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Behaviour of the Twill Weave Woven Fabrics during Relaxation

A. Alamdar-Yazdi*

Department of Textile Engineering, The University of Yazd, Yazd, Iran

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Abstract: This work looks into the behaviour of the twill weave woven fabrics during relaxation (when the weaving tension is released). Ten, 50-metre rolls of twill weave woven fabrics were produced. The fabrics were marked in a rectangular form at the weaving loom. After 48 hours of relaxation, the new shapes and sizes were recorded. The shapes of almost all of the samples were changed to parallelogram, even though they differed in size. The work showed that the manner of fabric deformation during relaxation depends upon the fabric structure. It indicates that contraction due to relaxation of the twill weave causes the woven fabric to skew. in the direction of the twill. The quantity of the skewness is related to the float length and the twill type. Fabrics with longer float length have higher skewness.

Keywords: Skewness, Weave structure, Twill weave, Fabric deformation

Introduction

Skewness in woven fabric is a condition where the warp and weft yarns, although straight, are not at right angles [1]. Due to the fact that skewed fabric may behave differently on each part of the body, and cause difficulties during tailoring, sewing, and the process of three-dimensional forming, so to help alleviate the problem, automatic weft-straightening devices are used during the finishing processes [2].

The main cause of this problem is known to be the tension variation during the lengthy textile process. So the right attentions have been paid to the proper working conditions of the machineries like warping, weaving and the finishing process. There is no doubt, the problem can occur in warping, weaving and finishing processes. Tension variation across the width of the warp beam could cause bow and skew at warping and weaving stage [3]. In case of sectional warping, improper slope or tension applied to each band of the warp can create the same distortion. On the weaving loom uneven let off or take up speed so that two sides of the weaving cloth are not equally tensioned causing the fabric to be skewed.

The main cause at any step of the finishing process is the variation in running speed across the width of the fabric which causes shear deformation (the warp and filling yarns rotate at the intersections from a right angle position to form obtuse or acute angle) [4].

But in this experimental work the effect of fabric weave structure on distortion of the woven fabric during relaxation (after the weaving tension is released) is considered and is shown that special structure of the twill weaves causes each float acts like in-plane lever making warp float with the neighbouring weft floats to act like the two arms of a scissor causing elongation of the main diagonal and shortening of the off diagonal making the fabric to shear and make the fabric to skew (perfect skewness (not the bow)).

*Corresponding author: aalamdar@yazduni.ac.ir

Experimental

Materials

Ten 50 meter rolls of cloth (in 2 stages), based on the conditions shown in Table 1 were produced. To eliminate the condition difference, the fabrics were all produced on the same loom (Dornier SW5 weaving machine, 200 picks per minute) and under the same condition.

Table 2 reveals the yarns specification: both, the warp and filling yarns were, made of 45 % wool and 55 % polyester.

Sample Preparations

During the weaving process, for each 2200 picks, one strip was inserted at both the edges of the fabric, so that each 50 meter roll of fabric contained 40 strips. The first strip was inserted when a five meter of the fabric was woven (after 11000 picks) and the last strip was inserted five meters to the end.

Measurements

Fabrics were unrolled by unrolling machine, and after 48

Table 1. The production conditions

	Weaves	Reed count (dents/ 10 cm)	Warp/ dent	Warp (width) in reed in cm	Weft density
Part I	2/2 (R)	65	4	167	22
	2/2 (L)	65	4	167	22
	3/2 (R)	65	4	167	22
	4/2 (R)	65	4	167	22
	3/3 (R)	65	4	167	22
	3/3 (L)	65	4	167	22
Part II	2/2 herringbone	65	4	167	22
	3/3 herringbone	65	4	167	22
	2/1 1/2	65	4	167	22
	3/1 1/3	65	4	167	22

L: indicates left hand twill and R: indicates right hand twill.

Table 2. Specification of the fibres and produced yarn

Material used	Yarn specification		
	Twist/meter		Count
	Single	Plied	
1. Australian merino fleece wool top as per international standard (IWTO) Wool specification: 22 micron (maximum average), 65 mm (minimum average), sliver weight 20 gr/m 2. Dupont polyester tops, 20 gr/m Polyester tops, 3 den, 76 mm, raw white, semi dull, low pilling	550 (Z)	550 (S)	48/2

hours of relaxation the changes were recorded. The deformation was measured according to ASTMD-3882-88 test method [5].

