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Hydrocavitational Surface Cleaning

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Abstract—In production, it is often necessary to remove contaminants from surfaces even though power washing is inadequate to the task. A hydrocavitation system simplifies such cleaning.

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In the present work, we describe a hydrocavitation system and compare the effectiveness of hydrocavitation and pressure washing in the surface cleaning of buildings and structures with unwanted paint, plaster, polymer and other coatings, decontamination of portable equipment, and removal of radioactive metal waste.

The process of cavitation (derived from the Latin *cavitas*) involves the formation of bubbles (cavities) in liquids and their subsequent collapse, with intense energy release, accompanied by noise and hydraulic impact [1]. Initially, cavitation was regarded as a harmful process, associated with noise, vibration, and erosion. Research on cavitation proceeded very slowly, because it was difficult to produce high liquid velocities in laboratory conditions.

Today, statistics and dynamics have been developed regarding a single cavitational bubble in infinite liquid and close to a wall [2–5]. Although cavitation is undesirable in many cases, there are also exceptions. Its benefits have been confirmed in medicine, for example [6].

At Ozersk Technological Institute (a branch of Moscow Engineering Physics Institute), cavitation is investigated on a patented system in which cavitation may be produced in a water flux at the required pressure and temperature (Fig. 1), in the following contexts: 1) surface cleaning; 2) modification of surface coatings; 3) structured water, which retains its structural modifications for two months or more.

Surface cleaning has attracted the most interest. Hydrocavitational cleaning is based on water jets created by a cavitation system such that bubbles collapse at the surface to be cleaned [7–9].

In cleaning a metal surface, grease, dust, and water are removed. The resulting surface is ready for coating application, without further treatment.

The details of the system for removing contaminants and coatings from surfaces by means of water, without any cleaning products, have been patented.

The device (Fig. 2) has a tubular housing with a coaxial cavitation tube, input and output turbulizers, an input tube (confusor), and an output diffuser extending beyond the cavitation tube. The input and output turbulizers are positioned so that the output flow from the input turbulizer passes along the axis of the channels in the output turbulizer. Patented measures permit increase in intensity of the cavitation processes.

The hydrocavitation system includes a high-pressure membrane pump supplying cold water to a high-pressure diesel heater. The hot water passes in a hose to a modified nozzle with a cavitation device. The water flux from the cavitation system ensures that bubbles collapse at the surface to be cleaned. The hydrocavitation equipment is shown in Fig. 3.

The effectiveness of hydrocavitation cleaning is confirmed in the removal of Protegol UR-Coating 32-60 and UP-1000/FRUCS 1000 A epoxy–polyurethane coatings (Figs. 4a and 4b); and in the removal of a multilayer coating (plaster and several layers of paint)

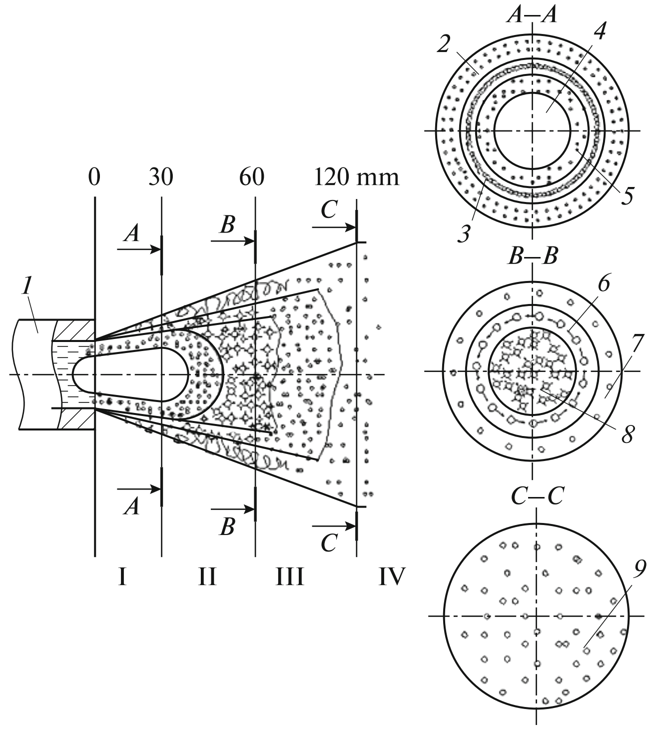

Fig. 1. Structure of turbulent conical jet: (I) formation of turbulent flow; (II) destruction of sublimated jets; (III) cavitation; (IV) damping of jets: (*1*) nozzle; (*2*) finely disperse spray; (*3*) rotation of sublimated jets; (*4*) low pressure; (*5*) cavitational bubbles; (*6*) rotation of sublimated droplets; (*7*) escape of vapor–gas mixture; (*8*) cavitation; (*9*) disperse activated water droplets.

