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HIGH VOLTAGE DISCHARGE SYSTEM FOR GRANULATING HARD MATERIALS

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Abstract: *The possibility of using high voltage discharge system for granulating and removing biological fouling of the underwater hull and appurtenances of surface like ships and submarines is discussed. The main idea of this method is to use electromechanical interaction between metallic surface - hard brittle cover - waters - discharge electrodes. Electromechanical model is analysed by computer simulation and experimental investigation. Different bending and tensile experiments for specimens to find negative boundary stresses where perform. To check up of the safety of organisms living in the water was made very easy experiment with fishes. The efficiency of high voltage discharge system for granulating others hard materials is shown.*
Key words: *high voltage discharge, ship, hull cleaning, granulating of hard materials.*

1. INTRODUCTION

The investigation is connected with project where cleaning and surveying task on the ship hull will be done underwater without the need of taking the ship to the dry dock by means of a low cost auxiliary climbing robot (Fig. 1.).

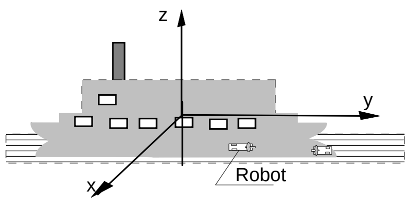

Fig. 1. Scheme of system with robot

Investigation shows that cleaning head is a critical point where new contributions and ideas will be very welcome because productivity of system must be very large, for example, about 70 m^2/h like cropper in the dry field.
Investigations shows that simple mechanical system like vibration technology under water not so efficiency against electromechanical plasma systems (Akinfiev & Armada, 2004; Akinfiev et al, 2003, 2002). With this aim high voltage discharge working element was made (Fig. 2.).

Fig. 2. High voltage discharge element and hard experimental cleaning surface.

The main element of high voltage discharge system is special power pack with condensers batteries and control system (Fig.3.).

Fig. 3. Power pack and control system for high voltage discharge system.

The electromechanical model was analysed parallel by computer simulation and experimental investigation. Computer simulation shows that full system includes many unknown parameters of electrical part and cover material. Therefore special experimental investigation was made with system: metallic surface - hard brittle cover - waters - discharge electrode.

2. PROBLEMS OF IMITATION OF BIOLOGICAL SEA ADHERENCE

At creation of the robot there is a necessity of its tests in a pool on the separate fragments of an underwater part of the ship hall. In this connection there is a problem of imitation of biological sea adherence on the surfaces of the fragment placed in a pool. Besides, the level of sea adherence on surfaces can be various. Biological adherence on surfaces of the ship hall can be subdivided on soft, hard and composite. The examples of soft adherence are slime, ooze and seaweed. They render the minimal influence on a course of a ship and stability of paint and varnish covering of its underwater part. Hard adherence have limy structure and render negative influence on a course of a ship and quality of a paint and varnish covering of its hall. Composite adherence essentially damages the ship hall, and also has an unfavourable effect on operation of the ship equipment. Significant difficulties are caused with clearing of ship hall from sea adherence with rating FR = 80 - 90, characterized by occurrence on the hall of a limy environment. Still the highest difficulties arise during the clearing from composite adherence with rating FR = 100. Thus, first of all it is necessary to simulate adherence with rating FR = 80 - 100.

3. PRODUCTION OF SIMPLE SPECIMENS

In condition of absence of the full analytical information on structure of sea adherence it is necessary to synthesize from available components the substance close on adhesive and strength parameters to real biological adherence with FR = 80 - 100. Besides, the synthesized substance should not damage ship paint during clearing. Therefore hydraulic cement of mark 500 and quicklime were used as knitting substances, but washed river sand of average granularity was applied as filler. Then samples of two types with various proportions of chosen components were made (Fig. 4, Fig.5). One sample had the form of a beam with the sizes 40 x 40 x 160 mm (it was used for determination of strength characteristics. The second sample has been executed in the form of a cube with the sizes 40 x 40 x 40 mm and with anchor; this sample was applied for determination of adhesive characteristics (Fig. 4., Fig.5. at the left). All samples were tested after normal solidification within three days.

