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A BRIEF SURVEY OF SHIP HULL CLEANING DEVICES

KUĢA KORPUSA TĪRĪŠANAS IEKĀRTU ĪSS APSKATS

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1. Introduction

The surface covered by sea adherence is about 80% of total ship hull and all sea adherences have to be cleaned before inspection. Besides preventing direct surveying, sea adherence causes a decrease of ship's speed and consequently augments consumption of fuel. For recuperation of ship's performance, it is necessary to dry-dock a ship and to proceed a clean off sea adherence. This cleaning is always required before any other repairing/maintenance activities can follow on. Nowadays cleaning is done manually in dry-dock with an employment of different adapted methods like grit blasting or water jet. It has to be noticed that, in itself, it is a very contaminant operation (the resulting dust always contains painting particles), it is harmful for human operators health and it is a very uncomfortable job.
The use of the new technical solution allows cleaning a ship from sea adherence without the use of an expensive dry dock. In this case it would be possible to clean a ship much more often, for

example, twice a year. Even in the case when it is necessary to make inspection, repair or restoration of a protective coat of a ship in a dry dock, it would be possible to make a ship's hull cleaning out of a dry dock first, which would allow using dry dock more efficiently [1].

2. Hull Performance and Propeller Efficiency

A vessel's fuel performance usually begins decreasing after six months from dry-dock and continues to decrease rapidly. Underwater marine growth, barnacles, and/or sea grass can cost a ship-owner millions of extra dollars in time and fuel costs each year. To prevent spending additional dollars for fuel, a ship should be cleaned twice a year.

A new VLCC tanker uses approximately 96 tons of bunker fuel per day and 610 barrels of fuel per 24-hour period. The cost per day for fuel alone would be approximately $30,000 with an additional $20,000 for operating expenses per day. On an average 15,000-mile cruise, the VLCC tanker would make the cruise in about 25 days with a clean hull. If the ship's hull is fouled with marine growth not exceeding 0.5 inch, the same trip would take 28 days. The difference is the loss in speed of over 2 knots, which equates to 3 days. Those additional three days cost $90,000 in fuel consumption alone. The propeller is particularly vulnerable to marine fouling since it is an unpainted surface that must remain clean and shiny for proper operation. The U.S. Navy determined that propeller fouling, despite its small surface area, can generate energy losses amounting to half that of the hull it so maintaining a clean propeller is critical. On military ships, the unpainted surfaces such as propellers, rudders, and sonar domes are cleaned twice as often as the hull surfaces. The propellers are also polished routinely to reduce friction and ensure that the propeller operates at optimum efficiency. Even with routine maintenance, surface roughness can occur as a result of erosion, corrosion, or from tubeworm Atracings. This roughness alone can increase fuel consumption up to 10 percent.

3. Hull cleaning intervals

The optimum interval between the periodic cleanings and inspections that comprise a preventive maintenance program will vary with the type of vessel, the location of the vessel, and its service profile (speed of operation, idle time, etc.). The type and condition of bottom coatings will also have an effect on the cleaning interval. Large vessels typically have several layers of coatings, up to 6 millimeters thick, and generally operate 4 to 6 months between hull cleanings.

The location of the vessel also has a substantial influence on the rate of fouling since marine organisms flourish in warm tropical waters. The U.S. Navy has established geographic fouling zones, indicating the frequency with which the hull and unpainted surfaces (propellers, rudders, and sonar domes) should be cleaned for vessels operating within each geographic zone. In Navy Zones 1 and 3, propeller cleaning is recommended up to six times a year and hull cleaning is recommended up to three times a year.

4. Instruments and Devices

4.1. Hand held rotary units

Figure 4.1.1. Brashes in action

Armada manufactures the largest line of underwater cleaning brushes (stainless, flat wire, heavy grit). All of Armada's brushes meet and exceed Navy standards. Armada also designs and manufactures brushes to meet any application.
Armada manufactures 13 different brush materials for cleaning any type underwater surface. Consult Armada for your specific cleaning needs. Armada can also manufacture brushes for custom applications that vary in size from 8", 10", 12", 14", 15", 16", 18", 20" in diameter. (203.2 mm, 254 mm, 304.8 mm, 355.6 mm, 381 mm, 406.4 mm, 457.2 mm, 508 mm).