Results and Discussion

Figure 1 shows the typical shape of the deformed fabrics after 48 hours of relaxation. As it was expected, the fabrics contracted in both directions (width and length). Although, on the loom, all of the fabrics were almost of the same size (167 × 100 centimetres), after relaxation the fabrics became different in size (Table 3). In other words, each fabric weave ended up with its own new size.

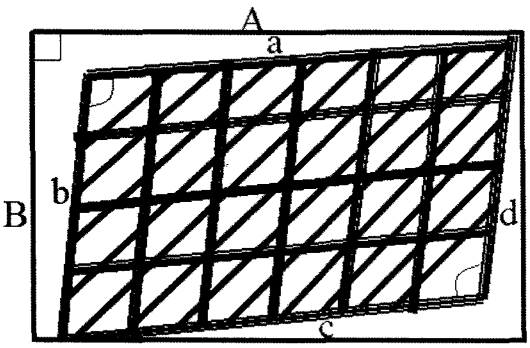


Figure 1. Typical deformed shape of the fabric (after 48 hours of relaxation).

It is obvious that when fabrics were released from the weaving conditions, the warps and wefts start to contract to their conditions of equilibrium. Naturally, floats get shorter, yarns get closer to each other and depending upon the existing space, each float finds its own seat. At this stage, when each float is finding and sitting on its final space the free spaces between the yarns play a vital role. In fact the free spaces would give neighbouring yarns (floats) an open space to move and fit in. Therefore, such conditions make each float to have two in-plane movements (Figure 2).

1. Shortening the length
2. Movement toward the free zone

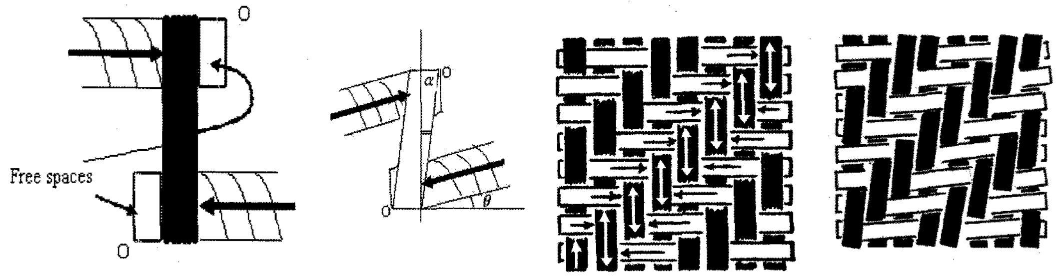
In order to have a better understanding, let's take two weaves into consideration, plain and simple 2/2 twill. In a 1/1 plain weave, the ends and picks float over one thread, causing each float to be surrounded (tightened) by 4 interlacing points. In such case, floats are comparatively small, interlacing points are high and free spaces between yarns are zero, (weave factor of 1) making the fabric to be relatively firm (giving the yarns no freedom to move).

In a 2/2 right hand twill weave the ends and picks float over two consecutive threads without any interlacing. Such a condition makes the floats to be longer, the number of

Table 3. The measurements

Case	Weave structure	Skewness (%)		Contraction (%)		Rectangular size of the samples after relaxation			
				Warp	weft	-a	-b	-c	-d
Part I									
1	2/2 (R)	2.50	R	4	4.20	159.80	96.00	160.15	96.00
2	2/2 (L)	2.60	L	4.05	4.16	160.00	95.93	160.05	95.98
3	3/2 (R)	2.75	R	4.95	4.91	158.75	95.00	158.85	95.10
4	4/2 (R)	2.80	R	5.80	5.60	157.60	94.18	157.70	94.23
5	3/3 (R)	3.00	R	6.70	6.50	156.10	93.27	156.20	93.33
6	3/3 (L)	3.05	L	6.80	6.45	156.19	93.17	156.26	93.24
Part II									
1	2/2 herring bone	0.60	R	4.05	4.10	160.20	96.00	160.10	95.90
2	3/3 herring bone	0.65	R	5.86	6.16	156.8	94.20	156.60	94.15
3	2/1 1/2	1.10	R	3.10	3.00	161.94	96.85	162.02	96.95
4	3/1 1/3	1.45	R	3.20	3.40	161.25	96.75	161.40	96.85

L: indicates left hand twill and R: indicates right hand twill.