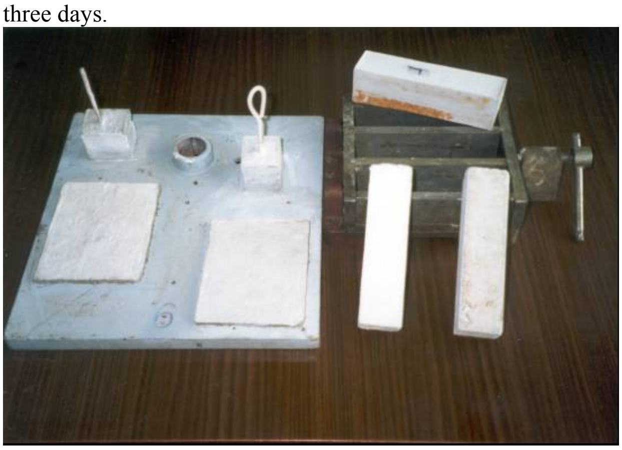

Fig. 4. Tree kinds of experimental specimens: - cubic; - thin plane; - beam. All was made by concrete structure with different proportions of components.

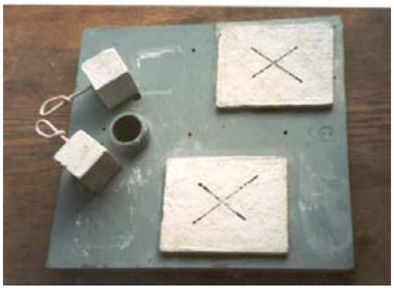

Fig. 5. Different tensile experiments for specimens to find negative boundary stresses (left side).

4. RESULTS OF TESTS

Tests on durability of beam-type samples were carried out by their mounting on two supports and further bending loading (Fig. 6. - 8.). Samples were tested to failure. Adhesive properties were determined in testing of cubic form samples with the same structure. Tests were carried out by sample's peeling from the painted surface. In total 24 samples (12 - for durability and 12 - on adhesion) have been tested. During tests the adhesive properties of paint coating executed by enamel paint have been determined, too. Result of this test is as follows: σ_{adg} = 4,6 кG/cm^2. Testing shows that cement mortars

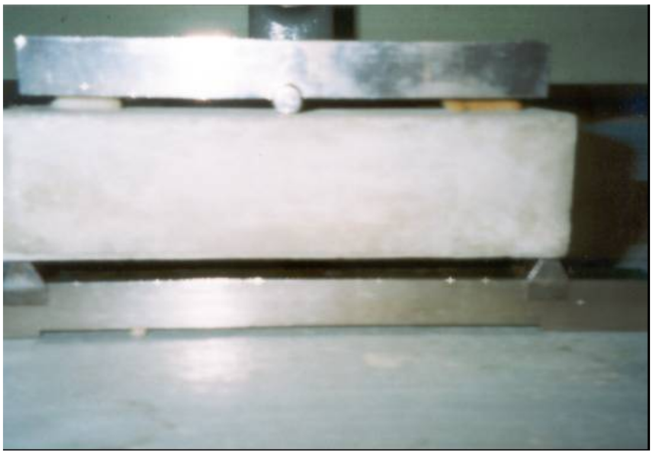

Fig. 6. Bending experimental device to find bound of crash strength. Crash fracture must be in the middle of specimen.

Fig. 7. Different bending experiments with different hardness of specimens to find crash strength. Crash fracture is in the middle of specimen.

can not be used as simulators adherence because of their rather high adhesion with the paint and varnish covering, exceeding the σ_{adg} of the paint. At the same time the given materials possess very good strength characteristics. Lime and cement mortars also cannot be used as the simulator of a covering because of their low durability (despite of their rather suitable adhesive characteristics).