Figure 4.1.2. Polypropylene -- Used for cleaning growth on fiberglass, aluminum, steel and wood.
017 Poly; 020 Poly; 025 Poly; 036 Poly

Figure 4.1.3. Nylon -- Light fouling, grass and slime on fiberglass, aluminum, steel, and wood.
017 Nylon
022 Nylon
028 Nylon

Figure 4.1.4. Grit -- Nylo Silicone Carbide available in 6 different grit materials, from heavy to light grit, on fiberglass, wood, aluminum, and steel hulls.095/46 Grit; 065/46 Grit; 050/080 Grit; 040/120 Grit; 035/180 Grit;030/240 Grit

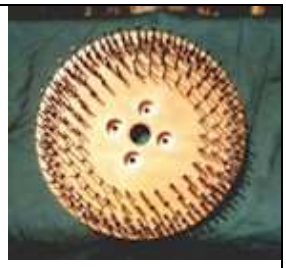

Figure 4.1.5. Flat Wire Steel Brush -- Heavy fouling of barnacles, tubeworms, Zebra mussels and grass on steel surfaces. (Heavy Gutter Broom Wire)

Figure 4.1.6. Stainless Steel Row -- Medium growth slime, grass, and barnacles on aluminum and steel surfaces

Figure 4.1.7. Sample Brush -- Contains 16 different materials to help in selecting the appropriate brush for the best cleaning results

AST- 407 Rebuildable Brush Bristle Material:
50 lb. bundle (makes five 14" diameter brushes with 8" to 9" trim per brush)
1. Stainless Steel Rope (AST-407SSR)
2. Nylon (AST- 407N)
3. Nylo Grit (AST-NG).
World's fastest underwater cleaning tool for removing barnacles, zebra mussels, and heavy sea-growth from ship hulls made of wood and steel, sea walls, dock pilings and peers.

Figure 4.1.8. Barnacle cutter

The "*Barnacle Cutter*" is a tool specially designed and developed for underwater removal of barnacles and other encrusted sea growth from steel, concrete and wood pilings, seawalls, bridge supports, bulkheads and ships. The tool's outstanding feature is its ability to remove 6" (152.4 mm) of barnacle-type growth at the rate of 3 to 6 sq. ft. per minute (278709 sq. mm to 557418 sq. mm per minute), and the capability of removing up to 18" (457.2 mm) of sea growth.

Here's how it works as the tool advances across the surfaces being cleaned, the outside knocker-cutter bars that are attached to the tool's outside housing (or diameter) shatter the barnacles and other heavy growth, while the rotating inside hardened steel cutting wheels follow up with their chipping and scraping action which attacks and removes the tough barnacle adhesive and balance of material left by the outside knocker-cutter bars, leaving the surface clean. The constant flow of water passing through the tool keeps the inside cutting wheels washed clean and free. These same round inner cutting wheels that do the chipping and scraping are also the wheel that the "*Barnacle Cutter*" rides and rolls on, acting like casters and adding to the tool's mobility and stability.

Displacement of water caused by the rotary action of the "*Barnacle Cutter*" creates a vacuum effect under the tool which results in the tool being pressed and held against the vertical work surface firmly yet gentle enough to allow the tool to yield to the divers' control to guide it in any direction by applying a slight pressure on either side of the tool. The tool performs equally well in a clockwise or counter-clockwise direction.

Barnacle Brush Cutter Blades. Part #ASLPCB-3 and ASHPCB-3

Figure 4.1.9. Barnacle brush cutter.

Designed for removing barnacles, heavy grass, and zebra mussels for painted surfaces. Three cutter blades are required per brush. Navy approved. Barnacle Brush Cutter Blades are available on the following brushes: Stainless, Flat Wire, and Heavy Grit.Low Profile -- ASLPCB-3 High Profile -- ASHPCB-3.Note: The Barnacle Brush Cutter Blades are paint safe, and are only available in 15" (381 mm) and 12" (304.8 mm) brushes.

