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ON THE POSSIBLE APPLICATION OF MICROBUBBLE CAVITATION IN PIPELINE TRANSPORT

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The article discusses the possibility of using microbubble cavitation in pipeline transport to reduce hydraulic losses due to a decrease in total resistance due to air bubbles. It was also concluded that further research of this phenomenon and its implementation in this industry is necessary.

In addition to the fact that pipelines guarantee the energy independence of our country, they allow to reduce transport loads on railway transport, thereby, contributing to an increase in the volume of transportation of other equally important cargo. The length of pipeline transport is growing more and more, technologies are being improved, technological re-equipment of existing pipeline systems is being carried out, more advanced and modern means of control and communication are being introduced, methods of delivery of high-viscosity and solidifying oils are being modernized.

The problem of reducing hydraulic losses in pipelines is very urgent. This is due to the huge energy and economic costs of transporting the product. Therefore, at present, there is an active development of reliable and effective devices for reducing hydraulic losses in pipelines using the example of various methods in other industries and in nature. So, it has been observed that emperor penguins in Antarctica represent an exceptional skill for reducing hydrodynamic drag when accelerating in water or jumping out of water onto slippery surfaces [8]. In addition to the streamlined body shape, studies have shown that the special structure and wettability of penguin feathers also play an important role in reducing fluid resistance. It turned out that small bubbles emerging from the entire plumage of the penguin could develop into a smooth layer - a bubble cloud, which can effectively reduce the resistance force that promotes its jumping out of the water or high-speed movement.

In 1973, McCormick first illustrated the drag reduction of a microbubble by electrolysis. Experiments have shown that bubbles can effectively alter both laminar and turbulent boundary layers resulting in significant drag reduction. In 1976, Bogdevich studied the effectiveness of reducing the resistance of microbubbles on the porous surface of a thin plate. The maximum reduction in the local resistance to friction of the wall was about 90%. It was found that a flat plate at a speed of 5 m/s showed a better drag reduction, while a plate with a porous surface was 15 m/s. The decrease in the resistance of microbubbles on the surface of the flat plate mainly occurred near the boundary layer, and they lose the decrease in resistance with distance from the boundary layer of the wall [8].

This phenomenon of bubble formation is called cavitation. This physical of the formation of bubbles (cavities, or voids) in liquid media is followed by their collapse and the release of a large amount of energy, which is accompanied by noise and hydraulic shocks [1]. Cavitation occurs as a result of a local decrease in pressure in a liquid, which can occur either with an increase in its speed, for example, behind a ship's propeller (hydrodynamic cavitation), or with the passage of a high-intensity acoustic wave during a half-period of rarefaction (acoustic cavitation). There are other reasons for the appearance of the effect as a result of external physical influences. Moving with the flow to a region with a higher pressure or during a half-period of compression, the cavitation bubble collapses, while emitting a shock wave. Basically, cavitation has the same mechanism of action as a shock wave in air, which occurs at the moment a solid body overcomes the sound barrier. The leading role in the formation of bubbles during cavitation is played by gases released inside the formed bubbles. These gases are always contained in the liquid, and with a local decrease in pressure, they begin to vigorously evolve into these bubbles.

The phenomenon of cavitation is also used in the military industry [2]. The Shkval complex was put into service in 1977. The cruising speed of a supercavitation torpedo of 375 kilometers per hour is achieved by moving in a cavitation cavity (vapor bubble), which reduces water resistance, and using an underwater jet engine powered by solid hydroreactive fuel. The use of cavitation significantly reduces the possibilities for maneuver, and instead of the homing head, a receiver of sea water is installed in the nose of the rocket, which is necessary for the engine to operate. Supercavitation is the movement of a solid object in an aquatic environment with the formation of a "cocoon" around it, inside which there is only water vapor. Such a bubble significantly reduces the resistance of the water. It is inflated and supported by a special cavitator containing a gas generator for pressurizing gases.

The sustainable examples of the use of the phenomenon of microbubble cavitation can be seen in marine navigation. Recently, of practical interest is the "air lubrication" of the bottom with the creation of a thin air film that reduces friction and increases the speed of the ship. The first proposals for the use of air lubrication on ships appeared more than a hundred years ago. So, back in 1865, Scott Russell wrote about this in his book "Modern Systems of Marine Architecture". Another famous shipbuilder, William Froud, also mentioned this. In practice, the first attempt to implement the idea of "transforming a surface in contact with water into a surface in contact with air" - a substance much less dense and viscous, was made in 1882 by the famous Swedish engineer-inventor Laval. He received a patent in England and built an experimental boat with air supply under the bottom through pipes. However, Laval failed to achieve a positive effect.