Fig. 8. Special plane specimen for imitation of main hard adherence.

By the results of the executed tests it is offered to use composite material as the simulator of adherence. In this case bottom layer with thickness no more than 1 mm is formed from a lime-cement and quick lime and the top layer (not less than 5 mm in thickness) is executed on cement mortar without quicklime. Thus the thin bottom layer possesses average adhesive characteristics and cannot destroy paint and varnish covering, but the top layer has rather high strength properties.

5. PRODUCTION OF COMPLEX SPECIMENS

To check up the influence of several hard and soft parts inside cover on the cleaning processes the additional complex specimens were made. They include same helix screws, mussels and herbage (Fig. 9. - 11.). Real experiments with complex specimens also show very good efficiency of high voltage discharge cleaning method.

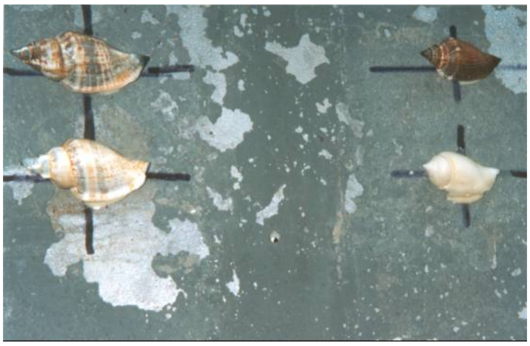

Fig. 9. Specimens of screws

Fig. 10. Specimens of mussels.

Fig. 11. Specimen of common adherence particles

6. EXPERIMENTAL SIMULATION BY HIGH VOLTAGE DISCHARGE SYSTEM

For experimental investigation and simulation where made several specimens. Part of them is shown in Fig. 9. - 12. Silicate bricks, ceramic tiles, sea cockleshells, the simulator of a limy covering, the simulator of composite coverings (a limy layer, cockleshells, seaweed) have been chosen as test objects under the following parameters of the high-voltage plasma discharge: - voltage U_c = 10 kV; - capacitance of the energy accumulator C_N = 14 μF; - type of the electrode -edge - to - edge; - distance from the axis of plasma filament up to the surface of tested object 20 mm.

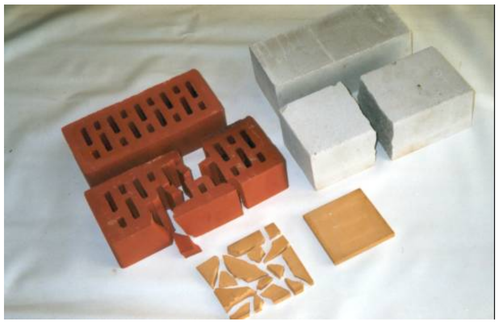

Fig. 12. Three cases of efficiency of high voltage discharge system: - demolish of porous brick; - demolish of full brick; - demolish of thin ceramics.