Figure 4.1.10. Divex Flexbrush

The Divex Flexbrush is a hydraulically powered rotary brush cleaning system for use in marine growth removal on ship's hulls and underwater structures. It comprises two hydraulic counter-rotating motors within hinged fiberglass housings. Cleaning brushes of the appropriate grade are selected for attachment to the motors. These can be steel bladed *"barnacle bashing,"* strength for removal of heavy calcareous marine growth such as mussels and other mollusks, or of simple wire or nylon filaments brushes for lightweight cleaning prior to painting, application of marine coatings, welding, NDT etc.

Figure 4.1.11. Surface Preparation Nozzle 1200 – 2800 bar, 2 – 3 – 4 or 6 nozzle set up.

From others Hand held rotary units my be mentioned RWD Rotating Nozzle (http://www.uraca-far-east.com/URACA5.htm).

4.2. Underwater Hull Cleaning Machines by qualified divers

The patented SEAVAC unit is operated and steered underwater by qualified divers. The hull cleaning machine, powered from an adjacent work vessel, travels across the underwater hull surfaces with an efficiency that cannot be matched by hand-held brushes or other ship hull cleaning machines.
The cleaning unit is 1.75 meters in diameter and has three rotating brushes and three traction wheels. A propeller thrusts the apparatus against the hull as it travels a horizontal path across the hull at the variable speed of 18.3 - 36.6 m per minute, and at successive depths. It can also be operated 0.46 m above the water line.

Figure 4.2.1.
http://www.umc.co.uk/services/index.htm

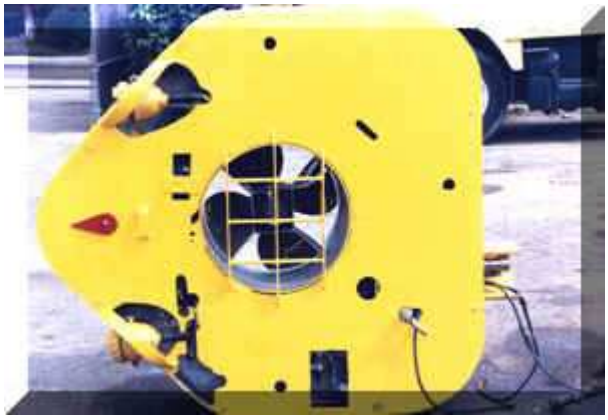

Figure 4.2.2.
http://www.seavac.net/seavac_mark_iv.htm

Seavac. The SEAVAC unit is totally hydraulic, with no electrical motors. It adheres to the underwater surfaces of the hull with a force in excess of 3000 pounds. The traction effect of the wheels is 2100 pounds, which enables the unit to travel at variable speeds against most tidal forces. The cleaning brushes are made of either stainless steel wire bristles which are specially designed to ensure that their tips do not point directly into the hull or polypropylene bristles for anti-fouling reactivation and removal of soft algae. The bristles go out at an angle of 39º and the last 10 cm of each one of them lies flat on the hull. This brush / bristle arrangement allows the unit to clean completely convex or concave surfaces, thereby negating the need to use gimbal suspension on the brush motors.

The SeaRazor SuperTwin AST 707 is designed to be a fast and efficient underwater cleaning system, with a cleaning path of 7 feet (84 inches, 2133 mm). It's specifically designed to clean the heaviest marine growth on large VLCC ships to the smallest freighter, floating dry docks, dams, and any underwater structure.

Figure 4.2.3. Rebuilding Brush

Figure 4.2.4. SeaRazzor Super Twin AST-707

The SeaRazor Twin reaches forward speeds of 100 feet (30.48 meters) per minute depending on the degree of fowling. The Twin is capable of effectively cleaning 700 square feet (65 square meters) per minute. The Twin's major advantage over other systems is its use of 2 large rebuildable aluminum brushes. This means higher profits because the operator only purchases brush bristle material in bulk. Four rebuildable aluminum brushes are included with the AST-707 with brush holder pedestal. The brushes can be reloaded in less than 30 minutes on the job site with appropriate bristle material to meet every changing fowling condition. This means less downtime, less inventory, and higher profits. The unit's brush speed which is diver-controlled ranges from 0 to 200 RPM minimizes paint damage even on the most sensitive ablative paints.

