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Pulsed electric discharge in an aqueous medium for processing raw amber

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Abstract. The paper presents the results on the use of pulsed electric discharge in an aqueous medium (Yutkin effect) for processing raw amber. The proposed method allows to achieve a high degree of purification of the surface of amber, including purification from the oxidized crust, almost without destruction of the original pieces, while there is no sticking of small fractions and other negative phenomena. Using the same method, but in other treatment modes, it is possible to crush off-grade feedstock for further refining. Fractional composition of the obtaining material and the degree of its purification are regulated by the treatment mode. So three technological processes (washing, peeling and crushing) can be carried out using only one installation, which significantly reduce the cost of industrial implementation.

1. Introduction

In the fundamental aspect, the main attention of researchers - physicists in this field is devoted to the study of the discharge itself in liquid media (primarily dielectric), but the number of works is very small and is mainly devoted to discharge formation mechanisms. The current state of researches in this field is described in the paper by Lesaint [1] and in the monograph by Ushakov [2]. In the same monograph refers to the lack of research in fluids with significant conductivity. Despite this, the processing of various materials by discharge in an aqueous medium, the Yutkin effect in particular, has been known for a long time and is used in various industries [3].

Currently, there are many methods for processing raw amber:

- peeling on peeling unit [4];
- ultrasonic treatment [5,6] with the addition of abrasive and surfactants;
- waterjet processing [7];
- hydroabrasive treatment with ferromagnetic powder and exposure to an electromagnetic field, vibration, with constant heating to a temperature not exceeding the amber melting point [8];
- treatment with tetrahydrofuran [9], followed by washing with water under pressure with additional exposure to ultrasound (unlike all the above, the latter method allows fractions to be processed up to 16 mm or less).

However, all these methods are either energy-intensive, and/or not environmentally friendly, and/or expensive (also due to high losses of raw materials).



In this regard, it was relevant to study the possibility of using a method based on the direct conversion of electrical energy into mechanical energy using a pulsed electric discharge in an aqueous medium (Yutkin effect) for processing raw amber.

2. Materials and methods

2.1 Experimental samples

Two types of raw materials were used in the research:

- amber of natural origin of the fraction – 20+5.
- amber obtained from the Kaliningrad Amber Factory JSC.

A characteristic feature of amber samples obtained from Kaliningrad Amber Plant JSC is its high flakiness. Almost all pieces of amber have a flat plate shape with a thickness of solid material in the plate from 1 to 5 mm. The amount of material in the sample is 1 kg in each experiment. Preparation of the samples included checking its fractional composition and weighing a portion of the material intended for washing and crushing.

2.2 Installation

The electro-hydraulic installation (figure 1a) consists of an electrical part (not shown in the scheme) and a mechanical part, which is a tank equipped with a discharge chamber with a working spark gap and a system for circulating the working fluid and pulp. The receiving part, in which the processed material accumulates, is made in the form of a straight vertical pipe. Figure 1b shows a general view of the installation. Water is supplied to the working tank from below and flows through the four upper polyethylene drain pipes to the geotextile filter.

The first stage of fraction separation occurs in the working tank. The size of the elutriated fraction is determined by the fluid flow rate inside the working tank. By adjusting the water supply rate, the size of the elutriated fraction can be controlled.

The second stage of separation occurs on the filter of geotextiles. On geotextile stay fractions that do not pass through it.

Fractions passing through geotextiles are sedimented in the special container under geotextiles. This is another step in the separation of fractions.