Silicate bricks compression strength is equal to σ_c = 150 кG/cm^2. Overall dimensions of the brick are as follows: 250 x 120 x 85 mm. Section of destruction: 120 x 85 mm. Pattern of destruction is presented in Fig. 12 (on the right).
Ceramic tiles compression strength is equal to σ_c = 900 кG/cm^2. Overall dimensions of the tile: 100 x 100 x 10 mm. Section of destruction: 100 x 10 mm with the subsequent crushing on more fine splinters. Pattern of destruction is presented in Fig. 12.
Isolated cockleshells placed in an epicentre of the high-voltage discharge are completely failed, and splinters are removed by a shock wave. Energy of the discharge was 700 J. Destroying tests of 10 cockleshells were preliminary carried out by shedding on them of a balance weight G from height H. Fragile failure came at energy of impact $W = G{\cdot}H = 7{\cdot} 0{,}15 \approx 1$ кGм = 10 J.
Group of cockleshells placed in an epicentre of the high-voltage discharge is completely failed, and splinters are removed by a shock wave. Peripheral cockleshells break away from the ship hall in radius up to 160 mm from an epicentre. Cockleshells have been fastened to the painted metal plate by epoxy adhesive with σ_{adg}= 6 кG/cm^2. For reliable work of installation the pressure providing breaking-off of cockleshells from a plate, should exceed the adhesive pressure σ_{adg} approximately in 2 times (pressure describes a force of coupling between cockleshell and layer of a paint). Hence, in this case it is necessary to realize a shock wave with rarefaction 12 кG/cm^2.
The lime adhesive structure was rendered on the steel plate with dimensions 450 x 180 x 10 mm and painted by enamel paint. After three-day hardening the simulator has been placed into water and then was exposed by a high-voltage plasma discharge. Pattern of destruction is the following: in an average part one can see fine pieces of substance of a covering, but to the right and to the left of an epicentre the separation of big pieces of adherence without their crushing is observed. The radius of the failed surface exceeds 200 mm, i.e. it is comparable with the diameter of one standard cleaning brush. But damages of paint on the plate of the simulator are not observed.
Composite adherence besides the limy covering, contains some cockleshells and seaweed. The pattern of the destruction is the

following: in the central part of the simulator fine pieces of substance of a covering and a shell of cockleshells are observed, but on the right and at the left separation of the big pieces without their crushing occurs.

7. THE DESIGN OF THE HEAD AND ELEMENTS OF FASTENING TO THE ROBOT

Fig. 13., 14. shows the real electrode head with a longitudinal electrode axis, which intended for clearing ship hall from sea adherence. It consists of the plastic case 1, the positive electrode 2 connected to a cable 3, a collar of fastening 4, a negative electrode 5 and template rollers 6.

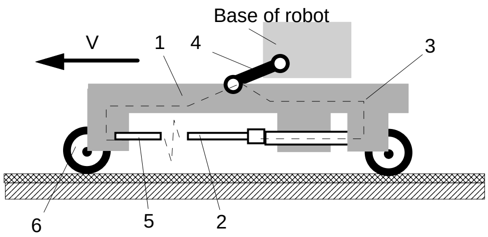

Fig. 13. Electrode head

The head is suspended on the robot by the elastic shock absorber. The purpose of the absorber is as follows: suppression of kinetic energy of the head during its jumping at explosion, and also acceleration of its returning in a starting position.

Fig. 14. View to electrode head from bottom

8. CHECK UP OF A SAFETY OF LIVING BEING

To check up of the safety of organisms living in the water was made very easy experiment with fishes. Inside round vessel with water 1 was insert fishes 2 (Fig. 15., 16.). This vessel was plunging inside the tank 3.with water too. The high voltage discharge process 4 was made close vessel 1. The results were very interesting and positive: when the high voltage discharge was switched the fishes stay closes border of vessel and stay alive.

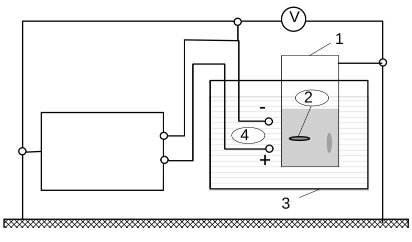

Fig. 15. Scheme of experimental equipment.

Fig. 16. Normal float of fishes after some experiments

9. GRANULATING OTHERS HARD MATERIALS

Experimental power pack and control system were used for granulating others hard materials inside water. Experiments show a good result. The main efficiency may be described with difference direction of huge tension and presses strains after high voltage discharge in water: - in the phase of tension stresses the hard cover crashed and spring down. For Example, testing of system by cleaning a tube from full rust gives a good results - after processing tube was completely clear (Fig. 17.).

Fig. 17. View to tube from full rust

9. CONCLUSION

It is shown that high voltage discharge method is very productivity for granulating the hard materials into water. The method may be also used for blend a liquids together or to blend dry fractions with liquids.

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