Research of the influence of ultrasonic oscillation on the drying of textile materials

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Abstract. The article presents the results of experimental studies of the process of convective drying of textile materials under the influence of ultrasonic oscillation. Research is carried out in a drum type dryer (based on LG household dryer) at different drying air temperatures. Were subjected to drying: cotton fabric, polyester and synthetic fluff. The drying process was carried out without ultrasonic exposure and with ultrasonic exposure at a sound pressure level of about 150 dB. The efficiency of ultrasonic exposure on textile materials at the initial stage of drying is shown. It has been found that ultrasonic exposure provides: for cotton fabric, increasing the drying rate to 12–14 % / min at the initial stage of drying; for polyester, increasing the drying rate by 65 % / min at a moisture content of 0.9–1.0; for synthetic fluff, the drying time is reduced by 33–37 %, with increasing the drying rate up to 30 % / min at the initial stage of drying. Thus, it been shown that it is advisable to apply ultrasonic exposure to increase the efficiency of drying textile materials, especially synthetic ones.

1. Introduction
Currently, the production of textile products is significantly expanded with synthetic materials. However, as before, the issue of drying textile materials is acute. Drying determines the quality of the finished material and the cost of electricity both at the production stage and its further use [1]. For drying textile materials, various types of dryers are used: convective, contact, radiation, combined. The most common type of textile product dryer is convective [2, 3].

2. Problem statement
To study the intensification of the drying process, conducting experiments on convective drying of textile materials with the addition of ultrasonic exposure was proposed.

3. Description of the facility for studying the process of convective drying of textile materials
To study the drying process, an experimental facility was developed on the basis of an LG dryer, model DLE5577W (figure 1). The machine implements a convective type of drying textile at home. To obtain an ultrasonic field, a disk acoustic radiator with a diameter of 320 mm, oscillating at a frequency of 20 kHz, was placed inside the dryer drum [4-10]. The radiator is installed in the back of the dryer drum. The measured sound pressure level in the volume of the drying drum was not less than 140 dB, and on
the acoustic axis of the radiator not less than 152 dB. The appearance of the facility is shown in figure 2.

![Figure 1. The structural diagram of the experimental plant. USG is an ultrasonic generator; USR – ultrasonic radiator; DP – drying plant; DPD – drying plant drum.](image1)

![Figure 2. The appearance of the experimental facility](image2)

4. Experimental results
Drying experiment was carried out for three types of textile materials (cotton fabric, polyester and synthetic fluff the form of balls with a diameter of 2–3 mm sewn into a chintz bag) at two temperatures of 40 °C and 70 °C. At each temperature, 2 types of experiments were carried out:

- the supply of heated air without ultrasonic exposure;
- the supply of heated air with ultrasonic exposure.

Figure 3 shows kinetics of drying cotton fabric at a temperature of 40 °C.

![Figure 3. Drying kinetics of cotton fabric at t = 40 °C. a) is drying curves; b) is drying speed curves; 1 is drying without ultrasonic; 2 is drying with ultrasonic.](image3)

An effect (insignificant) is seen on the drying curve of the cotton fabric when drying in an ultrasonic field. The excess of drying speed at the initial stage is up to 12 % / min relative to drying without ultrasonic.
Figure 4 shows kinetics of drying cotton fabric at a temperature of 70 °C.

![Graph](image1)

**Figure 4.** Drying kinetics of cotton fabric at t = 70 °C. a) is drying curves; b) is drying speed curves; 1 is drying without ultrasonic; 2 is drying with ultrasonic.

At a temperature of the drying agent of 70 °C, the influence of ultrasound on the intensification of the drying process is noticeable. On the graphs of the drying curve, it is possible to note a reduction in the drying time by 1–5 min to achieve tissue moisture content of w0 = 0.6 and less. During almost the entire drying time, an increased speed of drying with ultrasonic (at the initial stage up to 14 % / min) relative to drying without ultrasonic exposure is noted.

The experimental data on the drying of polyester are shown in figure 5 and figure 6.

![Graph](image2)

**Figure 5.** Kinetics of drying polyester at t = 40 °C: a) is drying curves; b) is drying speed curves; 1 is drying without ultrasonic; 2 is drying with ultrasonic.

From the dependencies presented it follows that at the initial stage of the process, the ultrasonic effect provides an increase in the drying rate by 65% / min with moisture content of 0.9–1.0. With a moisture content of 0.7, the drying speed with ultrasonic becomes less than without ultrasonic. This shows the advisability of using ultrasonic at the initial stage when there is free moisture in the material.
Figure 6. Kinetics of drying polyester at $t = 70 \degree C$: a) is drying curves; b) is drying speed curves; 1 is drying without ultrasonic; 2 is drying with ultrasonic.

At $70 \degree C$, the effect of ultrasonic treatment on the drying of polyester is not as significant as at $40 \degree C$. The increase in drying speed with ultrasonic is $20\% / \text{min}$ with a moisture content of $0.9–1.0$. It can be concluded that ultrasound is more effective at lower temperatures of the drying agent in the case of drying polyester.

The experimental data on the drying of synthetic fluff is shown in figure 7 and figure 8.

Figure 7. Kinetics of drying synthetic fluff at $t = 40 \degree C$: a) is drying curves; b) is drying speed curves; 1 is drying without ultrasonic; 2 is drying with ultrasonic.

On the drying curves of synthetic fluff, a significant influence of ultrasonic influence on the process was established. For example, to achieve a moisture content of $0.1–0.2$ (almost dry material), drying time with ultrasound is reduced by $10–14$ minutes. The maximum excess of the drying rate is observed at the initial stage and amounts to $25\% / \text{min}$, in the future, the increment of the rate drops to 0 at a moisture content of 0.1.
Figure 8. Kinetics of drying synthetic fluff at t = 70°C: a) is drying curves; b) is drying speed curves; 1 is drying without ultrasonic; 2 is drying with ultrasonic.

At a temperature of 70 °C, the influence of ultrasonic influence on the drying process is also significant as at 40 °C. The excess of the drying speed at the initial stage is up to 30%/min relative to drying without ultrasonic treatment.

The power consumption of the heating element of the dryer is 4.3–4.7 kW to maintain a temperature of 70 °C. Power consumption of the ultrasonic apparatus is 130–140 watts. Basing on this, it can be concluded that an increase in the consumed electricity by 3 ± 0.3% lead to decrease in the drying time of the synthetic fluff by 33–37%.

5. Conclusion
In general, it can be noted that the greatest effect of ultrasonic treatment is exerted at the initial stage of drying, regardless of the type of material and temperature. Moreover, synthetic materials (polyester and synthetic fluff) respond better to ultrasound exposure than cotton fabric. For synthetic fluff using ultrasound drying, time is reduced by 33–37% (moisture content of 0.1), at the same time, an increase in consumed electric power is only by 3 ± 0.3%. For polyester, increasing the drying rate by 65 % / min at a moisture content of 0.9–1.0. This shows the advisability of using ultrasonic at the initial stage when there is free moisture in the material. It can be assumed that synthetic materials absorb moisture worse and most of it is in an unbound state, which allows drying more effectively under the influence of ultrasonic.

The results obtained indicate the prospects of adding ultrasonic exposure during convective drying of textile materials.

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