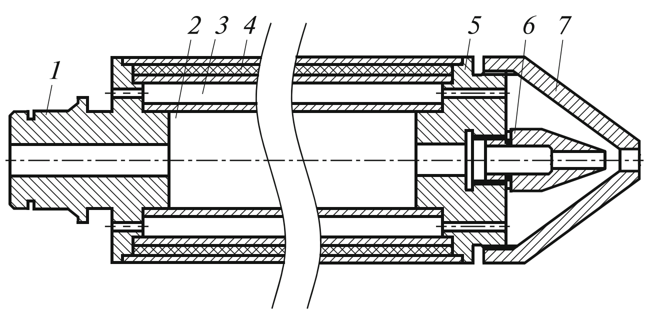

Fig. 2. Gas-jet system: (*1*) primary flange; (*2*) working-fluid chamber; (*3*) chamber with passive (indrawn) fluid; (*4*) heat insulation; (*5*) secondary flange; (*6*) nozzle; (*7*) diffuser.

from a complex array of walls and metal grids (Figs. 4c and 4d).

In surface preparation for further repair, the following results are obtained.

(1) The removal of paint from a 2400 × 900 mm cast-iron grid takes 3 min.

(2) The removal of paint and plaster from a 1000 × 800 mm brick wall takes 4 min.

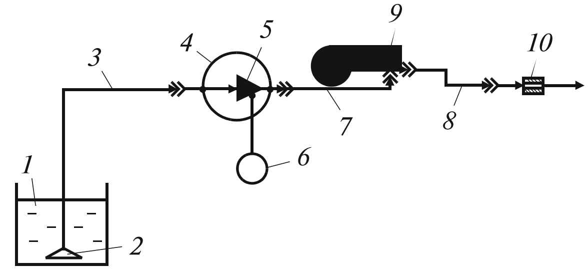

Fig. 3. Hydrocavitation system: (*1*) water chamber; (*2*) coarse filter; (*3*) hose; (*4*) high-pressure pump; (*5*) vibroacoustic module; *6*) frequency control unit; (*7*, *8*) high-pressure hoses; (*9*) high-pressure flow-through heater; (*10*) nozzle.

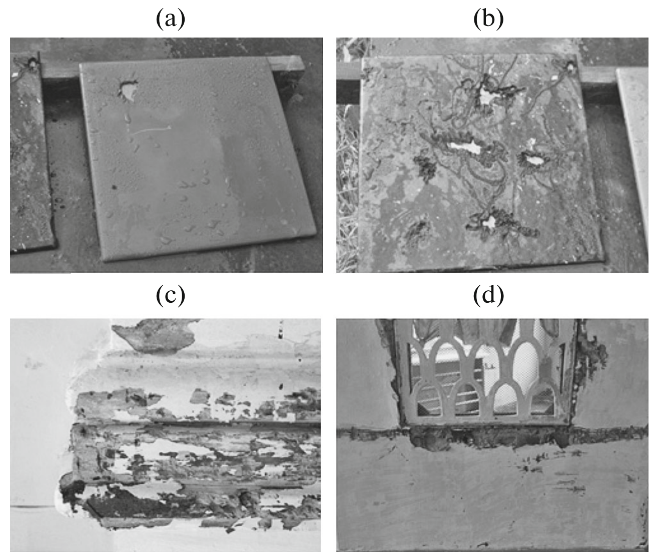

Fig. 4. Plates with Protegol UR-Coating 32-60 (a) and UP-1000/Frucs 1000A (b) coatings and surfaces of complex walls (c) and metal gratings (d) after hydrocavitational treatment.

(3) The removal of paint and plaster from a 1100 × 300 mm brick wall of complex configuration takes 4 min.

In the nuclear industry, portable equipment must be decontaminated in repair and decommissioning. Several groups of decontamination methods are available for radioactive metal wastes and components [10–12]: liquid, thermal, and mechanical methods.

In searching for new technologies with reduced water consumption, in accordance with current environmental and safety requirements, hydrocavitation has proven useful in removing contaminants such as paint, fuel oil, and rust from metals.

To assess the effectiveness of decontamination of portable equipment and radioactive metal wastes, we compare the cleaning of stainless steel, carbon steel,

Table 1

Material	Initial radioactive contamination, particles/(cm^2 min)	K_d	
		hydrocavitation	high-pressure treatment
09Г2С and Ст3 steel	30–7245	8–720	1.7–270
12Х18Н10Т steel	104–41 000	5.5–20.1	2.2–18.0
Cast iron	27–10 000	3.3–133	4.3–23.3

and cast iron by hydrocavitation and by standard high-pressure treatment [13].

In the decontamination tests, we consider fragments of water-treatment tanks from the reactor-cooling system and decommissioned equipment such as slide valves and pipeline flanges (Fig. 5). The surface is coated with industrial and/or corrosion deposits; in some cases, several layers of paint are present. All the equipment and radioactive wastes have surface contamination due to the presence of both alpha and beta radionuclides.

The effectiveness of decontamination is assessed by means of the coefficient $K_d = A_{in}/A_f$, where A_{in} is the initial radioactive contamination of the sample, particles/(cm^2 min); and A_f is the final value after decontamination, particles/(cm^2 min) [14].

