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Evaluation of Seam Pucker Using Shape Parameters

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The aim of the paper is to analyse the distribution dynamics of the waves having developed in the place of the stitching of the details assembled by different technological modes as well as to propose criteria for defect evaluation. Geometrical shapes of the puckered specimen obtained from captured photos have been analysed. Characteristics of a creasy contour have been measured as well as dynamics of the values were examined in order to obtain general distribution tendencies taking into account different development of height and length of waves. For each lightweight fabric, the inherent wave under different conditions of assembling has been determined. Analysis of geometrical shape of the projection of the wave profile in the specimen seams demonstrated that waves occupy not the whole working part of the test sample. This fact influences subjective perception of creasy surface, therefore, complex evaluation of the defect requires indicators with respect to sharpness of waves and relative length of the creasy portion. The applied method for assessment of puckering enabled to determine various puckering of the flexible fabrics assembled under different modes as well as to compare different puckering.

Keywords: textile fabrics, thready assembling, puckering.

INTRODUCTION

Constructional and technological means are applied to form spatial items from lightweight fabrics. When garment details are assembled, it is very important that composition of the designed item is preserved and places of join do not impair its final aesthetical appearance. It is rather difficult to ensure proper assemblage, especially when flexible textile materials are used. During sewing process fabrics are experienced the impact of external forces, therefore puckered surface may occur at the place of a seam. Formed waves are assessed as a defect of the garment.

There are several studies, where reasons of puckering occurrence as well as most significant factors influencing this defect are analysed [1 – 7]. For assessment of this defect, a range of methods is offered. Widely used ISO 7770, AATCC 88 B, ASTM D4231-83 standards are based on the subjective evaluation. Objective assessment of seam puckering may be provided by measuring thickness of the pack of the textiles sewn together in the place of a seam. Puckering is evaluated by measuring length of the specimens sewn together, also. Application of photo electronic and optical sensors, ultrasound waves and laser reading are used to evaluate this defect [8 – 12]. Objective assessment may be carried out through application of image analysis, fractal geometry, self-organising maps, artificial intelligence [13 – 17].

These methods are advanced and high-speed, however require sophisticated software and computer equipment to read specimen surface, to collect and to process obtained data. The simulation results are often contradictory and demand of real experimental validation. Advance equipment is too expensive for commercial application, particularly considering the fact that the amount of actually investigated specimens is moderate. However, both expensive equipment and skilled person are required; besides, time costs with respect to garment development increase significantly. Therefore, perspective development of modern and simple methods enabling objective quantitative to assess seam puckering is a relevant task.

The aim of this research is to analyse the distribution dynamics of the waves having developed in the place of the stitching of the details from lightweight fabrics assembled by different modes as well as to propose criteria for pucker defect evaluation.

METHODOLOGY

For analysis, three lightweight fabrics were chosen (Table 1). These fabrics are prone to puckering defect after assembling supposedly. Clothing garment from polyester fabrics are popular, notwithstanding tailorability of such fabrics are problematic, keeping in mind seam pucker defect, also.

Table 1. Characteristics of tested fabrics

Fabric code		F1	F2	F3
Composition		100 % PES	100 % PES	45 % PES, 55 % CV
Surface density, g/m^2		149	130	111
Thickness, mm		0.35	0.32	0.46
Weave		combined	plain	combined
Setting, dm^{-1}	warp	650	490	560
	weft	380	260	260

Performing puckering experiment fabric specimens were analysed in the directions of warp and weft. Specimens with dimensions 30 cm × 3 cm were sewn by two across the centre line using 301 stitch one-needle sewing machine Unicorn. Gűtermann sewing threads No. 120 and sewing needle No. 90 were used; stitch density was 4 stitches per centimetre. Specimens were sewn at four

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different speeds, i. e. 200, 900, 1600 and 2300 min^{-1}. Pressing force of a pressing foot also varied, i. e. 25, 45, 65 and 85 N. In the process of assembling, tension of sewing threads was chosen so as to form a well-balanced stitch. Geometrical shapes of the puckered seams were obtained from digital images of specimens by taking side strips photographs [18]. The height h and length l of the each wave were measured from both sides of the specimen in the image of captured contours of edge view. Taking away by 5 cm from edges, characteristics of waves were measured within the section of 20 cm. Height h was measured from the point where the wave starts increasing to the highest point thereof, whereas length l was measured from the point where the wave starts increasing ($h \geq 0$) to the place it reaches the lowest point ($h = 0$). The final results of puckering characteristics represent by the averages of height h_n and length l_n of the waves of all test specimens of one fabric, where n is the number waves in work zone (20 cm) of specimen.

