

IMPROVING THE EFFICIENCY OF THE EXTRACTION PROCESS IN PRODUCTION OF HYGROSCOPIC FIBROUS MATERIALS

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Keywords: cotton fiber material; extraction; intensification; technosphere safety; ultrasound.

Abstract: The aim of the paper is to make a reasonable choice of a resource-saving method to increase the efficiency of producing medical hygroscopic cotton wool, which is a strategically important dressing material. The paper explores the possibility of practical use of the chosen method of intensification and the proposed formulation of the technological solution to increase the efficiency of the extraction process (decoction), which largely determines the quality of the target product. The process is carried out in periodic devices with sodium hydroxide and other chemical reagents, and is characterized by high duration and energy intensity. The study is based on the experimental study of the process of extracting process contaminants (decoction) of cotton in the production of medical hygroscopic cotton, including a reasonably chosen ultrasonic effect for intensification.

The country has adopted a course to restore its own raw material base for cotton production, instead of importing raw materials that are constantly rising in price. The development of this segment is of strategic importance for Russia because cotton is used to make dressings, such as cotton wool, bandages, gauze, etc. The United Nations Organization declared October 7 the World Cotton Day. The basic requirements for medical hygroscopic cotton are regulated by GOST 5556–81. The processing of fibrous material into medical hygroscopic cotton wool is associated with the use of mechanical and chemical technology processes used to improve the quality of cotton. For medical hygroscopic cotton, the capillarity indicator is of great importance, since the degree of absorption of various secretions depends on it. At the same time, it is necessary to develop and introduce energy-efficient and environmentally friendly technologies into production [1 – 4].

It is not accidental that the process of extracting contaminants from fibrous cotton materials through decoction has been chosen for this research. It is during the brew that substances that worsen the quality of cotton are removed. Natural satellites in the form of pectin, nitrogen-containing, waxy and mineral substances, as well as woody parts of the plant: boxes, stems, cotton leaves and seeds. All these impurities are almost completely removed during mechanical and chemical treatments.

The process of boiling is carried out in periodic devices and, consequently, is characterized by a high duration and energy intensity. When it is carried out, harsh chemicals are used, such as sodium hydroxide. The process of decoction is insufficiently studied from the point of view of intensification and kinetic calculations. As shown in [5 – 10], in order to carry out calculations of the process of extracting technological contaminants from fibers and fabrics, it is necessary to accumulate data on kinetic coefficients, in addition, knowledge of the mass transfer and mass conductivity coefficients obtained on the basis of experimental data is necessary when justifying the method of intensification. Therefore, the results of an experimental study of the decoction process have practical and scientific significance.

The study was carried out at the Department of Energy and Resource Efficient Technologies, Industrial Ecology and Safety (ETPEB) shows that it is the use of ultrasonic effects on the mass transfer processes of chemical finishing technology that is one of the most effective for saving electricity and chemical reagents during mass transfer processes in conditions of internal or mixed mass transfer tasks, while increasing environmental and industrial safety [1, 2, 5 – 8].

The study of the process of decoction of cotton fiber was carried out in the laboratories of the Department of ETPEB and JSC TSNITI. The methodology of the experiments and the choice of the formulation of technological solutions were carried out taking into account the developments of the Department of ETPEB of the Kosygin Russian State University, JSC TSNITI, NPC ULTRASONIC.

Figure 1 shows a laboratory installation with a built-in bath bottom and an immersion ultrasonic radiator, which allows conducting studies with various parameters of ultrasonic exposure (ultrasound) and without the use of ultrasound. A large series of experiments was carried out when changing the composition of the working solution, using ultrasonic intensification and without it.

Figures 2 and 3 present the results of the study of the effect of the concentration of alkali in the working solution on the capillarity K of cotton during ultrasonic decoction and without intensification are presented. During the study, as can be seen from the figures, the concentration of sodium hydroxide in the working solution and the amount of textile excipients (TVB) changed.

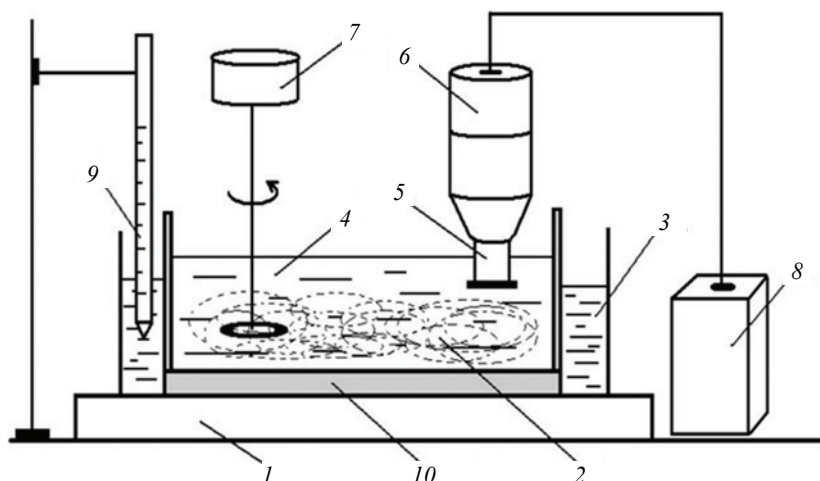


Fig. 1. Experimental laboratory setup:

1 – electric heater; 2 – fiber; 3 – glycerin bath; 4 – working solution; 5 – radiator; 6 – ultrasonic installation housing; 7 – agitator; 8 – ultrasonic generator UZH-01-04; 9 – thermometer; 10 – bath bottom

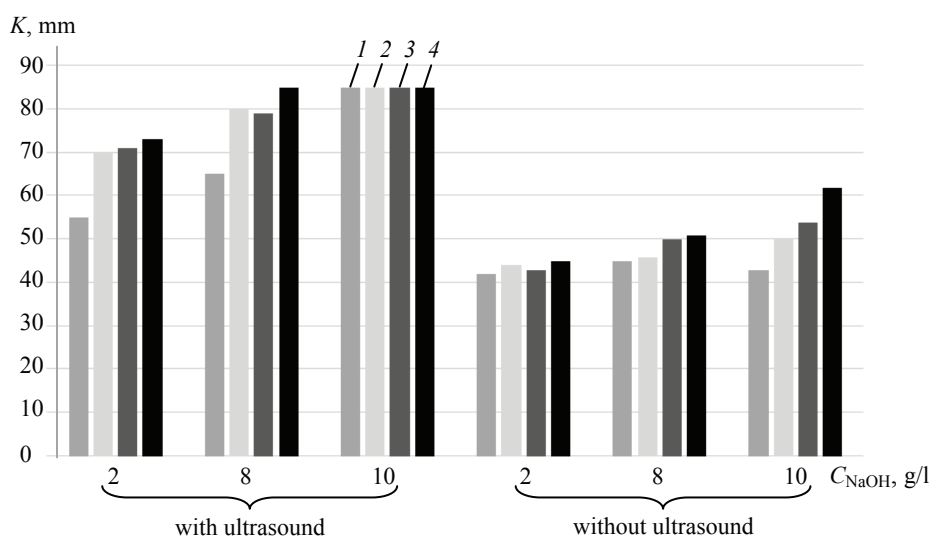


Fig. 2. The results of the study of the effect of the concentration of alkali in an aqueous solution on capillarity during ultrasound boiling and without intensification: decoction time, min: 1 – 20; 2 – 30; 3 – 40; 4 – 50

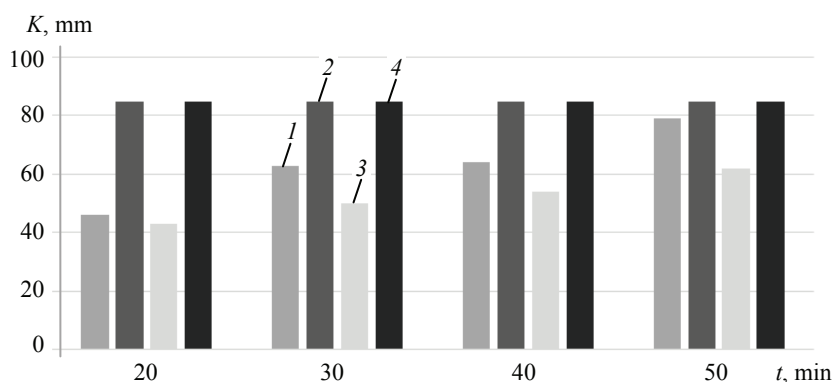


Fig. 3. Results of the study of the effect of the composition of the working solution on capillarity, when boiled with ultrasound (2, 4) and without intensification (1, 3): 1, 2 – C_{NaOH} 10 g/l, wetting agent 0.5 g/l, gintol 1.0 g/l, fiolent 1.0 g/l; 3, 4 – C_{NaOH} 10 g/l, wetting agent 0.5 g/l

The analysis of the results shows that it is possible to reduce the concentration of sodium hydroxide from 10 g/l to 2 g/l, while the concentration of TVV (EM-31 wetting agent) can be 0.5 g/l with the exclusion of such TVV as gintol and fiolent. The use of ultrasound will reduce the consumption of clean water, as well as the volume and degree of contamination of wastewater. At the same time, the boiling time t is reduced from 2.5 hours to 50...40 minutes, with a capillarity value corresponding to GOST. Reducing the duration of the process will generally reduce the negative impact of hazardous and harmful production factors and improve environmental safety [1, 2, 10].