Figure 4.2.5. SeaRazzor AST-307

The SeaRazor Twin AST 307 is designed to be a fast and efficient underwater cleaning system, with a cleaning path of 37 inches (1 meter). It's specifically designed to clean the heaviest marine growth on large VLCC ships to the smallest freighter, floating dry docks, and any underwater structure. Only 10 GPM (37.84 LPM) at 2000 PSI (13793 kPa). It's specifically designed to clean the heaviest marine growth on large VLCC ships to the smallest freighter, floating dry docks, and any underwater structure.

The SeaRazor Twin reaches forward speeds of 60 feet (18.3 meters) per minute depending on the degree of fowling. The Twin is capable of effectively cleaning 180 square feet (54.86 meters) per minute. The Twin's major advantage over other systems is its use of 2 rebuildable aluminum brushes. This means higher profits because the operator only purchases brush bristle material in bulk. Two rebuildable aluminum brushes are included with the AST-307 with brush holder pedestal. The brushes can be reloaded in less than 30 minutes on the job site with appropriate bristle material to meet every changing fowling condition. This means less downtime, less inventory, and higher profits. The unit's brush speed which is diver-controlled ranges from 0 to 300 RPM minimizes paint damage even on the most sensitive ablative paints. Unlike other

models that are dependant upon brush suction to adhere to the hull of the ship, the AST-307 uses a HYDRO IMPELLER SHROUD mounted on the backside of the unit facing away from the hull for maximum thrust and diver safety. This allows the unit to adhere to the side of the ship and move to other areas with the brushes turned off virtually eliminating paint damage. Inferior designs use a propeller mounted in a center hole which enables the unit to adhere to the side of the ship, but pulls all dislodged heavy barnacle and shell through the propeller which can cause propeller failure, hydraulic motor damage, and oil leaks. Even diver safety is a concern with lowered visibility from the debris.

4.3. Underwater Maintenance Vehicle

The AHMV is a remotely operated vehicle (ROV). ROV is a generic term for an underwater vehicle operated with an umbilical cable from the surface without the use of divers. The purpose of this project is to design, develop and build an ROV for ship hull maintenance.

Figure 4.3.1. Outlook to AHMV lower part

Figure 4.3.2. Common outlook to AHMV

One way to extend dry-docking time is to enable the AHMV to conduct underwater inspections to support maintenance planning. This AHMV has a sensor that measures paint thickness. Monitoring the thickness of paints is crucial because the antifouling paints are ablative and wear away with time. Fouling occurs if the paint wears away prematurely. Also, the AHMV will be able to measure the thickness of the steel plate. Periodically, hulls must be measured to ensure they are not thinning due to corrosion and, consequently, putting the operation of the ship in jeopardy. Additionally, the AHMV can measure the impressed current cathode protection potential, an electric field around the hull that prevents corrosion. Measuring the field is a gauge of any current corrosion. Finally, the AHMV is capable of taking video and still photos of the hull to help maintenance planners prioritize work. If solved, these are all pieces of the puzzle that will keep the ship out to sea longer. The AHMV will result in a great cost-saving benefit. The Navy spends about half a billion dollars each year on propulsive fuel, which pushes ships through the water. The primary way propulsive fuel losses occur is by allowing marine fouling to build up and remain on the hull. For example, barnacles growing on the hull cause drag, which slows a ship down and uses more fuel. Between 10% and 15% of Navy propulsive fuel is spent trying to overcome that drag. Ten or 15% of $500 M is a significant amount of money, around $50M a year. Development cost of this vehicle might total about 15 or 20 million. Once the AHMV is fully deployed, it will pay itself back in less than one year, which is a pretty good return on investment. The Automated Hull Maintenance Vehicle is designed to clean fouling

from a vessel's hull and capture and treat the effluent that is produced. The ROV features automated navigation and operation, image acquisition using a 3 MHz sonar, and analysis of captured images for identification of fouling. A filtering system removes particles greater than 20 microns in size from the effluent. Currently are investigated various 'polishing' techniques in an effort to reduce levels of copper and zinc in the effluent to the low ppb range.