EXPERIMENTAL RESULTS

Analysis of the all geometrical shapes of the waves formed in the specimens was performed. It was established that the contours of specimens are unlike significantly (Fig. 1). In consideration of this, specimens' wave height h, length l, quantity and nature of distribution are different. Also, the character of the puckering of the same fabric is different depending on the cut direction of the specimens. It was obtained that the most characteristic case is formation of the waves of similar height and length. Another typical situation is colliding of longer and higher wave with shorter and lower one.

The results show that formation of a very high wave height value deviates from the average significantly leads to the formation of the nearby wave that is considerably smaller than an average one. Analysis of wavelength dynamics has enabled to determine extreme cases of encounter between a very long and a very short pucker. Length of one wave may differ considerably. The difference between the longest and shortest pucker amounting to 32.9 mm and 33.5 mm was established in the specimens of fabric F2 cut in the directions of warp and weft respectively. In the direction of weft, the difference is greater about 4 times.

Applying different technological modes during the sewing process, puckering of specimens also varies. The waves were higher at greater rotational frequency of the main shaft and at lower pressing force; variation of the wave height also results in variation of the length thereof. Taking into account formation of the waves with different characteristics, the efforts were made to determine the general tendency of wave formation of a fabric. Correlation analysis was applied to find out dependence of the values of height h_i and length l_i of all measured waves in each specimens. The family of curves, when pressing force 65 N and main shaft rotational frequency 200, 900, 1600 and 2300 min^{-1} is presented in Figure 2. The obtained results illustrate that length of a higher waves is generally greater. That means, when pucker height is greater the length of this pucker is greater, mostly. In some 72 % of all cases, strong or very strong linear correlation dependence has been established, correlation coefficient R varies between 0.71 and 0.94; ~24 % of specimens display average correlation (R varies between 0.5 to 0.7). It is relevant to know the relationships between height and length of the wave in the view of pucker simulation. The dependence of pucker shape parameters on initial conditions of specimen are shown as well in the research of other authors [19, 20].

After analysis of distribution dynamics of puckering waves at different technological parameters, the efforts were made to distinguish the inherent wave of each fabric. Also, determine the following characteristic of this pucker for comparative purposes: height h and length l. For this reason, average values of height h and length l of each fabric was calculated. According to them the inherent wave was formed that represent the general tendency of wave formation in the specimens of each investigated fabric sewn with different technological parameters (Fig. 3).

With increase in rotational frequency of the main shaft, the inherent wave becomes higher. These results were demonstrated by all the fabrics investigated. The highest wave formed in fabric F1 (in both investigated directions) and fabric F3 (in the direction of warp). Fabric F3 also demonstrates a significant difference between the inherent waves obtained in the directions of warp and weft. In the direction of warp, the waves are high, whereas in the direction of weft height of the waves fall within the range of smaller values compared to the values of other fabrics (Fig. 3, e – f). Different puckering of the specimens cut in the directions of warp and weft is determined by anisotropy of textiles. A change of the wave parameters among other factors depends of particular fabrics properties. The influence of fabric properties on seam puckering is confirmed by other authors [4, 6] as well.

Anisotropy of this fabric in the direction of warp and weft differs most of all, therefore, the shape of the inherent wave is the most different. The height of inherent wave of fabric F2 in the direction of warp and weft is similar.

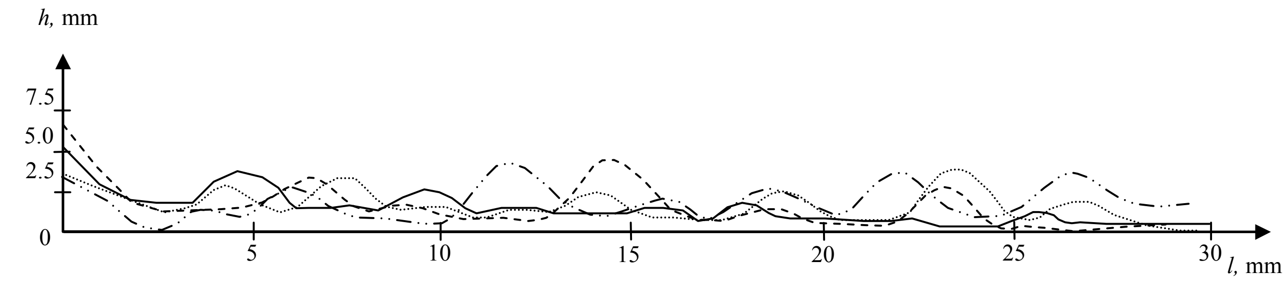

Fig. 1. The example of geometrical shape of assembled specimens cut from fabric F1 in warp direction, when pressing force 65 N and main shaft rotational frequency: 200 (______), 900 (.............),1600 (_ _ _ _) and 2300 min^{-1} (_ . . _)

