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CAVITATION METHOD FOR WASHING OUT FABRICS IN THE FIELD OF ELASTIC VIBRATIONS

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Abstract: *The results are presented of the research related to the influence of ultrasonic and hydroacoustric vibrations on the process of washing out fabrics after operations of dying and printing. Kinetic experiments demonstrated that application of hydroacoustic generators to intensify the process allowed to increase the rate of washing out of fabrics by a factor of 3 or 4.*

Key words: *cavitation, washing out fabrics, desorption, ultrasound, elastic vibrations, magnitostrictive transducer, hydroacoustic generators, rate of washing out.*

1. INTRODUCTION

During the recent years a special attention has been paid to the application of cavitations' effects in various technological processes [1]. In many countries cavitation is used for cleaning dirty surfaces, washing workpieces, degreasing, making coatings on materials with poor wettability, removing boiler deposits and carbon, etching, dispergating and emulsification to obtain particles with nanodimensions. It is known that cavitation exerts an effective action on various technological processes in the chemical and food industry [2]. The principal possibility has been demonstrated to use acoustic vibrations, primarily ultrasonic vibrations, to intensify the washing out of fabrics after dying and printing operations [3, 4].

Under the action of elastic vibrations on the processes in liquids the following main effects occur [5]:

- modification of the structure of the interface layer solid – liquid – gas that leads to a substantial increase in the diffusion rate;
- degazation of liquids and materials;
- fine dispergation and homogenization of two-phase systems under the action of cavitation field.

In the present paper the results are presented related to the intensification of fabric washing out in the cavitation field generated by elastic vibrations.

2. EXPERIMENTAL RESULTS AND DISCUSSION

The influence of elastic vibrations on the kinetics of washing out of fabrics after printing was studied using the cavitation washing out setup (Fig. 1), which allows to perform the process under the action of stationary ultrasound generated by the generator of diaphragm type with the frequency f = 22 kHz or in the cavitation field of a hydroacoustic generator. The quality of washing out was determined according to the dye desorption degree C_D, which was defined as the ratio of the quantity of the desorbed dye in the specified time moment τ to the initial content of the unfixed in fibers dye C_0. The desorption rate was controlled over the change in the dye concentration in the rinsing solution. The results of the experiments on the desorption process are presented in Table 1.

The experimental data showed that the ultrasonic treatment does not influence the equilibrium degree of the dye desorption, though it changes dramatically the kinetics of the process (Fig. 2). The treatment by the ultrasonic field diminishes the time, during which the equilibrium desorption can be reached, by a factor of 2 – 4.

Thus, at the ultrasonic washing out at the temperature of 80 C, the desorption process practically finishes for 40 – 60 s. In this case, the values of the constants of the desorption rate K calculated using the kinetic curves are by a factor of 2 – 3 greater than those for the case, when washing out is performed without ultrasonic treatment [3].

This can be explained by the fact that for printed fabrics the components, which should be removed (the vis-

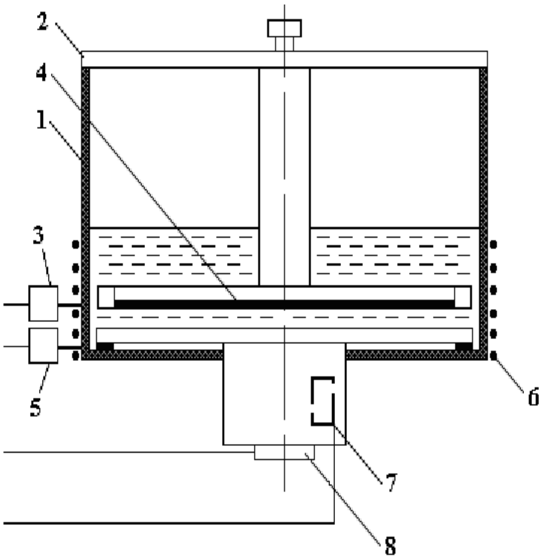

Fig. 1. Setup for washing out textile materials: (1)- bath; (2) regulating unit; (3) transduser for the registration of cavitation; (4) sample; (5) thermocouple; (6) heater; (7) piezosensor for measuring amplitude; (8) magnitostrictive transducer PMS-6M.