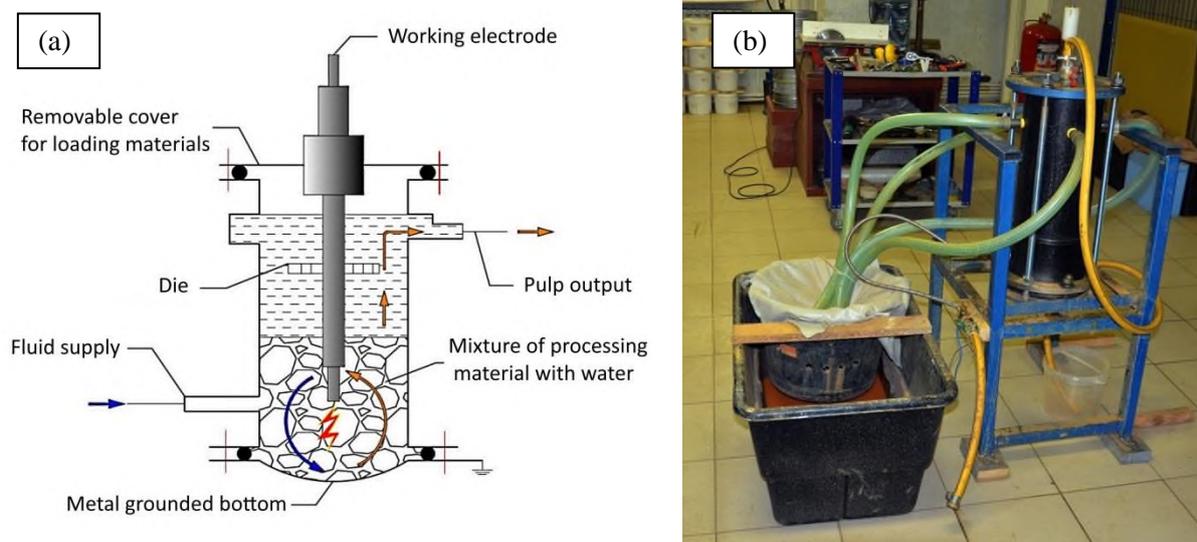


Figure 1. The experimental electro-hydraulic installation for washing and crushing amber: (a) – scheme; (b) - general view.

2.3 Operating modes

The operating modes of the electro-hydraulic installation are determined by the discharge voltage, the capacity of the storage capacitor, the size of working spark gap, the treatment time and the upward flow rate.

The experiment on washing and crushing amber was carried out using the modes established on the basis of experience in carrying out such work (table 1).

Table 1. Electro-hydraulic unit operating mode.

Indicator	Operating mode	
	Washing	Crushing
Capacitance, μF	2	3
Discharge voltage, kV	24	36
Size of working spark gap, mm	10	30
Discharge steps, units	200	200
Water consumption, l / min	10	10

3 Results and discussion

3.1 Raw Amber Washing

The main gemological properties of amber are given in the Appendix N1 to the Development Strategy of the Amber Industry of the Russian Federation for the period until 2025, however, they are most fully described in the enterprise standard of Kaliningrad Amber Plant (http://www.ambercombine.ru/customers_and_partners/description-of-amber/standart.pdf).

Assessment of the presence of inclusions, peels was carried out visually, with the naked eye and under a microscope. The degree of disintegration of the oxidized crust was also visually determined on sections.

As a result of the experiment on samples of natural amber, it was obtained not only washed, but also with removed oxide film from the surface (figure 2a).

Similar results were obtained during processing of amber from Kaliningrad Amber Plant JSC (figure 2b).

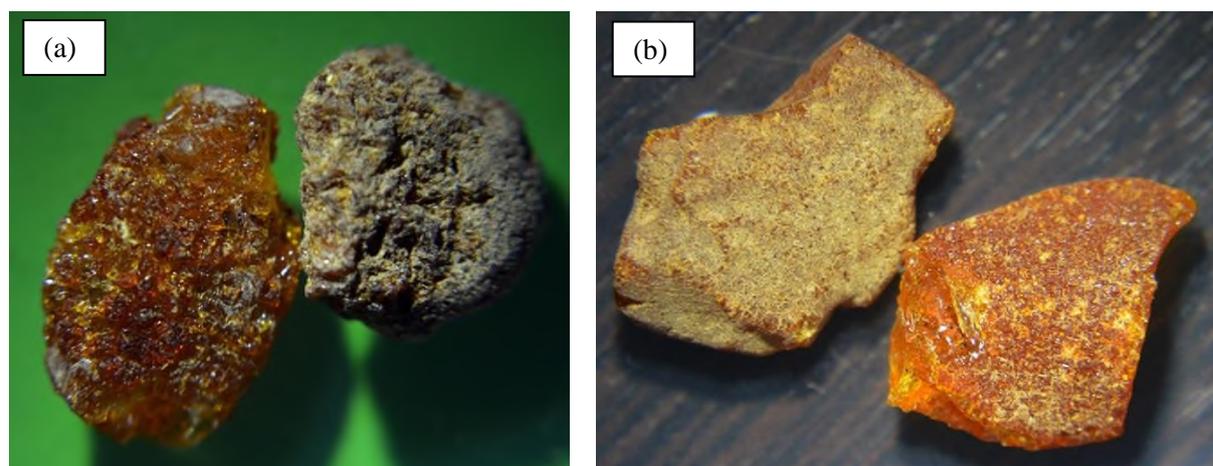


Figure 2. Washed and peeled samples of amber in comparison with the original: (a) - natural amber; (b) - amber from Kaliningrad Amber Plant JSC.