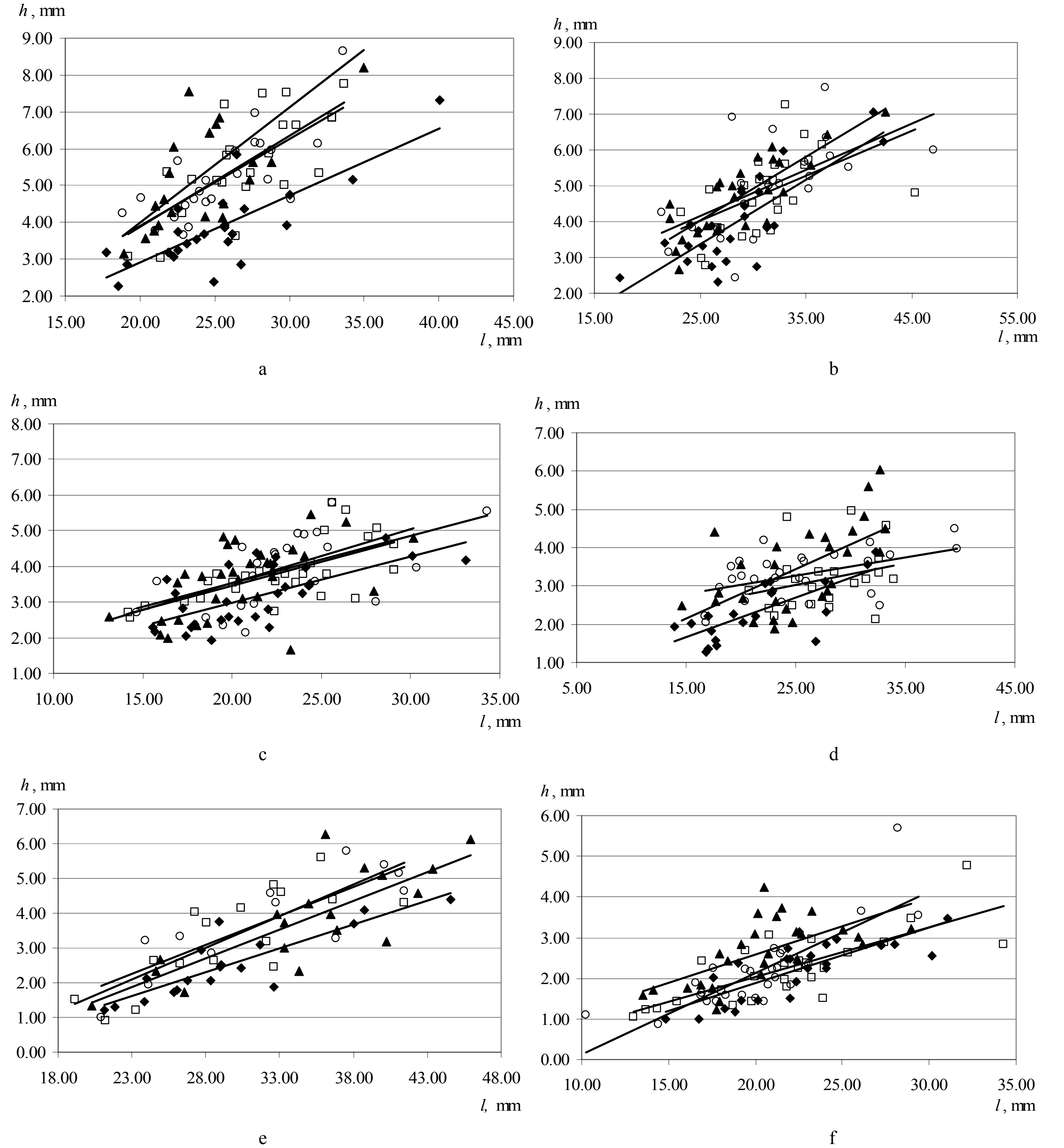

Fig. 2. The relationships between the wave heights h_i and lengths l_i values in fabrics F1 warp (a) and weft (b), F2 warp (c) and weft (d), F3 warp (e) and weft (f) directions when pressing force 65 N and main shaft rotational frequency 200 min^{-1} (♦), 900 min^{-1} (□), 1600 min^{-1} (▲), 2300 min^{-1} (○)