Table 1

Desorption degree C_D, % in the washing out process of printed fabrics

no.	Methods used for washing out fabrics	Temperature, °C	C_D, %						
			Desorption time, τ, min						
			1/3	2/3	1	2	3	4	5
1	Hydroacoustic cavitation	60	52.3	68.5	75.3	80.2	82.4	82.6	82.6
2	Without cavitation action	60	30.0	44.5	58.5	72.2	82.3	82.4	82.6
3	Ultrasonic cavitation	60	72.2	78.2	80.1	80.4	82.4	82.6	82.6
1′	Hydroacoustic cavitation	20	19.5	28.0	33.2	48.2	50.5	51.0	54.5
2′	Without cavitation action	20	8.3	17.5	23.4	38.0	41.1	44.3	45.6
3′	Ultrasonic cavitation	20	25.3	32.0	38.3	47.8	51.7	52.1	54.6

cosifier film or unfixed dye, for example) are located on the surface of the textile material or in the layer adjacent to it. The ultrasonic action during the washing out process is to a significant degree related to the mechanical action on the fabric surface. In this case, owing to the influence of the sound pressure, acoustic flows and capillary effect the conditions are created for dissolution and emulsification of the unfixed dye and of the viscosifier film from the fabric surface. It was shown that when the ultrasonic method is used with the aim to intensify the washing out to the maximal possible extent, it is expedient to place the ultrasound source parallel to the fabric plane at the distance of 8-10 mm from it.

The results of our investigations give evidence that application of the ultrasonic cavitation is effective to intensify the washing out of printed fabrics.

However, despite its high efficiency, the application of ultrasound is not economically advantageous, because it is linked with the great energy consumption and com plicated equipment used. The possibility to use hydroacoustic generators was studied, because they possess some energy advantages. These generators produce a wide sound spectrum; however, their maximal acoustic power corresponds to the basic frequency f_0, which depends vs. the generator geometrical parameters and the liquid pressure at the generator inlet.

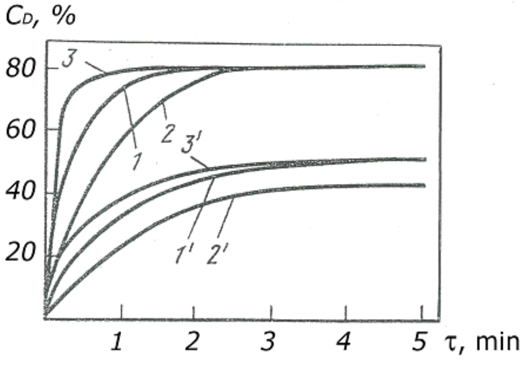

Fig. 2. Kinetics of desorption of the dye during washing out the printed fabric. The fabric speed amounted to 75 m/min. (1, 1′) Washing out in the cavitation field of the hydroacoustic generator (P_{vapor} = 1.5 atm, f = 11.5 kHz, P_{pump} = 5 atm); (2, 2′) washing out without ultrasound; (3, 3′) washing out in the ultrasonic cavitation field (I = 2 W/cm^2, f = 22 kHz). Solution temperature: (1, 2, 3) 60 °C; (1′, 2′, 3′) 20 °C. The active red dye 6S was used.

The kinetic research showed that the washing out rate using hydroacoustic generators is by a factor of 1.5 – 2 greater that the rate without generators (Fig. 2). This is somewhat lower than under the ultrasonic action; however, hydrodynamic generators have some advantages if compared with magnitostrictive generators of the membrane type. They are energy efficient, compact and easy-to-make. The optimal results were obtained using hydroacoustic generators feeded with a rinsing solution at the inlet generator pressure of P_{pump} = 4 – 5 atm and the distance between the generator and the fabric of S = 70 – 80 mm (Fig. 1).

Similar generators were used to intensify the washing out process in the operating washing out lines of a cotton mill. With this aim, the generators mounted on a hollow metal rod were installed in the washing out baths of the unit in the LPS-120 line between the loops of the fabric in such a way that their effective range covered the fabric width. It was shown that it is expedient to use hydroacoustic generators with the aim to improve the washing out rate and quality. Operating the hydroacoustic generators in plant conditions it is necessary to install a pump to maintain the high pressure of 4 – 5 atm at the generator inlet. This pump allows to provide the circulation of the rinsing solution in the closed loop: washing out bath – pump – filter – hydroacoustic generator – washing out bath.