Figure 3 shows comparison of the surfaces of washed and original amber, respectively - in photographs under a microscope with 40x image magnification or more, the crust of the original samples has a relatively large thickness and a strongly developed surface. Under the microscope, it is clearly visible that the crust does not have a sharp boundary with the body of amber. It smoothly passes into the main array. On the surface of amber, purified by electro-hydraulic method, the crust is practically absent (see Figure 6).

Electro-hydraulic washing technology allows removing extraneous inclusions from the surface without crushing the amber itself.

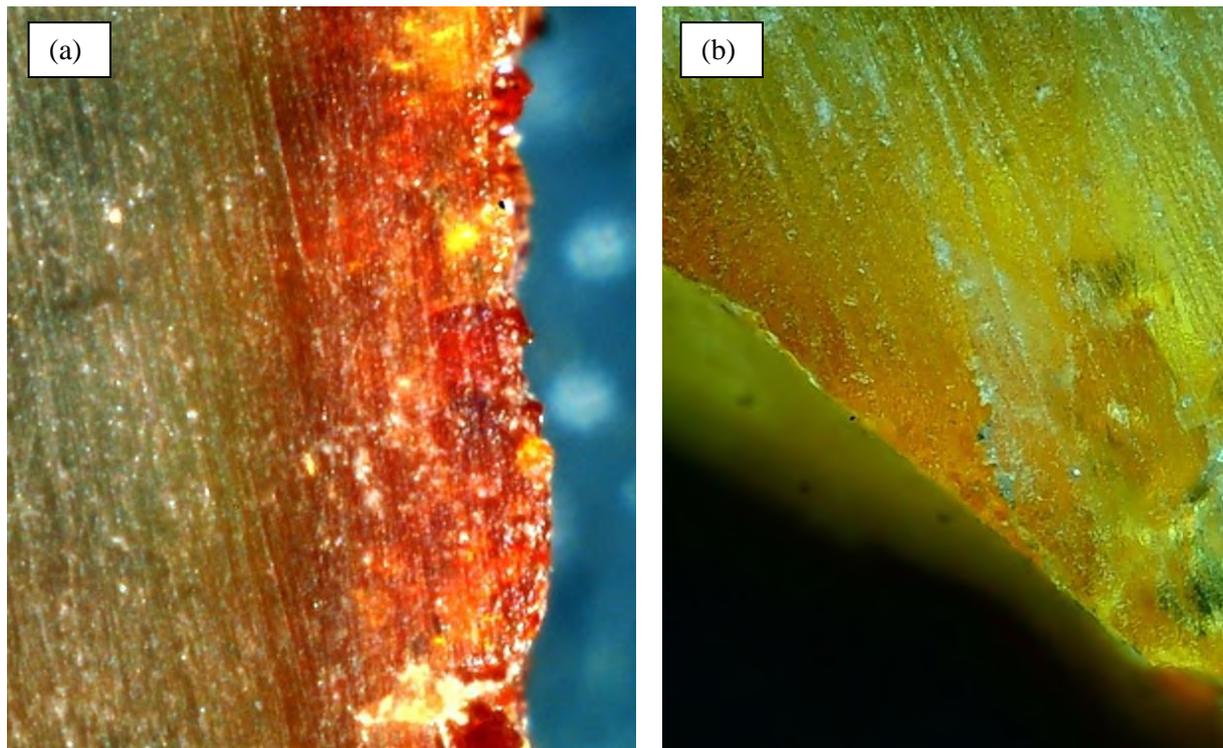


Figure 3. Photographs of crust of different samples of amber on slices (x40): (a) - original amber; (b) - washed amber.