Lengths of wave are different, however, results illustrate that influence of technological parameters on lengths is lower than influence thereof on wave height. The cut direction of specimens has been noticed to have greater influence on lengths. In fabrics F1 and F2, distribution of wave lengths in the direction of warp and weft differs almost twice. In the direction of warp, lengths in these fabrics differ by some 5 mm subject to different assembling parameters, whereas in the direction of weft this difference amounts to some 10 mm.

The carried out analysis of inherent wave has supported the former results of the investigation with respect to parameters of wave and technological parameters of assembling [2].

Analysis of geometrical shape of the projection of the waves in the specimens demonstrated that wave occupy not the whole working part of the test sample. Therefore, for characterisation of seam puckering nature in different fabrics length, height and the ratio between the length of the wave formed and the general length of the part under consideration are important. Upon examining what percentage in the ratio between a creasy portion and non-creasy portion is held by waves, it was established that just in 5.2 % of the specimens this ratio varies from 0.2 to 0.4; and in 20.8 % of specimens, it varies from 0.4 to 0.5. In the rest of specimens (~74 %), waves occupied the greater part of specimens length, and in this case the ratio between a creasy portion and non-creasy portion varied from 0.5 to 0.7. Visually, such seams look like being creasy throughout. Due to the fabric deformation having occurred in the place of the stitching, a refraction angle of light beams falling on the fabric changes in this zone, the darker and lighter spots appear that serve for perception of the creasy surface. In order to asses puckering in an objective way, sharpness of the wave is evaluated obtaining it as a ratio between wave's height and length as visual perception of an object that is known to be dependent on the distance between the adjacent points. Thus, when in the section of given length a higher number of waves develops, a seam looks wavier [2]. More accurate assessment of puckering, however, shall be based both on sharpness of the waves and distribution nature of waves and quantity thereof in the specimens. Comparing for this purpose the characteristics related to the ratio of waves and quantity of waves within the section of given length, relative puckering coefficient k was analyzed [1]. This coefficient allows complex evaluation of crease distribution nature in the specimen of fabric.