With the aim to intensify the solution heating and to increase the cavitation cavity power in the hydroacoustic generators, we investigated the possibility to feed them with a saturated vapor. The visualization of the cavitation cavity shows that at the combined feeding of the generator by the solution and the saturated vapor, a pulsating jet is observed formed by the mixture of tiny vapor bubbles with the liquid. The geometrical dimensions of the jet increase with the increasing in the pressure of the feed

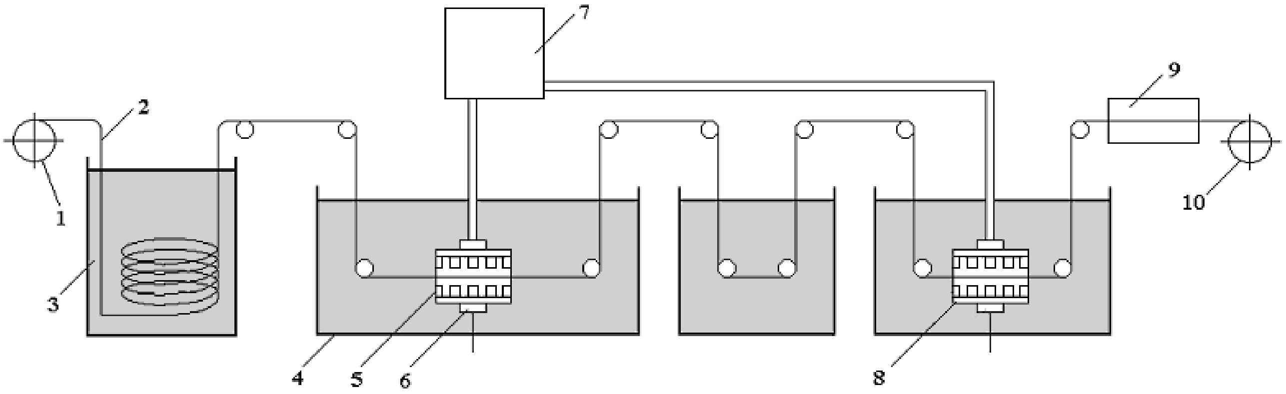

Fig. 3. Schematic of the washing-out unit LPS-120: (1) Feed cylinder; (2) fabric; (3) basin for fabric; (4) washing-out bath no. 3; (5) hydroacoustic radiator; (6) hydroacoustic unit; (7) pump; (8) washing-out bath no. 9; (9) dryer; (10) receiving cylinder.

vapor; at the same time the average dimensions of the bubbles forming the jet decrease.

It was interesting to clarify whether the action of the cavitation cavity (of the jet) is limited only by the surface layers of the fabric or the solution penetrates through the bulk of the fabric. With this aim the pressure was measured, which the jet exerts on the fabric as well as on the elastic membrane placed behind the fabric sample. The fabrics chosen for the investigation (muslin, coarse calico and flannel).significantly varied by their density, thickness, and hence, by permeability for the rinsing solution.

It was found that during the washing out in the cavitation field of the hydroacoustic generator, the mechanical action of the rinsing solution on the fabric surface was observed as well as the solution pressing through the bulk of the fabric. The pressure of the feed vapor of 1 – 2 atm and that of the solution of 4 – 5 atm should be considered to be the optimal parameters at the distance between the generator and the fabric of 70 – 80 mm. In this case the cross jet plane has maximal dimensions at the high intensity of its action on the fabric.

On the basis of experimental and theoretical research [5, 6] we can suggest the following washing-out mechanism under the action of elastic vibrations. The bubbles, which are present inside the fabric, pulsate in the cavitation field, move under the action of hydroacoustic flows, and carry along a part of the unfixed dye. Due to the motion, the unfixed dye separates from the fabric fibers. Simultaneously the other process takes place: the cavitation bubbles spray the tiny water drops on the surface of the unfixed dye and mix it. Because the pulsating bubble is a kind of a source of elastic vibrations, water drops can be rejected and divided at its surface. Hence, the cavitation cavities have a double function: they attract the dye drops due to microstreams, and then divide and spray the drops on the dye surface, thus forming fine emulsions. During vibrations of the emulsion, which consists of tiny water and dye drops, and also of tiny gas bubbles, the latter are displaced to the interface emulsion – washing-out medium - fabric. The cavitation cavities during their pulsations generate intensive spraying near the drop surfaces. This favors the emulsion formation of the dye with water, which can be easily eliminated form the bulk of the fabric.

