties when used as additives to lubricating materials applied for lubricating cylinder surfaces.

Fig. 2 shows data on the restoration of the cylinder surface of an internal combustion engine where scratches up to 0.1 mm deep were observed, which disappear when revitalizant is introduced into the lubricating material

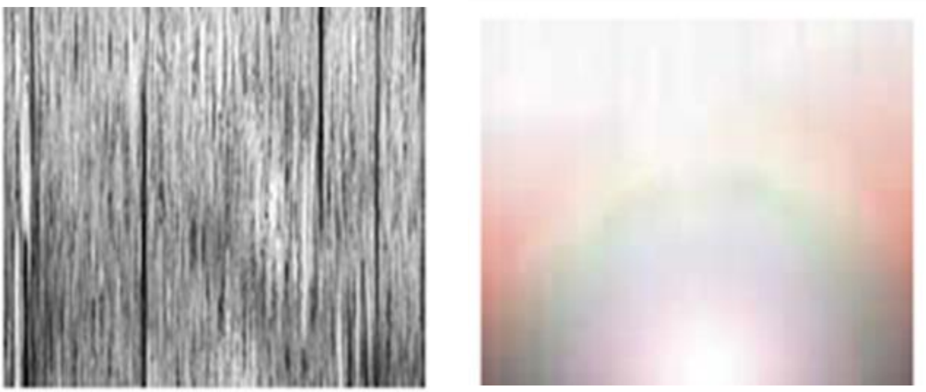
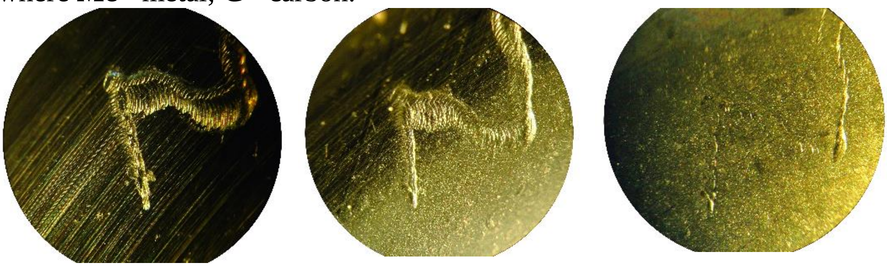


Figure 2. Left – scratches up to 0.1 mm deep on the engine cylinder surface, right – surface restoration by forming a smooth metal-ceramic coating [9]

The phenomenon of revitalization makes it possible to reverse the wear process and restore the worn surface by forming a metal-ceramic coating. Revitalization begins in the zone of greatest wear, as it is here that there is enough excess energy to start a new process, and metal atoms have the largest number of uncompensated bonds, which capture and hold the building material - revitalizant - precisely in the places of wear. Thus, a new coating is formed on the old base. The substances included in the revitalizant, under the influence of pressure and temperature arising in the parts during friction, act as a catalyst for the formation of metal carbides [8] according to the scheme:

$$nMe+mC \rightarrow Me_nC_m,$$

where **Me -** metal; **C -** carbon.



a) b) c)

Figure 3. The process of metal-ceramic coating formation [8]

A demonstration of coating formation is shown in Fig. 3: a) surface of the part magnified, b) effect of revitalizant after 15 min. - small scratches disappear and surface restoration begins, c) eliminated surface defect after one hour of revitalization due to the formation of a metal-ceramic coating [7,8].

The "XADO" company reports that the use of revitalizant yields the following results:

- Complete elimination of scratches and micro-seizures on the working surface of cylinders up to 0.03 mm deep;
- Increase in lifespan by 1.5 ~ 2.5 times;
- Equalization and increase of compression and maximum combustion pressure across cylinders;
- Fuel savings up to 8%.