4.4. High Pressure Underwater Water Jetting HydroCat

The revolutionary, new HydroCat is an omni-directional surface preparation robot that attaches itself, using vacuum, to any vertical, horizontal or overhead surface. It collects 100% of the water, removed coatings and rust, and runs with a single operator. Advanced Systems Technologies, Inc. (AST) provides environmentally friendly, automated water jet and coating systems and services. Our nationwide service center network is ready to service your stripping, cutting and coating needs. AST's patented coating removal and application products are called Automated Robotic Maintenance Systems (ARMS®). ARMS® are designed for a variety of applications. AST's innovative methods, including state-of-the-art robotics equipment and patented nozzles, transform labor-intensive operations into fully automated operations. Semi-automated and manual systems are also available. Coating removal ARMS® products are designed to harness the power of pressurized water up to 55,000 PSI. These systems are used by aerospace, marine, power, transit, and other industries to remove thermal spray coatings, ceramics, rubber, plastic, silicone, epoxy, paints, primers, contaminants and other coatings.
Coating application ARMS® coat hardware as an integral part of a totally automated process or as a stand-alone manual process. They are used to apply specialized thermal, ablative, non-skid, foam, and protective coatings to spacecraft, aircraft, roadways, roofs, and other parts. AST's Convergent Spray Technology (CST™) allows application of high-solid, solvent-free coatings.

Figure 4.3.3. Common outlook to HydroCat V

5. Russian technologies

5.1. Cavitation

Principal mechanism underlying this technology consists in generation of plenty of tiny vapor-and-gas-filled bubbles in a stream of liquid due to sharp forced increasing of stream speed, and bubbles' further collapsing under natural pressure of fluid environment. This process is known as hydrodynamic cavitation.

Ultrahigh pressure (up to 4000 bar) and high temperature (up to 5000^{o} K) are generated in points of collapsing of cavitation bubbles for a very short time, of the order of several microseconds.
As a result of the dynamic impact at the end of collapse process, shock waves are generated. Shock waves reach a cleaning surface and cause intensive erosion (destruction) of fouling.
Intensity of cavitation erosion of submerged objects depends on many factors, among which are: strength characteristics of processing substance; temperature of liquid; ratio between operational pressure of the tool and natural pressure of liquid environment; distance from the edge of the working tool to the substance which should be removed, and other.
Intensity of cavitation erosion can be adjusted by optimum tool selection in order to optimize solution of specific problem of cleaning.

5.2. Kingston chests and frames

Chests and lattice frames of kingston valves are of especial difficulties when using brush-based tools for cleaning. There are at minimum two kingston valves on each vessel, which are: bottom valve and side valve. According to Register regulations, dimensions of orifices or slots in kingston valves' lattices should not exceed 20 mm, therefore these slots can be easily constricted by biological growth, what will significantly reduce the water intake into the engine cooling system.
Number of kingston valves and their lattices is determined by vessel’s project, depending on a ship class, its destination and size.

5.3. Description of new underwater hull cleaning technology

Developed by Russian firm, principally new technology of underwater hull cleaning is based on the use of energy of submerged cavitation jets which are created by the special equipment called generator of cavitation jets or cavitator. It exceeds all existing underwater (dry-docking excluded) cleaning methods in capacity. On average, specific output of one cavitator is equal 250 sq. m of clean surface per hour.The operational pressure of the cavitation tool does not exceed 2150 psi/150 bar, that is 10-15 times less, than in the hydrokinetic tools. One pump with output of 165 l/min enables simultaneous work of four generators of cavitation jets, and each of them, on average, has in-use output about 250 sq. m of clean surface per hour. In other words, this technology allows to vary actual output over a wide range of situations. This technology reduces process of cleaning to a single run of the tool over a surface being processed, and that is enough to achieve any prescribed degree of cleanness, with preservation of a paint or up to "white metal" (for example, before dry-docking).
The cleaning tools can be configured for manual use with the help of diver, and also as remotely controlled automated complex at capacity up to 2000 sq. m per hour. The automated complex significantly reduces need for use of an expensive, hard and dangerous labour of divers. Nevertheless, in many cases the necessity of use of divers for works coupled with underwater cleaning still remains.Works carried out with the use of the given technology on cleaning of underwater parts of various vessels, including large-capacity vessels, such as tanker "Kuban", have confirmed its high efficiency and excellent quality of cleaning.Beside cleaning of underwater parts of ships, cavitation technology can be used for inspection and cleaning of submerged parts of marine petroleum platforms, berths, underwater pipelines and other hydraulic engineering structures (both at the bottom and/or on vertical walls), including cutting and destruction of underwater concrete constructions.
The technology of cleaning with use of a cavitation does not affect an environment, because the cavitation provides possibility to remove biological growth, not causing any harm of a wholeness

of a stratum of paint. The deleted organic remains are deposited on a seabed, not causing any contamination for a marine environment, and what is more, they are involved into feeding and metabolic processes going on in a sea.

