Experimental determination of the wave height of the base and yarns in the tissue and a new method for measuring the tissue thickness without contact

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Abstract. In many spinning and weaving processes, fibers and threads are bent. To be more precise: in the textile industry there is no technological process in which fibers, threads or textiles do not pass through a curved surface. Therefore, this article highlights the research work on a new method of contactless determination of the wave height and thickness of the warp and weft threads in the fabric using the capabilities of information and communication technologies. Experiments of research work are considered on the example of crêpe de Chine fabric.

1. Introduction

The formation of the fabric is influenced by certain forces - in the process of throwing the weft thread into the gusset, the warp formed from the threads, and pulling it over the edge of the fabric [1]. As a result, an element of texture is formed, and the strands are in equilibrium at a certain tension. This affects the wave height of the warp and weft yarns found in tissue analysis [2]. Preliminary experimental studies have revealed the influence of crêpe de Chine fabric on the crêpe ornament, the height of the wave of the strands. This makes it necessary to determine the sensitivity of the threads when analyzing the pancake ornament and the height of the waves in the fabric, taking it into account [3].

To do this, let us consider in more detail such an important indicator as the
elasticity of the thread. In many spinning and weaving processes, fibers and threads are bent. To be more precise: in the textile industry there is no technological process in which fibers, threads or textiles do not pass through a curved surface [4]. Thus, in the production of yarns and fabrics, their bending is an integral part of the technological process, and this should be taken into account separately when analyzing textiles.

A large number of literature and scientific articles are devoted to the analysis of tissue structure. Most of them are based on the theory of Professor N.G. Novikov, created in the middle of the last century [5]. These studies are presented in the form of monographs, textbooks and manuals, in which they are analyzed on the basis of a geometric model of the tissue structure. According to these studies, we analyze the factors that determine the tissue structure of crêpe de Chine [6]. Figure 1 shows a geometric model of a crêpe de Chine texture with warp and weft cutouts.

![Figure 1. Layout of the threads on the warp and weft in the fabric: l_F, l_A - density of fabrics on warp and weft and h_F, h_A - wave height warp and weft](image)

2. Materials and Methods
The main factors in the formation of the fabric on the loom are the tightness of the warp and weft threads. From the moment the formed fabric is received from the loom, the tension changes until the dress is ripe for a certain time. As a result, the fabric is reduced in width and height [7]. The amount of shrinkage depends on the factors that determine the textural structure - the linear density of the warp and weft threads, the number of threads in 10 cm, the type of braid and other indicators. As a result of shortening the strands, they are deposited on the fabric in a wavy shape [8]. The wave arrangement of the filaments is customary to have in nine states according to the theory of Professor N.G. Novikov, and they differ in the phase order of the structure. The first structure is located in phase order, the arc is straight, the warp has a maximum bend. In the ninth phase, the strings of the wefts are curved as much as possible, the strings of the body are in a straight line. In the fifth phase, the warp and weft are bent in the same way [9-11]. The disadvantage of the theory of Professor N.G. Novikov is that when determining the structure of the fabric, the forces acting on the
warp and weft threads were not taken into account. This drawback is described by Professor G.V. Stepanov in the monograph "Theory of the structure of tissues" [5] is eliminated. Based on this theory, we determine the heights of the warp waves and weft threads that occur during the formation of the crêpe de Chine fabric [10].

For the convenience of the calculation, we take into account the entire wavelength of the thread. The warp yarns are subject to NT tensile forces, M torque and QT shear forces. These forces are shown in Figure 2 a and b. Since in our case the stroke is the stroke of the canvas, we will assume that the force acting on the bending of the thread lies in the plane of its symmetry. Such a bend is called a straight bend [5].

\[
\begin{align*}
B_t^* \frac{d^4 v}{dx^4} - N_t^* \frac{d^2 v}{dx^2} &= q(x) \\
h_t &= \frac{4Q_T}{\pi^2 P_A (\pi^2 B_t + N_t)}, \text{mm}
\end{align*}
\]

Using the case in Figure 2b and taking into account the above transformations, an equation similar to (2) for the rope of ducks was obtained:

\[
h_A = \frac{4Q_A}{\pi^2 P_A (\pi^2 B_A + N_A)}, \text{mm}
\]

Equations (2 and 3) represent a mathematical model of the fabric and, in contrast to the geometric model of Professor N.G. Novikov, take into account the sensitivity of the threads and the forces acting on them when determining the heights of the warp and weft threads in the fabric.
The problem was solved using the Mathcad program and the following graphs were obtained (Figure 3 and 4).

**Figure 3.** Effect of tension on string wave height.

**Figure 4.** Influence of virginity on yarn wave height.

The graphs show the influence of the tension and sensitivity of the threads during the weaving process on their wave height. With increasing tension and sensitivity, the wave height of the strands decreases. While increasing or decreasing warp tension and stiffness results in an increase or decrease in the wave height of the weft, changes in the tension and stiffness of the weft affect the wave height of the warp.