3.2 Crushing of off-grade amber

Fine crushing amber finds widespread practical application. However, with fine crushing by conventional methods, it is necessary to solve a number of problems caused by the properties of amber. The electro-hydraulic method for fine crushing of off-grade amber has significant advantages over traditional mechanical grinding.

Experimental crushing of amber raw materials was conducted, the results of which are shown on the diagram Figure 4.

The largest amount in the original natural amber is the fraction $-10+7.5$ mm - about 56%. Fractions smaller than 5 mm are almost completely absent. In the sieving of the crushed natural material, there is no fraction larger than 5 mm. The maximum content falls on the fraction $-2.5+0.63$ - almost 44%. The appearance of the fractions is shown in figure 5. Fractions have an uncharacteristic color, but at high magnification, each particle has a typical amber appearance (figure 6).

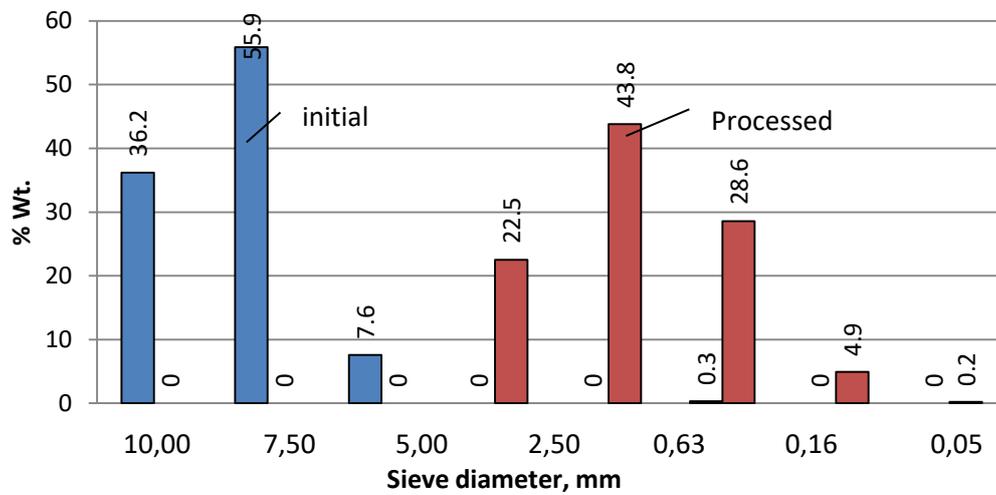


Figure 4. Fractional composition of natural amber raw materials before (blue) and after (red) electrohydraulic grinding