5.4. Performance characteristics of Russian technology

The technology under consideration exceeds in many respects the technology based on use of the diving brush tool of firm PHOSMARINE, which is the most widespread in the world mean for underwater hull cleaning.
Opportunities and restrictions in application of the technologies used for cleaning of various surfaces under water are submitted in the table below:

WORKS, OPPORTUNITIES, EFFECTS	BRUSH-BASED TECHNOLOGIES	CAVITATION TECHNOLOGY
Hull cleaning of vessels up to "white metal"	is impossible	is possible, at increase of time of processing
Cleaning of Kingston valves' lattices	is restricted	is enabled by each single tool simultaneously at once over all directions
Cleaning of vessel's rudder and propeller complex	is restricted	is possible without loss of capacity
Cleaning of submerged parts of industrial marine platforms and structures	is impossible	is possible up to any degree of cleanness
Cleaning of yachts and boats	is restricted	is effective, without risk of damage of a surface of the case
Cleaning of small-sized objects (devices) and surfaces of the complex form	is impossible	is possible without loss of capacity
Number of passes of the tool to achieve the given degree of cleanness	depends on type and degree of fouling (several)	is just one
Automation of process of cleaning	is very complex technically	is realized by installation on ROV.
Cleaning of pipelines, internal surfaces of ground industrial tanks	is impossible	is possible
Damage of sheeting	is inevitable	is absent
Environmental contamination	is inevitable (by toxic elements of a ship paint, oil of a hydro drive)	is absent
Need for account materials and also deterioration of the tool	are present (depending on type and a degree of fouling)	are absent

Below, the comparison of two methods of cleaning using results of tanker (displacement 50 thousand tons) cleaning is given. An area of tanker's underwater surface was near 10 thousand sq. m, and one-brush model "Sea Brush" at designed capacity of 300 sq. m. per hour was taken for a comparison.

Performance parameters of tanker cleaning	Cleaning method	
	Sea Brush	Cavitation
Designed output, sq. m/hr	300	250
In-use output, sq. m/hr	100	250
Total time to complete the whole job, hr	100	40

Generator of cavitation jets is arranged in such a manner that at its work it is not exposed to destruction as the working body consisting of vapour-and-gas-filled bubbles is formed already outside the tool. Brushes periodically should be changed because of deterioration. Cost of a brush depends on its design and purpose, and makes in US dollars:

Nylon	45	to remove reasonable fouling
Steel	52	to remove reasonable fouling
Hard steel	95	to remove hard fouling
Stainless steel	130	to remove hard fouling
Special brush	770	to remove very hard fouling (barnacles)

6. BoatScrubber International Limited NESSIE

"NESSIE" is the first effective in-water hull cleaning system in the world. It cleans the hulls of boats whilst they remain in the water. Large circular rotating brushes attached to long arms are fixed to a frame on the sea bed. The brushes move to water line and locate the sides of the boat, and then automatically find the bow. The specially designed brushes auto locate to the contours of the hull, cleaning from top to bottom as the boat is winched through the unit. A typical 10 metre yacht will take about 10 minutes to clean. The unit is designed to be gentle and remove the slime before the weed and barnacles appear. However, tests have shown that even with light pressure, heavily weeded boats have been cleaned. The specially designed circular brushes have been chosen for their thoroughness in cleaning around corners, keels and propellers, as well as getting into acute angles and ridges often found on power boats. This means it will clean most boats even with non conventional shapes.

The unit is designed to operate in the harshest of environments. It will operate in rivers, tidal areas and with cross winds and currents. The unit can also be placed between pontoons, piles or put on a launching trolley.