To clarify whether it is efficient to use this method of intensification for washing out of fabrics after operations of dying and printing in plant conditions, the tests were performed at a cotton mill with the aim to determine the number of hydroacoustic generators and their location, as well as their optimal parameters, the pressure of the solution and of the vapor at the generator inlet.

Fifteen generators were mounted on a hollow rod and installed in one of the baths of the washing out unit in the LPS-120 line (Fig. 3) between the fabric loops in such a way that the entire width of the fabric could be subjected to the action of the generators. The hollow rod was mounted in a closed pipeline for the solution circulation and was connected with the vapor pipe by a flexible hose. Parameters of the feed solution and vapour were registered using manometers at the inlets of the hydroacostic generators. The efficiency of the action of the generators on the washing out process was estimated by determining the dye desorption degree both on the treated and untreated sides of the fabric.

The tests showed that the most effective action was observed, when the generators were installed in the third bath of the washing out unit, since in the case of the printed fabric, the main share of the components that should be removed (viscosifier and unfixed dye) were located on the surface of the fabric. In the first two baths of the washing out unit a soaking of the viscosifier film and the fabric occurs, which is necessary for the effective removal of the dye from the surface of the fabric. The action of the cavitation field of the hydroacoustic generators installed in the third washing out bath on the surface of the fabric facilitates the removal of the viscosifier and of unfixed dye soaked in the first two baths and at the same time maintains the high solution temperature.

In Table 2 the results are presented of the production tests related to the washing out of the printed fabric for the case, when one branch of generators (30 pieces) was installed in the third bath of the washing out line LPS-120 ((P_{vapour} = 1.5 atm, P_{solut} = 5 atm, S = 6 cm). The desorption degree of the dye from the fabric was measured after the third washing out bath and at the unit outlet (after the ninth bath).

It follows from the presented data that installation of one rod with generators allows to increase the washing out efficiency by 5 – 7 %; however, it is not enough to improve the dying stability index (in points) during wet

Table 2

Washing out degree for the printed fabric in the baths of the LPS-120 washing out unit

Dye type	Initial content of an unfixed dye, mg/l	Dye desorption degree, C_D, %, after washing out in baths No. 3 and No. 9	
		No. 3	No. 9
Orange	0.249	78.3 *) 72.4	90.0 83.4
Brown 6S	0.205	82,4 77.2	92.7 85.6
Blue OSR	0.195	71.8 64.8	85.1 80.0
Brown NG	0.368	81.3 76.2	85.6 79.6

*) With ultrasonic action (numerator); without ultrasonic action (denominator).

processes. It is known that, when the desorption degree of the unfixed active dye amounts to 95%, this provides the high stability indices of dyed fabrics [7, 8]. In this case, 15–20% of the dye should be removed out from the fabric after the third washing out bath. Hence, for the unfixed dye to be completely removed out from the fabric, it is necessary to install 2–4 branches in the washing out baths each containing 30 generators. This allows to reach the high washing out quality and at the same time to reduce 2–3 baths in the line; significantly reduces the water expenditure, equipment costs and production area.

The feeding of the hydroacoustic generators demands some additional vapour expenditure. The hour average vapor expenditure for water heating in the washing-out lines of the LPS-120 unit amounts to about 1890 kg/h. Because the feeding vapor at the same time is used for the heating of the washing-out solution, the additional costs for the vapour in one LPS-120 line (with 60 generators and two washing-out baths) amounts to less than 630 kg/s; the vapour expenditure per one generator is 21 kg/h. Diminishing in the number of the washing-out baths allows to decrease the water expenditure and to compensate by this the vapour consumption.

3. CONCLUSIONS

The presented investigations allow to conclude that it is expedient and promising to use the cavitation effects produced by hydroacoustic generators to intensify the washing out process of printed and dyed fabrics, because there is no need to change the design of a standard washing out bath. The generators are simple and easy to make and operate. Generators of the specified type can be manufactured and mounted using facilities of machine shops of finishing plants.

The possibility was shown to diminish the time, during which the equilibrium desorption can be reached, by a factor of 2–4 using the treatment in the field of elastic vibrations. Application of hydroacoustic generators allows to increase the efficiency of washing out fabrics by 30% and to reduce 2–3 baths in the line. This also reduces the equipment costs and water expenditure by a factor of 3; the production area reduces by on third of its quantity.

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