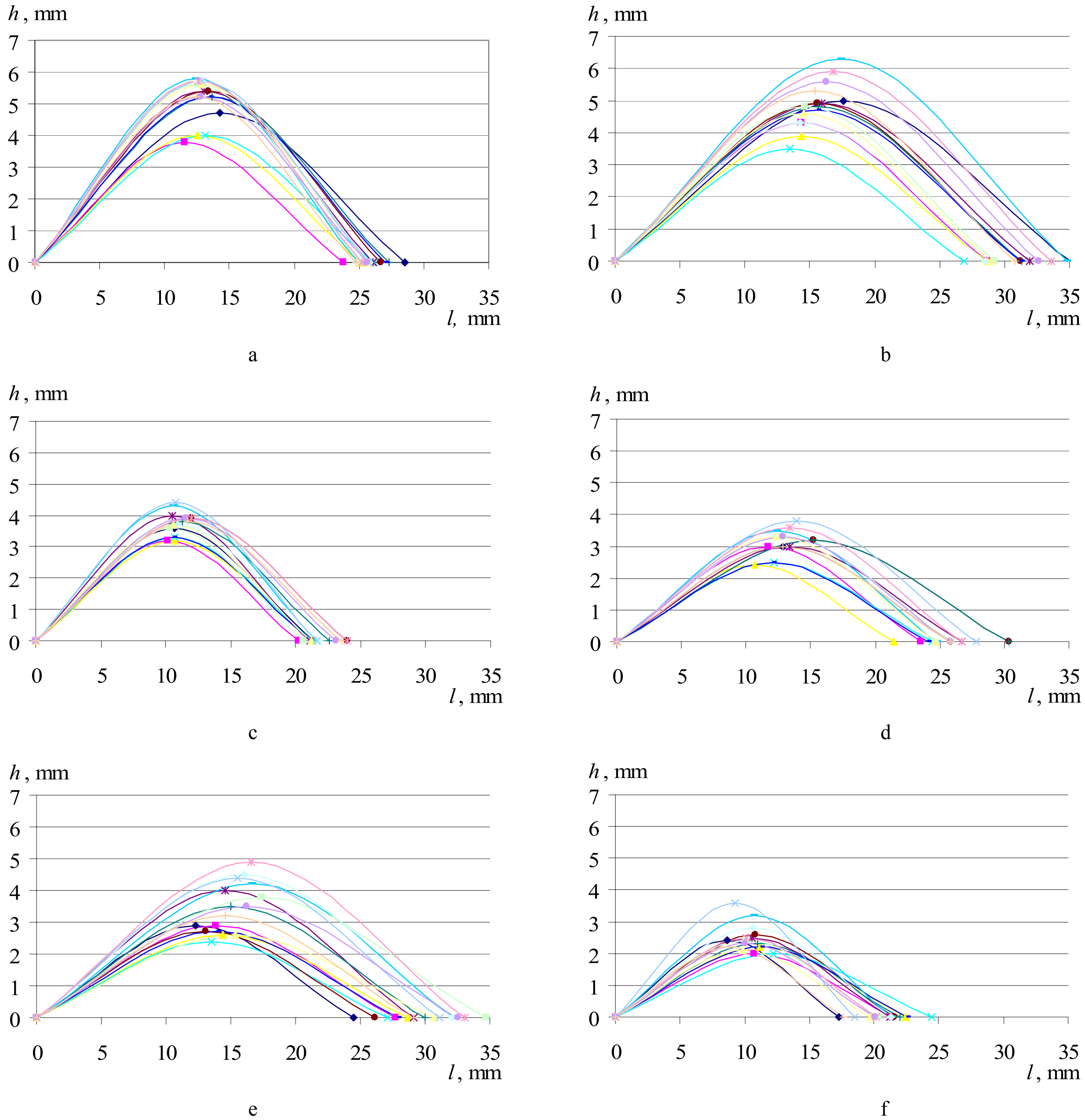

Fig. 3. (in colour on-line) Inherent waves in the fabrics F1 warp (a) and weft (b), F2 warp (c) and weft (d), F3 warp (e) and weft (f) directions when main shaft rotational frequency 200 min^{-1} and pressing force 25 N (—◆—), 45 N (—■—), 65 N (—▲—), 85 N (—×—); main shaft rotational frequency 900 min^{-1} and pressing force 25 N (—✱—), 45 N (—●—), 65 N (—+—), 85 N (—▬—), main shaft rotational frequency 1600 min^{-1} and pressing force 25 N (—▬—), 45 N (—◆—), 65 N (—■—), 85 N (—▲—); main shaft rotational frequency 2300 min^{-1} and pressing force 25 N (—×—), 45 N (—✱—), 65 N (—●—), 85 N (—+—)

Comparison of the results with respect to the formed inherent wave and distribution dynamics of waves demonstrates the same variation tendency of wave's characteristics. It is possible to maintain that performances of the characteristic crease together with other seam puckering parameters analysed during former investigations such as wave height *h* and length *l*, wave sharpness *h*/*l* [2], puckering coefficient *k* [1] may represent nature of thready assembling puckering of each fabric under different technological modes of sewing.

The obtained results are valuable for elaborating investigations with respect to influence of fabric properties of garments to manufacturing processes, selection of technological modes of assembling as well as for improving an experimental base of this field.

CONCLUSIONS

The obtained results with respect to the height and length of the inherent wave and distribution dynamics of waves demonstrate the same variation tendency of wave's characteristics. Height of the inherent waves grows with increasing rotational frequency of the main shaft. The difference between heights is more obvious at lower speeds, whereas increasing speed leads to stabilisation of height and changes are not so expressive. The tendency demonstrating that growing pressing force results in a smaller inherent wave is observed, however, change of this performance is not as significant as in the case of speed increase. It has been obtained that the established height and length of the inherent wave distinguishes nature of puckering at different technological parameters of assembling. After supplementing these performances with the sharpness *h*/*l* of waves and puckering ratio *k*, quantitative expression of the defect under consideration is determined more accurately. In fact, this expression represents the assembling defect of the sophisticated spatial shape under discussion.

Results of the research have demonstrated finding of characteristics of the inherent wave enable to assess puckering of thready assembling quantitatively. It has been established that the used method enabled to determine seams pucker of the fabrics assembled under different technological modes. These provided to compare different fabric puckering.

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