In 1887, mechanical engineer S. Timokhovich made an application for granting him a privilege for "a method of reducing the friction of ships on water and sticking it to their surface." His idea was to supply air or water-oil emulsion to the underwater part of the hull through specially arranged pipes, the layout of which varied depending on the shape, purpose and dimensions of the vessel. In the United States, the first privilege to use a similar method was issued in 1911. The American engineer D. Moore proposed supplying air under a specially shaped bottom. The vessel was supposed to have a triangular shape and gradually turn into a back-keeled ("sea sled") in the stern. The air was supposed to flow under the hull through pipes brought out to the deck - through holes in the bottom, equipped with special visors-deflectors. The author believed that when the vessel is planing, the vacuum created by the deflectors will cause a natural suction of air under the bottom.

In the 1920s and 1950s, many researchers turned to the idea of "air lubrication". In the USSR, L.M. Lapshin, N.N.Kabachinskin, L.G. Loitsiansky were engaged in this issue. KK Fedyaevskin and other scientists. At the suggestion of LM Lapshin, the air was to be pumped by a special installation, and the bars placed along the bottom were to prevent it from leaking to the sides. In 1924, on the Livenka River, LM Lapshin began experiments with a rough model of a shallow-draft flat-bottomed river vessel measuring 2.5x0.22x0.02 m, and later continued experiments on a 25-meter plank. The air intake under the bottom gave an overall drag reduction of about 20%. It is also worth noting the experiments of NN Kabachinsky with models that had a bottom of a special shape - with a recess of the "air bell" type. These experiments, carried out at the Gorky Industrial Institute in 1936, showed a decrease in the total resistance due to the supply of air under the bottom by 17%, and the frictional resistance by 30%.

After World War II, warships began experimenting with a system called the Prairie-Masker, which pushed bubbles through the hull and tips of the propeller blades in an attempt to disguise the acoustic signature of the ship's equipment as a defense against submarines. In the process, they also found that these bubbles increase the efficiency of the hull when moving in water. The first tests of full-scale air-lubricated vessels were carried out two years later. In the course of these experiments, it was possible to reduce the total resistance of a specially equipped wooden barge with a length of 25 m by 22.6%; in addition, an important fact was established of the dependence of the blowing efficiency on the air flow rate. During experiments in 1957, air supply under the bottom of a serial-built steel dry-cargo barge provided an increase in travel speed by about 6.5%, which corresponds to a decrease in drag by 20% [3].

The accumulated research experience is now being applied at the Japanese company Nippon Yusen Kaisha, which completed two years of experiments with air lubrication systems installed on two of the group's carriers, Yamato and Yamatai [4]. The air lubrication system effectively reduces the frictional resistance between the bottom of the boat and the seawater due to the bubbles generated when air is blown to the bottom of the boat. In fact, it was the world's first stationary blower system. The system was installed on two ships during their construction, and experiments were carried out during the sea voyage. After analyzing the data obtained by two vessels over two years under various weather and sea conditions, the optimal mode of bubble behavior control in real sea conditions was confirmed. Compared to a 10% reduction measured in sea trials, CO2 emissions have been proven to be reduced by an average of 6% under various weather and sea conditions.

For nearly a decade, Samsung Heavy Industries and Mitsubishi Heavy Industries have been experimenting with "air lubrication" to reduce fuel consumption on flat-bottomed ships. To do this, there are many small holes on the bottom of the vessel. Air is pumped through them under the water. The resulting bubbles create an "air cushion" that saves 4-5% of fuel. For example, DSME built the first LNG tanker using bubble cavitation technology. DSME is considering the use of air lubrication systems for other types of vessels: LPG carriers, medium tankers and large container ships [5, 6].

Additionally, model tests of this technology have been carried out in the Marin test pools in the Netherlands [7]. Damen's R&D and Marinvention team developed a completely new concept that utilized a corrugated body design. After successful testing, the traditional flat-bottomed ship models were completely changed to an air-lubricated design. Results ranged from 5% to 40% fuel economy, with a total calculated annual savings of 15% with normal seaworthy design. It was noted that fuel economy improved at lower speeds. In addition, Marinvention found that it was much easier to make a corrugated bulkhead for meridian sailing directions. The height of the corrugations depends on where the force is applied - there is a less humid area - since the gaps are filled with air. There is also an underwater hull system that allows a small amount of air to pass to the propeller, which reduces propeller vibration.

In the research, it can be concluded that this method is effective in the pipeline transport industry. This porous structure approach can be applied to the internal polymer coatings of main steel pipelines. To introduce microbubble cavitation into large-scale use, it is necessary to carry out additional studies using computer modeling and make additional calculations to clarify the coefficient of hydraulic resistance, which affects the hydraulic resistance of the pipeline.

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