In existing studies, the dimensions $h_t, h_A$ are determined only theoretically. It did not take into account the linear and bulk density of the strands, irregularities. This necessitated the development of a method for the experimental determination of the actual value of the studied indicators. For this purpose, a method was developed for using modern information technologies to determine the wave height of threads in a fabric.

The development of information technology in recent years has made it possible to create fast, accurate and perfect methods for determining the quality indicators of textile products. Image processing technology using computer technology has evolved with the rapid development of the textile and clothing industry in various fields, in particular in aviation, biomedical, engineering communications, military police and others. Imaging technology can be used in the textile industry to evaluate fibers, yarns, and textures.

Above, we theoretically established that the threads in the fabric are deformed under the action of certain forces during the weaving process, as a result of which they pass from a flat to a wavy shape.

But, despite the possibility of visually viewing the height of the wave of the filaments from the cross section of the tissue using a microscope, there is no experimental method for measuring its wave height and pitch.
3. Results and Discussion

In order to test theoretical studies by practical methods and develop a method for the experimental determination of the wave height using a digital microscope "Anyview Microscope", an image of tissue cross sections was obtained. For this, a special device was prepared using a 3D printer to hold the fabric in a transverse position (Figure 5).

![Device used to obtain a cross-sectional image of tissue](image)

**Figure 5.** Device used to obtain a cross-sectional image of tissue: 1- digital microscope, 2-base, 3-paper, and 4-fabric sample.

Using a microscope and a device, we photographed cross-sections of crêpe fabric on the weft (Figure 6).

![Lateral shift of raw crêpe de Chine fabric to weft](image)

**Figure 6.** Lateral shift of raw crêpe de Chine fabric to weft

Figure 6 shows the lateral shift of an untreated crêpe de Chine fabric along the back. Using the program Determine the wave height of the ducks. The weft wave height is 0.021 mm. After boiling the fabric of the crêpe de Chine for the purpose of discoloration and discoloration, their cross sections along the warp and along the weft were photographed (Figure 7 a and b).

The experimentally detected raw tissue of crêpe de Chine shows differences in the height of the warp yarn wave from 0.021 mm to the wave height from 0.091 mm to 0.291 mm after boiling, i.e. the base wave height has increased from 0.07 mm to 0.27 mm.
In Figure 7a, the experimental weft wave height varies from 0.039 mm to 0.050 mm. The difference between them was 0.029 mm. In Figure 7b, the experimental weft wave height varies from 0.008 mm to 0.106 mm. The difference between them was 0.098 mm. For this reason, as the weft bends in the crêpe de Chine fabric increase, the width penetration of the fabric increases.

Figure 8 shows an experimental measurement of the warp yarn wave height. On it, the wave height ranges from 0.088 mm to 0.091 mm. The difference between is 0.003 mm.

In the untreated state, the weft wave height ranges from 0.039 mm to 0.106 mm, after boiling, 0.021 mm. The difference was 0.085 mm. Unfinished fabric text made of waves on warp and weft. After boiling, we see that it has become unkempt both on the base and on the ducks. In particular, with an increase in the twist of crêpe threads, the wave height and uneven heights (structural phase order) of the threads increased. Such a change makes it difficult to determine the exact phase order of the tissue according to the theory of Professor N.G. Novikov. For example, if a certain part of the string corresponds to the second phase order, some parts correspond to the fourth or fifth phase order. This is only the case when a cut is made, which may change again when other cuts are made. This is because the surface of the texture of the crêpe is wavy.
The surface ornament of the texture depends on the type of wicker, the height of the waves of the threads and their ratio. From the image of the cross sections of the crêpe de Chine fabric and their sizes, it became clear that the wave height of the strands is different.

The development of a method for determining the height of the wave of threads in the fabric empirically made it possible to measure with high precision, non-contact, not only the wave height of the threads, but also its thickness along the transverse sections of the fabric. With the existing method for determining the thickness of the tissue, a special touch comes into contact with the surface of the tissue, and the tissue is crushed under the action of the palpator. This creates a large error in determining the thickness, especially for relatively soft nonwovens. With the proposed contactless method for determining the thickness, the fabric does not crumble. Due to this, the method is universal and allows you to accurately determine the thickness of all types of fabrics with high accuracy. The method of non-contact determination of the tissue thickness of Crêpe de Chine from its cross section is shown in Figure 9 below.

![Figure 9. Non-contact cross-sectional tissue thickness measurement](image)

4. Conclusions
The results of the studies carried out on the experimental determination of the wave height of the warp and weft threads in the fabric, the creation of a new method for non-contact measurement of the thickness of the fabric include:

a) Based on the use of information and communication technologies, a method has been developed for the experimental determination of the wave height of threads in a fabric. As a result, it became possible to experimentally determine the wave height of warp and weft threads in fabric with an accuracy of one thousandth of a millimeter.

b) From the image of the cross-sections of the crêpe de Chine fabric it can be seen that the wave height of the threads was determined experimentally in the range from 0.104 mm to 0.291 mm per warp and from 0.008 mm to 0.106 mm per weft.

c) A new non-contact method for determining tissue thickness has been developed.
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