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METHOD FOR PRODUCING WAFFLE-WEAVE FABRICS WITH AN OCTAGONAL RELIEF ELEMENT

B.B. Muminov
Fergana State Technical University, PhD student.
G.N.Valiyev
Fergana State Technical University, Professor of the Department of Light Industry Engineering.
I.I.Tuychiyev
Uzbekistan Research Institute of Natural Fibres, Head of the Laboratory of Textile Fibre Spinning, PhD in Technical Sciences, Senior Researcher.
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Abstract. The paper proposes a new method for producing waffle-weave fabrics with an octagonal relief element. It extends the method for waffle weaves with a hexagonal relief element: an even number of extra threads is inserted into the centre of the initial rhombic weave in both the warp and the weft at the same time. The rhombus turns into an octagonal cell, the repeat grows to $R_o = R_\gamma = R_b + n$, the floats become longer and the fabric becomes more porous. Ways to raise the air permeability and moisture absorption of a towel fabric made of cotton yarn Nm 54/2 and Nm 34/2 in the warp and Nm 27/1 in the weft are shown.
Keywords: waffle weave, octagonal relief element, rhombus, twill, weave repeat, float length, porosity, moisture absorption, air permeability.

Introduction

Waffle weaves belong to the class of small-pattern (dobby) weaves and are produced on looms with a dobby or jacquard shedding mechanism. They are widely used for towels, bathrobes and household fabrics, because the deep cells on the fabric surface absorb moisture well.

In the classic method, the waffle cell has a rhombic shape: the cell walls are formed by long warp and weft floats, and its hollow centre is formed by alternating single interlacings [1]. At Ivanovo State Polytechnic University, methods have been developed for producing waffle weaves with a rhombic relief element [2] and with rectangular, diagonally arranged relief elements [3, 4]. The method in which square additional elements are placed at the vertices of the rhombi is taken as the prototype [5].

The common drawback of these methods is that additional rhombic elements break the relief pattern into smaller parts. As a result, the warp and weft floats that form the cell walls become shorter, and the porosity and moisture absorption of the fabric decrease. In the method with a hexagonal relief element,

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an even number of extra threads is inserted into the centre of the rhombus; the floats become longer, and the cell changes from a rhombic to a hexagonal shape [6].

The aim of this work is to develop the hexagonal method further into a method that gives an octagonal cell, and on this basis to justify the structure of a towel fabric with high air permeability and moisture absorption.

The production of waffle-weave fabrics, the improvement of their structure and of their hygienic properties have been studied by a number of local and foreign scientists. In particular, the book by G.B. Damyanov, Ts.Z. Bachev and N.F. Surnina “Fabric Structure and Modern Design Methods” describes the geometric features of fabric structure, the mutual arrangement of threads, and the effect of the weave repeat and float length on fabric properties. These studies serve as an important theoretical basis for designing the structural parameters of waffle-weave fabrics.

Russian Federation patent No. 2587076 by G.I. Tolubeeva, E.E. Demidova and N.S. Tokareva proposes a method for producing waffle fabrics with a rhombic relief element. It shows that the surface structure of a fabric can be changed by forming rhombic relief elements. In later patents No. 2619041 and No. 2623989, the same authors improved the technology for producing waffle weaves with rectangular, diagonally arranged relief elements and with relief elements oriented in different directions.

The book by A.F. Potyagalov “Technique of Fabric Construction” sets out the theoretical and practical basics of constructing weaves, of the interlacing of warp and weft threads, and of forming various weave patterns. This work is of methodological importance for designing the geometric structure of waffle fabrics and developing new weave variants.

In addition, an invention developed in 2025 for producing waffle fabrics with a hexagonal relief element considers how inserting extra threads into the centre of the rhombic cell changes the geometric shape of the relief element and increases the float length. This approach provides a basis for further improving the structural properties of waffle fabrics.

Standards GOST 3816-81 and GOST 12088-77 are important for evaluating the hygroscopic properties and air permeability of textile materials. The first standard sets out methods for determining the moisture absorption and water repellency of fabrics, and the second sets out the procedure for measuring the air permeability of materials.

The review of the above sources shows that certain scientific and technological solutions exist for improving the relief shapes of waffle-weave fabrics. However, forming an octagonal relief element by inserting an even number of extra threads in the warp and weft directions at the same time requires further study. Therefore, this study develops a method for producing waffle fabrics with an octagonal relief element based on the hexagonal method, and proposes technological solutions for improving their air permeability and moisture absorption.