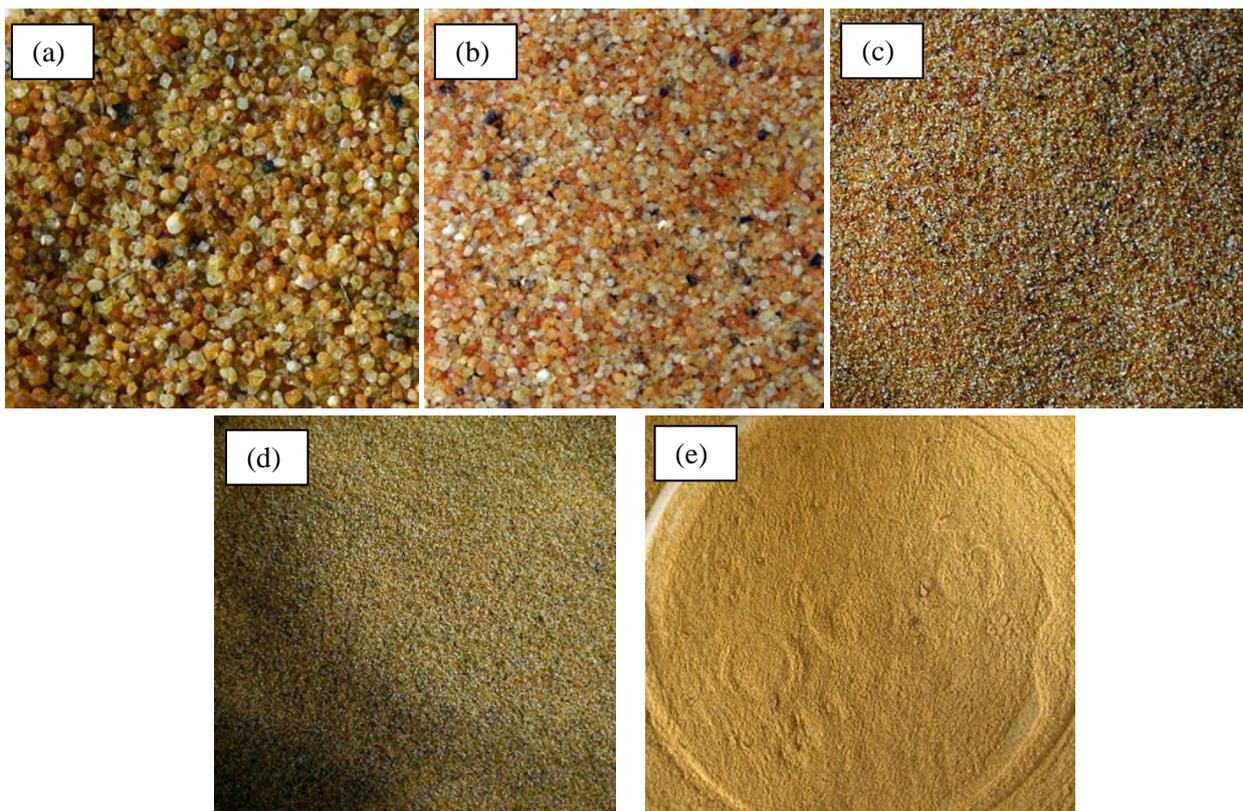


Figure 5. Photographs of samples of various fractions of amber obtained after crushing: (a) - 5+2.5; (b) - 2.5+0.63; (c) - 0.63+0.16; (d) - 0.16+0.05; (e) - 0.05 + 0.

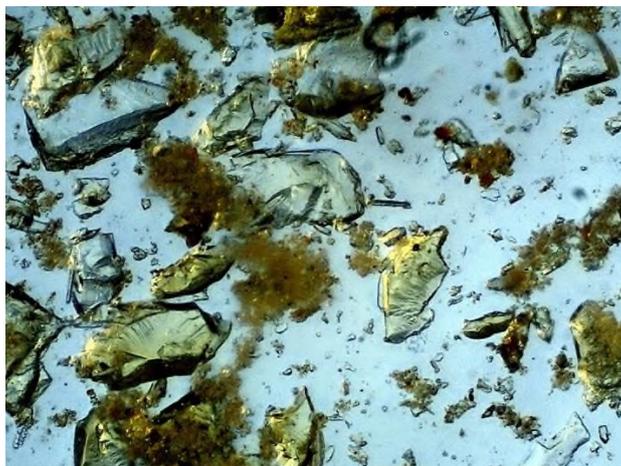


Figure 6. Small particles of amber at 60x magnification.

Fine crushing experiments were also carried out with highly flaky amber from Kaliningrad Amber Plant JSC. The dispersion of the original amber showed that 95% of the pieces have a fractional composition in the range of less than 20 and more than 8 mm. The most effective in crushing amber was the average mode of electro-hydraulic effect. Wherein, more than half of crushed amber falls to the fraction $-3 + 0.63$ mm - 54.32%, and to the fraction 3 mm - 39.09%. A fraction of less than 0.63 was washed with water on a special filter. The amount of this fraction was 10%.

4 Conclusions

Electro-hydraulic technology allows achieving a very high degree of purification of the amber surface with no destruction of the original pieces. The crushed crust obtained during washing is easily captured in washed form and can be used as raw material for further processing.

Electro-hydraulic technology allows the disintegration of off-grade amber with a high degree of grinding even during non-optimized operating modes and not at specialized installations, but at general-purpose installations. Amber disintegration occurs by splitting impact of acting factors of the electro-hydraulic effect in the aquatic environment. Therefore, in the activator there is no clogging and sticking of crushing products and another side effects.

The fractional composition of the obtained material and the degree of its washing are regulated by the selection of modes and the use of the necessary special activators. Optimization of the operating modes of the installation requires additional experiments and a sufficient amount of source materials.

Thus, it is possible to combine the washing and peeling of raw amber in one technological stage, as well as to carry out three technological processes in one device - washing, peeling and crushing.

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