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OVERVIEW OF THEORETICAL PROSPECTIVE METHODS TO REDUCE HYDRAULIC LOSSES IN A PIPELINE SYSTEM

V. SAVELYEVA, E. OVCHAROV, A. VARONIN
Polotsk State University, Belarus

This article is devoted to the biomimicry engineering approaches. It presents the idea of smooth antifrictional coatings, vortex flows, scaly coating, tubercle technologies and their advantages. The convenience of usage of natural mechanisms in the main pipeline transport is formulated.

Pipeline transport has a conclusive impact on the formation and development of the country's fuel and energy industry. The most important element of this industry is the main pipeline transport. This system is designed for the transportation of liquid and gaseous hydrocarbon energy resources. The main pipeline transport accounts for more than 4% of the total global energy consumption during transportation [4]. This fact is due to the high-energy demands of pumping equipment which, accounts for up to 20% of the world's electricity consumption [1]. According to energy consumption statistic, it is on the third place after urban transport and lighting. Thus, this is a significant energetic issue.

The hydraulic resistance appears from the side of the pipeline system and is estimated by the amount of specific energy losses that is irretrievably spent on the work of the friction forces where the flow undergoes deformation. The problem of reducing hydraulic losses in pipelines is very urgent. There are many methods of reducing hydraulic losses. Their practical use can significantly reduce the hydraulic fluid loss in pressure pipelines which in turn allows reducing the energy cost of transportation. One of the alternative approaches to technical problems is bioengineering.

Biomimicry is a practice that studies and imitates the strategies of adaptive mechanisms which were created by nature. Scientists have analyzed a large amount of material for the prospective application of some theories to such systems as airplanes, underwater vehicles, surface ships, trains and pipelines. During the analyzing of the bioengineering approaches, our attention was paid to the field of application in the main pipeline transport. The ideas of engineering bionics are applicable to both on-site and linear pipeline transport facilities.

A good example of biomimicry is the more streamlined Shinkansen train, which is not only quieter but also 10% faster and consuming 15% less electricity [5]. JR West's engineer and ornithologist used his knowledge of the splashless entry of kingfishers and the quiet flight of owls to reduce the noise made by trains. Kingfishers move quickly from air, a substance with low resistance, to water, a substance with higher resistance. The kingfisher's beak provides an almost perfect shape for such a strike. Similar to the streamlined beak of the kingfisher is the sand lizard, which due to its natural cover moves freely in the sand dunes. The application of this idea in the linear part of the main pipeline transport is in smooth surfaces. The main advantage of smooth coatings is the reduction of friction during transportation by reducing the roughness of the internal surface of the pipes. All that increases the throughput capacity of the pipelines.

With regard to the linear part of oil transport the ideas of the Austrian inventor Viktor Schauberger, who was inspired by nature, are extremely important for the designers of modern gas pipelines, oil pipelines and whirlpool hydroelectric power plant [3]. The point is about using the phenomenon of swirling flow in pipelines that is still not used as a positive effect. This approach can be used to reduce the dynamic resistance of main pipelines and water pipelines of hydroelectric power plants. With a screw twist of the water flow during the fed from the reservoir to the hydroelectric turbines of hydroelectric power plants the kinetic energy of the water flow can be increased significantly. So that the height of the dam can be reduced respectively while saving the same power of electric units. Turbulent motion involves the waste of kinetic energy, turning it into heat, which is caused by randomly emerging and disappearing vortices of the liquid. The vortices randomly collide with each other, as well as with the walls limiting the flow. The natural flow of liquid and gas is a vortex motion, which make consistent with the environment.

In traditional circular pipes the fluid tends to a natural swirling and tapering flow pattern. However, this flow shape doesn't align with the shape of the pipe. When the fluid moves in a circular pipe an intense turbulence occurs in the peripheral zones, which leads to additional hydraulic losses. Twisting the flow along the central axis using devices made of polymer coatings, such as elementary butterfly inserts or a twisted spring inside the pipe, can significantly reduce the energy cost of moving the contents up to 7 percent [2]. This is due to the more favorable energy state of the natural vortex flow of the liquid in comparison with the rectilinear one. Installing a swirler in front of a circular pipeline allows to give the fluid flow this natural flow shape and reduce hydraulic losses. The positive effect of the device can be explained by the fact that any object or substance, being left to itself, tends to take the most energetically favorable state and moves along the most favorable trajectory, providing minimal energy loss. This installation can have the form of a vortex cutout in the polymer coating, which significantly simplifies the manufacturing process and reduces the cost.