Nanomaterial "NanoVit Motor Renovator" (NVMR)

The product is a mixture of nanodispersed powders: SiO_2 - 80%, Al_2O_3 - 10%, and thermally exfoliated intercalated graphite - 10%. The average particle size of the nanopowder composition is 14 nanometers[10]. When NVMR is used as an additive, the nanoscale materials interact with the friction surfaces and form protective films [10] according to the following mechanism: In the friction zone, where high stresses occur, the aluminum-oxygen bonds in aluminum trioxide break, causing the substitution of iron atoms by aluminum atoms on the surface. The resulting plating film is a solid solution with significant plasticity and strength due to the formation of aluminum and iron oxides and carbides, which increase its wear resistance, while graphite particles on the friction surfaces participate in the formation of a wear-resistant layer.

The antifriction properties of NVMR have been repeatedly tested under various lubrication conditions, different load magnitudes, and product concentrations in oil [11]. Unambiguous conclusions were drawn about the reduction of friction coefficients under certain conditions to values of 0.01-0.001, with lower coefficient values recorded as the load increased. Engine disassembly showed that as a result of using NVMR, stable gel-like films form on the walls of parts in friction zones, which retain the lubricating material. Silicon dioxide (SiO_2) and graphite create a two-dimensional sliding layer, which sharply reduces any additional damage to the frictional parts of the engine. Oil does not drain from its surfaces, which additionally protects friction pairs during cold engine starts from increased wear and restores the cylinder mirror [10].

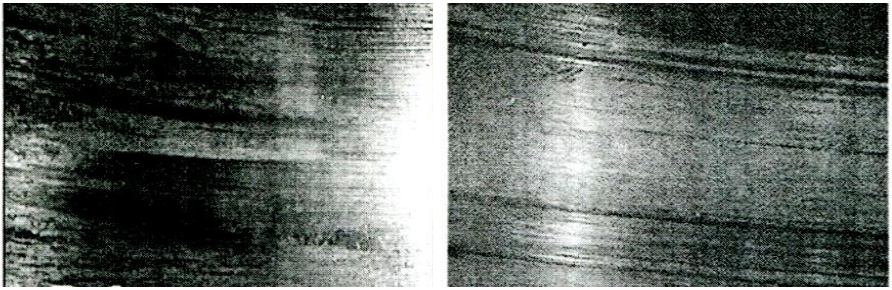


Figure. 4. Result of using the NVMR product – cleaning of the cylinder surface and restoration of its "mirror" [10]

Tests on a real engine under high loads showed that NVMR treatment leads to a 3-fold reduction in the wear rate of piston rings, and a 5-fold or more reduction in the wear rate of crankshaft bearing shells. Fig. 5 shows photographs of the piston surface after 80,000 km on base oil (left photo) and when using the NANOVIT additive (right photo).

Figure. 5. Cleaning and restoration of the piston surface when using the "NanoVit" nanoadditive [10]

It was established that after 50,000 hours of operation of a ship diesel generator, adding the product to the engine oil during the subsequent 12,000 hours of operation led to an increase of up to 30% in compression pressure in the cylinders, reduction of the friction coefficient to the optimal value after 6,000 hours of operation, a 4-fold increase in the interval between scheduled oil changes (3,000 hours), fuel savings of up to 12%, and cleaning of friction surfaces from combustion product deposits.

Conclusions

Research confirms that the application of nanomaterials in ship mechanisms is a promising direction for enhancing their operational characteristics. Nanomaterials, such as revitalizants from "XADO" and nanoadditives "NanoVit," significantly improve the strength, wear resistance, and thermal conductivity of friction surfaces due to their unique physico-chemical properties. A key advantage of these materials is their ability to form protective metal-ceramic films that reduce the coefficient of friction, prevent wear, and restore damaged surfaces. Experimental data indicate an increase in the lifespan of mechanisms by 1.5–2.5 times, fuel savings up to 12%, and reduced maintenance costs. Thus, the use of nanotechnologies in shipbuilding opens up new possibilities for increasing the efficiency and durability of ship engines and mechanisms, which is an important step in the development of the modern maritime industry

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