(a) (b)

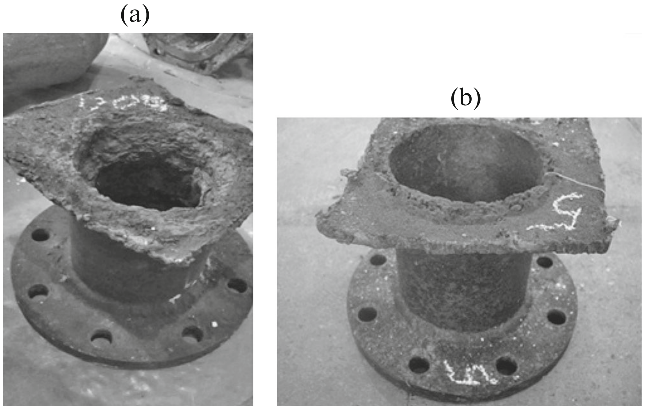

Fig. 5. Radioactive metal wastes before (a) and after (b) high-pressure treatment.

The treatment of stainless-steel samples does not result in satisfactory final contamination. Overall, however, the comparison of points in the treated equipment with identical parameters (initial level of contamination and type of deposits) shows that the hydrocavitation system is more effective than high-pressure treatment.

The experiments indicate that the effectiveness of decontamination depends most on the effectiveness of removing deposits and protective coatings from the metal surface. Since the cleaning of the metal is better by hydrocavitation, the K_d values are at least twice those for high-pressure treatment. Table 1 summarizes the decontamination results for the radioactive metal wastes.

Table 2 presents the effectiveness of decontamination and quality of surface cleaning for a concrete floor with applied paint; a brick wall covered with plaster and paint; a concrete wall with a layer or paint and/or plaster; floor tiles; and asphalt [15].

Building surfaces before and after treatment are shown in Fig. 6.

Table 3 presents the results for the decontamination of a road surface (asphalt) contaminated by β radionuclides.

The results show that, in most cases, the required values are obtained in the deactivation of portable equipment, radioactive metal wastes, building surfaces, and road surfaces.

(a) (b) (c)

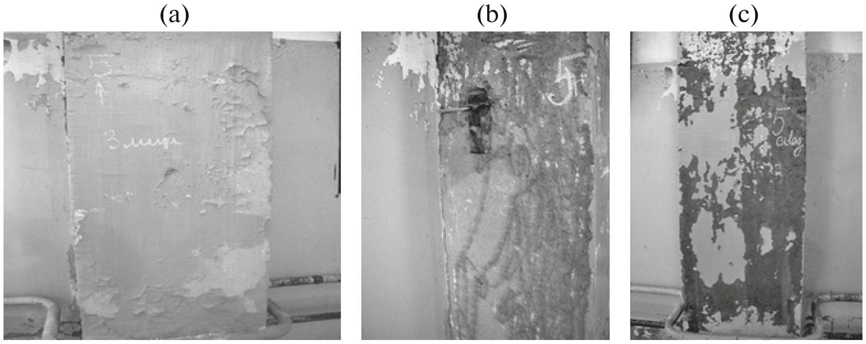

Fig. 6. Paint-covered concrete support before (a) and after hydrocavitation (b) or high-pressure treatment (c).

Table 2

Material	Initial contamination (flux density), β particles/(cm^2 min)	Visual assessment of coating removal, %		K_d	
		hydrocavitation	high-pressure treatment	hydrocavitation	high-pressure treatment
Paint, plaster, concrete	10–100	85–100	0–80	1–9	1–5

Table 3

Treatment method	Initial contamination (flux density), β particles/(cm^2 min)	K_d
Hydrocavitation	130–357	8.8–57
High-pressure treatment	170–280	3.5–5

The effectiveness of hydrocavitation exceeds that of high-pressure treatment by at least a factor of two in the surface treatment of carbon- and stainless-steel radioactive wastes contaminated with β radionuclides, by about factor of two in the treatment of building structures, and by at least a factor of three in the treatment of road surfaces.

The hydrocavitation system more effectively removes industrial, corrosion, and other deposits from dismounted equipment, with less water consumption. The use of hydrocavitation instead of high-pressure treatment decreases the volume of secondary liquid radioactive wastes by a factor of at least three (up to 15 in the decontamination of asphalt in the open air).

Hydrocavitation is considerably more effective than high-pressure treatment in removing paint, plaster, and other coatings from building surfaces and in cleaning asphalt surfaces.

The hydrocavitation system, which combines three cleaning methods (hydrocavitation, air jets, and steam), is also preferable in environmental terms, since it relies on superheated water (above 120°C) and high pressures (above 170 atm), thereby eliminating the need for further treatment (such as sand or shot blasting).

We find that the cost of cleaning 1 m^2 of surface is 2.3 times greater for high-pressure treatment than for hydrocavitation.

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