Figure 4 shows the effect of the concentration of alkali in the working solution when boiled with ultrasonic treatment and without it for 50 minutes. As can be seen from the data shown in Fig. 4, if an alkali concentration in the working solution is equal to 2 g/l, the capillarity is 75 mm, which meets the GOST requirements.

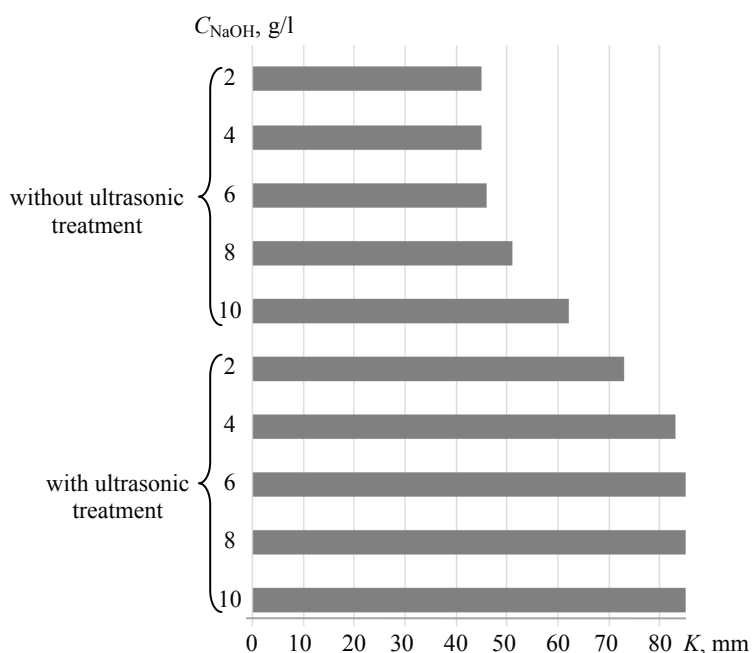


Fig. 4. The effect of the alkali concentration in the working solution when boiled with ultrasonic treatment and without ultrasonic treatment for 50 minutes

Table 1 shows the results of comparing such important indicators of the decoction process as the concentration of alkali in the working solution, the temperature and duration of the decoction process, and power consumption. As can be seen from the table, all indicators are significantly reduced.

As a consequence, the reduction in the above indicators will lead to a decrease in the consumption of clean water, as well as the volume and degree of contamination of wastewater.

Table 2 presents the results of an indicative assessment of the economic efficiency of the practical implementation of ultrasonic exposure in industrial conditions on existing equipment.

Reducing the duration of the boiling process and the time of exposure to hazardous factors reduces the harmful effects of production factors on shop workers, reducing the likelihood of injuries and occupational diseases. Reducing the concentration of NaOH in the solution by 5 times, reduces the purchase of alkali. Money savings

Table 1

Comparison of extraction process indicators

Indicators of the boiling process	According to the working technology	When using ultrasound	Decrease in the indicator
Concentration of alkali in the working solution, g/l	10	2...3	7...8
Process temperature, °C	125	95	30
Process duration, min	125...150	30...40	90...110
Electricity consumption, kW	37,5	12	25,5

Table 2

Indicators of the extraction process

Indicator	Forworking technology	When using ultrasound
Time spent in the work area and exposure to hazardous factors, min	120...150	40...50
NaOH concentration in solution, g/l	10	2
Purchase costs at an average price, RUB/year	691 200	138 240
The final content of caustic soda in wastewater, g/l	4	1,5
Payment for the discharge of NaOH into surface and underground water bodies, in 2020 prices, RUB	29 086,08	21,84

will amount to more than 550 thousand rubles per year (with cotton wool production volumes of about 1000 tons per year (960 tons per year). Reducing the concentration (alkali) in wastewater will reduce the fee for HCV for sodium hydroxide by more than 50 times. Money savings will amount to more than 29 thousand rubles per year for sodium hydroxide.

Economic efficiency for a typical small enterprise will be significant, and the costs of purchasing and implementing ultrasound equipment will pay off within 15 months (at prices in 2021).