The next effective example of biomimicry is the structure of fish scales. Researchers from the Universities of London and Stuttgart have found an opportunity to reduce the drag of airplanes and, as a result, to increase their speed [6]. Scientists have studied the topology of the scales of European sea bass and carp. The study made it possible to formulate a conclusion that overlapping areas on the surface of fish scales lead to a zigzag movement upon contact. The zigzag motion of the liquid creates a so-called "striped flow". This type of motion neutralizes unstable fluctuations that leads to turbulence. The use of this experimental approach in aviation contributed to a reduction in aerodynamic drag by more than 25%. This discovery may affect the shape of the polymer coatings on the internal surface of the pipeline, which will lead to an even greater reduction in hydraulic losses.

The additional example of the possibility of applying the natural approach in technical systems is the study of the Mako shark, which is considered to be the fastest of all existing sharks [7]. This type of shark can reach speeds of up to 100 km/h. One of the secrets of this mobility is the scales, which reduce the resistance of their body in water. The scales of Mako sharks have three "teeth". It was found that the scales create small vortices. In the course of the study the secret of the "super-speed" of this shark species was revealed. The secret consists in the ability to lift the scales, changing the angle of inclination of its plates. The use of the Mako shark scale structure has already found application in the coating of swimming suits. This idea can be applied to the adaptive internal surface of the pipeline, as a coating with small plates, which will also lead to a reduction in hydraulic resistance.

A specific feature of the scales is the absence of bacteria on it. The coating, which was copied from the scales of the Galapagos shark by Sharklet [5], is a plastic sheet product structured to prevent the growth of bacteria. This invention is used in hospitals and other places with a relatively high potential for the spread of bacteria and the occurrence of infections. While in operating oil pipelines, there is a problem of asphalt-tar-paraffin sediments on the walls of the pipeline. This technology is a potential solution to this problem.

Talking about on-site structures, the most important part is the main pumps which require a lot of electricity to convert the rotational energy into kinetic energy. In this case, observing nature can help solve the engineering problem of improving the pump's operating parameters.

It was noticed that whales have special bumps on the edge of the fin, which help them to divide the water into several streams. Studies have found that the addition of bumps to the leading edges of aerodynamic surfaces directly eliminates the fundamental limitations of conventional aerodynamic performance. Such surfaces have a number of advantages where the aerodynamic surfaces of the bumps have an increased stable lifting force.

The bumpy aerodynamic surfaces provide stable performance over an unsurpassed range of stall angles, and when they do stall, they stop gradually. That fact makes this technology even better. They literally revolutionize low-speed performance, far superior to any conventional blades. Based on this, WhalePower Corporation is ready to apply this technology to turbines, compressors, pumps and air fans [8].

At the core of wind turbines is the problem of root leakage, which deprives them of power. To solve this problem the scientists turned to the two most effective natural ways of moving in liquids: kingfisher and maple seeds [5]. As noted earlier, the kingfisher owes its reputation to the way its beak allows it to dive in the water with barely noticeable ripples and actually moving the liquid around it at a precise speed. When a maple seed falls to the ground, it moves through the air with the least resistance. The PowerCone is based on these principles of time-dependent energy efficiency. It absorbs wind gusts and smoothly directs the wind from the base to the outer spaces of the blades (smoothes incoming wind gusts and equalizes the air flow relative to the turbine blades), increasing the torque, reducing the start-up speed and increasing the power factor of the turbine. This reduces turbulence, vibration, and associated loads on the rotor, bearings, and transmission.

The engineering solutions of WhalePower and PowerCone can be used in the design of pump wheels which are a significant local resistance. Thanks to the PowerCone technology, a flow of material can be directed to the pump blades, which will rapidly reduce the local resistance of the pump. Due to the high energy consumption, increasing the efficiency by every hundredth of a percent is a win.

The aforementioned cases of the application of natural adaptive mechanisms of the environment and living organisms have shown that natural selection, which took place over 4 billion years, created optimal engineering adaptations in ecosystems with the best technical solutions. The study of existing adaptive natural structures was carried out with an emphasis on their extrapolation to the objects of the main pipeline transport.

The review has shown that such natural mechanisms can be used both on linear and on-site facilities. So, to reduce hydraulic losses in steel pipelines, smooth antifriction coatings, swirling of the flow by changing the geometry of the internal polymer surfaces, a scaly internal polymer coating with a small size of each element and an adaptive internal coating can be used. To reduce losses in the main pumping equipment, it is possible to use the structure of special diagonal cutouts on the impeller blades and the inner surface of the pump casing, as well as a structure that directs the pumped flow from the center to the periphery of the impeller. These proposals are of a theoretical nature and require further research on physical experimental equipment or in special complexes for modeling.

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