The BoatScrubber is designed to occupy the minimum of space. The unit has been made to sit on the sea bed along side any existing pontoon or sea wall. When the unit is not in use the arms rest on the sea bed, thus allowing the berth to be used in the normal way and maximising the navigable area within a marina or harbour.

Figure 6.1. NESSIE

Conclusion

In this paper, observe of main solutions of cleaning a ship is offered, allowing to make decision about necessity of underwater ship hull cleaning by robotic devices. Such systems will enable excluding the use of dry dock for performance of this operation that will reduce many times the cost of ship maintenance.

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Akinfijevs T., Januševskis A., Lavendelis E. Kuģa korpusa tīrīšanas iekārtu īss apskats

Rakstā veikts kuģu korpusu tīrīšanas tehnoloģiju un iekārtu apskats. Vispirms apspriesti kuģu korpusu un dzenskrūvju apauguma izsauktie tehniski ekonomiskie aspekti un nepieciešamie to tīrīšanas intervāli. Apskatītas eksistējošās rotējošās birstes, kas izgatavotas no dažādiem materiāliem un domātas virsmu ar dažādu apauguma pakāpi tīrīšanai. Aprakstītas iespējas „Seavac" tīrīšanas iekārtai ar trīs birstēm, trīs atbalsta riteņiem un hidropiedziņu. Analizēta no attāluma vadāmā kuģa korpusa apkopes iekārta „AHMV" un tās tehniskie parametri. Apskatīts augstspiediena ūdens strūklas robots „HydroCat" zemūdens virsmu tīrīšanai un kavitācijas tehnoloģija. Veikts kavitācijas tīrīšanas tehnoloģijas salīdzinājums ar tradicionālo birstu tīrīšanas metodi. Apskatītas unikālās zemūdens liela diametra rotējošās birstes „Nessie", kas ar manipulatoriem tiek pozicionētas attiecībā pret peldošu kuģi tā korpusa tīrīšanai. Darbā parādītas zemūdens kuģu korpusu tīrīšanas priekšrocības salīdzinājumā ar sausā doka paņēmienu.

Akinfiev T., Janushevskis A., Lavendelis E. A Brief Survey of Ship Hull Cleaning Devices

In this paper is proposed a survey of technologies and devices for cleaning of ship hull. Firstly, technical and economical aspects of ship hull and propeller fouling influence and necessary cleaning intervals are discussed. Different brushes are considered for underwater cleaning of surfaces with various fouling degree. Possibilities of the "Seavac" cleaning device with three rotating brushes, three traction wheels and hydraulic actuator are described. The technical characteristics of remotely operated vehicle "AHMV" for ship hull maintenance are analyzed. High pressure water jetting robot "HydroCat" for cleaning of underwater surface and cavitation technology are considered. The cavitation cleaning technology comparison with traditional brush cleaning method is provided. The unique device "Nessie" is considered for in-water hull cleaning by means of large circular rotating

brushes that by long manipulators are positioned against the hull of boat. Paper demonstrates the advantages of underwater ship hull cleaning in comparison with dry dock method.

Акинфиев Т., .Янушевскис А., Лавенделис Э. Краткий обзор устройств для чистки корпуса корабля
В статье предложен обзор технологий и устройств для чистки корпусов суден. Вначале обсуждаются технико-экономические аспекты вызванные обрастанием корпусов и гребных винтов кораблей и необходимые интервалы их чистки. Рассматриваются существующие ротационные щетки, изготовленные из различных материалов и предназначенные для чистки поверхностей с различной степенью обрастания водорослями. Описываются возможности чистящего устройства "Seavac" с тремя щетками и тремя несущими колесами и гидроприводом. Анализируется устройство удаленного управления „AHMV" по уходу за корпусом судна и его технические характеристики. Рассматривается робот водяной струи высокого давления „HydroCat" для чистки поверхностей под водой и кавитационная технология. Проведено сравнение кавитационной технологии с традиционным щеточным методом очистки. Рассмотрены уникальные вращающиеся под водой щетки большого диаметра „Nessie",. которые посредством манипуляторов позиционируются относительно судна на плыву для чистки его корпуса. В работе показаны преимущества подводной чистки корпусов кораблей по сравнению с чисткой в сухом доке.