Thus, the possibilities of practical use of the chosen method of intensification, the results obtained by the formulation to reduce the use of harsh chemicals in working solutions and improve the environmental and industrial safety of the studied process are considered. A preliminary economic justification for the implementation of the chosen method of intensification has been carried out. The methodology of the experiments and the choice of the formulation of technological solutions were carried out taking into account the developments of the Department ETPEB Russian State University named after A.N. Kosygin, Central Research Textile Institute (JSC TSNITI), Scientific and Production Center (NPC) ULTRASONICS. A series of experiments was carried out when changing the formulation of the working solution and using ultrasonic intensification. The criterion for assessing the effect of the formulation and ultrasound exposure on the effectiveness of the decoction was capillarity, which was determined in accordance with GOST. The analysis of the obtained results showed that ultrasonic treatment makes it possible to reduce the concentration of sodium hydroxide in the cooking solution by 5 times while simultaneously reducing the concentration of textile auxiliaries. The ultrasonic exposure will reduce the flow of clean water, as well as the volume and degree of contamination of wastewater. The boiling time can be reduced from 2.5 hours to 30...40 minutes with a capillarity value corresponding to GOST. An indicative estimate shows the possible economic efficiency with a payback of the costs of ultrasound equipment within 15 months.

The paper described a reasoned choice of a resource-saving method to increase the efficiency of producing a cotton fiber material – medical hygroscopic cotton wool, which is a strategically important dressing material. Taking into account the task of mass transfer, an ultrasonic effect on the extraction process (boiling) was chosen, which ultimately determines the duration, resource intensity and safety of the cotton wool production technology. An experimental study of the mass-exchange periodic

process of boiling cotton in the production of cotton medical hygroscopic cotton wool was carried out. The analysis of the obtained results shows the possibility of reducing the concentration of sodium hydroxide, other chemical reagents, the boiling time while maintaining the required quality of the material. Reducing the duration of the boiling process enables to reduce the negative impact of hazardous and harmful industrial factors in general, as well as to increase the environmental safety of the technology for obtaining medical hygroscopic cotton wool.

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Повышение эффективности процесса экстрагирования в производстве гигроскопического волокнистого материала

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Ключевые слова: интенсификация; техносферная безопасность; ультразвук; хлопковый волокнистый материал; экстрагирование.

Аннотация: Представлен обоснованный выбор ресурсосберегающего способа повышения эффективности получения медицинской гигроскопической хлопковой ваты, являющейся стратегически важным перевязочным материалом. Показаны возможности практического использования выбранного способа интенсификации и предложенной рецептуры технологического раствора для повышения эффективности процесса экстрагирования (отварки), который во многом определяет качество целевого продукта. Процесс проведен в аппаратах периодического действия с применением гидроксида натрия и других химических реагентов, отличается высокой продолжительностью и энергоресурсоемкостью. Экспериментально исследован процесс экстрагирования технологических загрязнений (отварки) хлопка в производстве медицинской гигроскопической ваты, в том числе с обоснованно выбранным ультразвуковым воздействием для интенсификации.

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Verbesserung der Effizienz des Extraktionsprozesses bei der Herstellung von hygroskopischem Fasermaterial

Zusammenfassung: Das Ziel der Arbeit ist eine fundierte Wahl des ressourcenschonenden Verfahrens zur Verbesserung der Effizienz der Herstellung von medizinischer hygroskopischer Watte, die ein strategisch wichtiges Verbandsmaterial ist. Berücksichtigung der praktischen Verwendung des gewählten Verfahrens zur Intensivierung und der vorgeschlagenen Formulierung der Prozesslösung zur Verbesserung der Effizienz des Extraktionsprozesses (Abkochung), der weitgehend die Qualität des Zielprodukts bestimmt. Der Prozess wird in periodischen Apparaten unter Verwendung von Natriumhydroxid und anderen chemischen Reagenzien durchgeführt, zeichnet sich durch eine hohe Dauer und Energieintensität aus. Die Umsetzung des Arbeitsziels umfasste die experimentelle Untersuchung des Prozesses der Extraktion technologischer Verunreinigungen (Abkochung) von Baumwolle bei der Herstellung von medizinischer hygroskopischer Watte, einschließlich einer vernünftigerweise ausgewählten Ultraschallwirkung zur Intensivierung.

Augmentation de l'efficacité du processus d'extraction dans la production du matériaux fibreux hygrosopique

Résumé: Le but du travail est un choix argumenté d'un moyen efficace d'augmenter l'efficacité de l'obtention de la laine de coton hygrosopique médicale, qui est un matériau de pansement stratégiquement important. L'examen de la possibilité d'utiliser concrètement la méthode d'intensification choisie et la formulation proposée de la solution technologique pour augmenter l'efficacité du processus d'extraction (ébullition) détermine en grande partie la qualité du produit cible. Le processus est effectué dans des appareils à action périodique utilisant de l'hydroxyde de sodium

et d'autres réactifs chimiques et se caractérise par une grande durée de vie et une forte intensité énergétique. La réalisation de l'objectif du travail comprend une étude ex-périmentale du processus d'extraction des salissures technologiques (décoction) du coton dans la production de coton hygrosopique médical, y compris avec une exposition échographique raisonnablement choisie pour l'intensification.

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