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Proposed method

In the hexagonal method, extra threads are inserted into the centre of the rhombus in one direction only, so only two vertices of the rhombus are cut off and the cell becomes hexagonal. In the proposed method, extra threads are inserted in the warp and the weft at the same time and in equal numbers. All four vertices of the rhombus are then cut off and the cell becomes octagonal: the four inclined sides are formed by the twill diagonals, and the two vertical and two horizontal sides are formed by the extra threads.

The method is carried out in the following steps:

1. A regular weft twill $1/(R_s - 1)$ (or warp twill $(R_s - 1)/1$) is chosen, for example the 1/6 twill ($R_s = 7$).

2. The initial rhombic weave is built from the twill and its mirror image. The main diagonals of the rhombus consist of single warp or weft interlacings; the base repeat is $R_b = 2(R_s - 1) = 12$.

3. The inside of the rhombus is filled vertically and horizontally with floats of threads of the same system: warp floats in one rhombus and weft floats in the neighbouring one.

4. n extra warp threads and n extra weft threads are inserted into the centre of the rhombus (n is an even number: 2, 4, 6, 8, 10). The extra threads repeat the interlacing of the central thread, so the floats become n threads longer, and straight sides about n + 1 threads long appear in place of the four vertices of the rhombus.

The square gaps formed between the octagonal cells are filled with plain weave. For decoration, a 2/2 hopsack, a zigzag or a small rhombus can be used instead of plain weave.

The fabric repeat is equal in both directions and grows in the same way:

$$R_o = R_u = R_b + n = 2(R_s - 1) + n$$

The float length changes in steps of 2, and its maximum value ranges from 3 to $R_b + n$. Because the weave is symmetric about both axes, the threads are drawn into the heald shafts in a symmetric (point) draft, and the required number of shafts does not exceed:

$$K \leq \frac{R_o}{2} + 1$$

The projection of the inclined side of the cell is approximately $a \approx R_b/2$, and the straight side is $s \approx n + 1$. The cell approaches a regular octagon when $s \approx a\sqrt{2}$; for $Rb = 12$ this condition is met at n = 6–8.

Fabric types

The variants obtained on the basis of the 1/6 twill ($R_b = 12$) for different numbers of extra threads are given in Table 1. n = 0 corresponds to the classic rhombic cell and is given for comparison.

Table 1. Parameters of the octagonal waffle weave depending on the number of extra threads ($R_b = 12$)

HSR (LONDON),
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Extra threads, n	Repeat $R_o = R_\gamma$, threads	Straight side, threads	Heald shafts, max.	Cell shape
0	12	—	7	rhombus (classic waffle)
2	14	3	8	rhombus with cut-off vertices
4	16	5	9	octagonal, inclined sides dominate
6	18	7	10	close to a regular octagon
8	20	9	11	close to a regular octagon
10	22	11	12	straight sides dominate, close to a square

Four patterns developed by this method are shown in Figs. 1–4. In the drafts, a red square is a warp float and a white square is a weft float. The structural parameters determined from the drafts are given in Table 2.

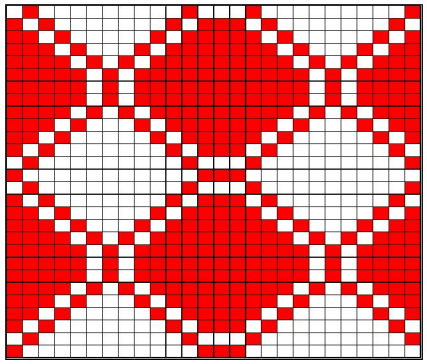


Fig. 1. Variant 1: n = 2, the spaces between cells are filled with plain weave.

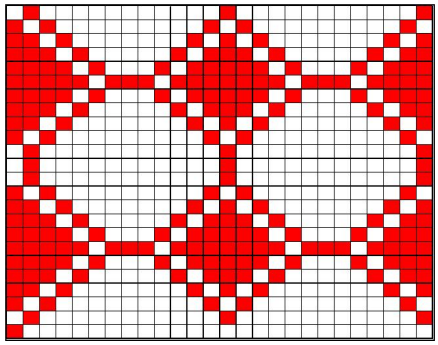


Fig. 2. Variant 2: a narrow stripe between the cells.

HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
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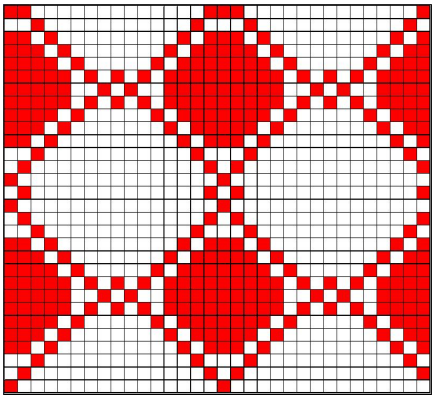


Fig. 3. Variant 3: a zigzag ornament inside the dense area.

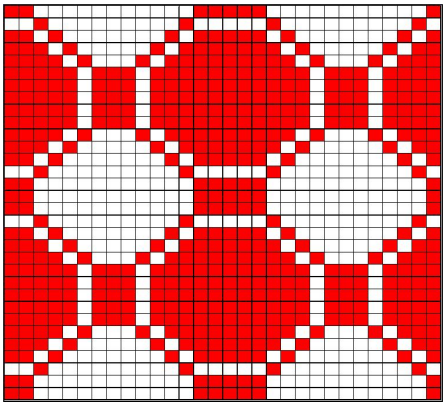


Fig. 4. Variant 4: n = 4, rectangular ribs on the cell walls.

Table 2. Structural parameters of the developed patterns

Variant	Repeat, threads	Share of warp floats, %	Longest float, threads	Interlacing coefficient
1	14 × 14	54.6	11	0.36
2	12 × 12	34.0	11	0.35
3	16 × 16	34.8	15	0.32
4	16 × 16	55.9	11	0.27

The interlacing coefficient is the ratio of the number of changes in thread direction in the repeat to the number of squares. The lower it is, the longer the floats and the deeper the cell.

Raw materials and hygienic properties of the fabric

Two types of plied cotton yarn, Nm 54/2 and Nm 34/2, were used in the warp, and single yarn Nm 27/1 in the weft. The linear density was calculated as $T = 1000/Nm$, and the yarn diameter as $d = 0.0357\sqrt{(T/\delta)}$ ($\delta = 0.85$ g/cm³).

HSR (LONDON),
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Table 3. Characteristics of the yarns used

Yarn	System	Resultant linear density, tex	Calculated diameter, mm
Nm 54/2	warp	37.0 (18.5 × 2)	0.24
Nm 34/2	warp	58.8 (29.4 × 2)	0.30
Nm 27/1	weft	37.0	0.24

The air permeability and moisture absorption of a waffle fabric depend on the cell depth and the surface fill. The linear fill is estimated as E = P·d (E in %, P is the number of threads per 10 cm, d in mm). When E is low, the gaps between threads are large and air passes through easily.

In the octagonal method, the floats become longer in both directions at the same time. Therefore the cell is deeper and larger than in the hexagonal method, and the porosity of the fabric increases.

Table 4. Weaving recommendations for higher air permeability and moisture absorption

Factor	Recommendation	Effect on air permeability	Effect on moisture absorption
Number of extra threads	n = 4–8 (repeat 16–20)	The channel inside the cell widens	The cell becomes deeper, the surface area grows
Placement of warp yarns	Nm 34/2 in the cell walls, Nm 54/2 in the cell bottom	More gaps between the thin bottom threads	Higher relief, more moisture is held
Weft yarn	Single, low-twist Nm 27/1	Loose yarn lets air through	Hairy surface absorbs moisture quickly
Weft density	Slightly lower than the warp density ($E_\gamma < E_o$)	Lower fill	Threads are free, capillary absorption improves
Filling between cells	Plain weave	Tight binding keeps the cell shape	Cells stay open after washing
Finishing	Scouring and washing, without starch or silicone softeners	Shrinkage opens the cells	No hydrophobic coating

At n greater than 10, the floats become too long, and abrasion resistance and shape stability decrease. Therefore the optimal values of n and the weft density are chosen experimentally (moisture absorption by GOST 3816, air permeability by GOST 12088).

Conclusions

A method is proposed for producing waffle fabrics with an octagonal relief element by inserting an even number of extra threads into the centre of the basic rhombic weave in the warp and the weft at the same time. The repeat is $R_o = R_\gamma = R_b + n$.

`On the basis of the 1/6 twill, a nearly regular octagonal cell is obtained at n = 6–8; the repeat is 18–20 threads and 10–11 heald shafts are needed, so the pattern can be woven on a dobby loom.

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To raise air permeability and moisture absorption, it is recommended to place the Nm 34/2 warp yarns in the cell walls and the Nm 54/2 yarns in the cell bottom, and to use low-twist Nm 27/1 weft at a reduced weft density.

At the next stage, the moisture absorption, air permeability and abrasion resistance of the fabrics will be determined experimentally.

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