Original case when fabric is on the loom (under tension) | Shortened the length and skewed clockwise | Contraction forces to cause scissoring movement | Fabric(warp and weft) skewed

Figure 2. Creation of the scissoring movement of warp and weft (in even 2/2 twill weave) during the relaxation due to contraction.

Table 4. Structural comparison of the 1/1 plain weave and 2/2 twill weave

2/2 twill weave				1/1 plane weave
	4	Number of floats	8	
	1/4	Float length	1/8	
	4	Interlacing points	8	
	4	Free spaces	0	

interlacing points to be lower (weave factor of 0.75) and the existence of a free space between each of the two yarns makes the fabric relatively loose (Table 4). In addition, the points of intersection move one to the right and one upward on succeeding picks forming the diagonal line in the cloth.

In fact, in the 2/2 twill, between the two yarns over which a thread floats, there is a gap or free space at least equal to the actual diameter of the yarn. This free space makes it possible for the floated length of the yarn to bring the crossing yarns closer to each other due to contraction. This statement is shown in Figure 3.

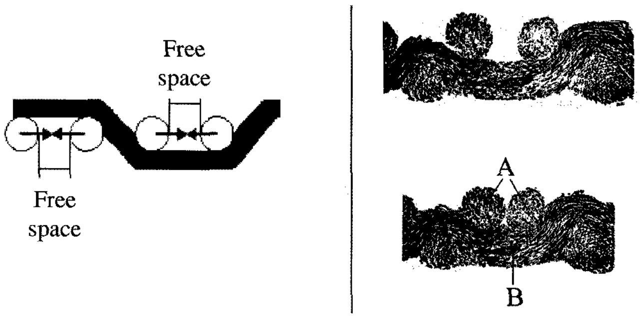


Figure 3. Yarn behaviour due to fabric contraction (shortening of the yarn B causes the crossing yarns A to get closer to each other).

Shortening the floats (yarns) due to contraction in such a condition causes the floats to be affected by two forces acting opposite to each other and makes each float work like an in-plain lever (Figure 2(a) & (b)). This is, warp float shortening causes the weft floats to act like in-plane lever and the same for weft floats. This phenomenon and the relation between warp and weft floats in twill structure (Figure 2(c)) will create a free zone in the diagonal direction of the fabric which warp and weft floats act like the 2 arms of a scissor and come closer to each other causing elongation of the main diagonal and shortening of the off diagonal.

At interlacing points where each yarn is held and kept tight by the 2 neighbour crossing yarns, there are also two types of movements (Figure 4).

a) In-plane movement. This portion of the yarn, in one hand is shrinking and causing to bring the crossing yarn closer to each other and clamping itself tighter and on the

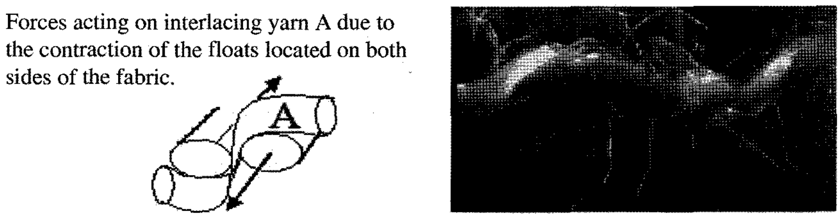


Figure 4. Deformation of the yarn in the twill weave.

other hand is effected by the shrinking forces of the crossing yarns. The shrinking forces acting on the interlacing part of the yarn are opposing to each other and act against the in-plane float movement. But the resultant quantity of the moment is relatively low due to the short length of the yarn and lower freedom to migrate.

b) The second movement is in the direction perpendicular to the plane of the fabric (in the thickness direction of the fabric) and does not have a direct effect on in plane movement of the floats.

However, total moments acting on each yarn in one repeat is the sum of the forces acting on floats (making the floats to skew) and moments acting on the interlacing portion of the yarn. No doubt, effective movement is related to the characteristic of the yarn (capability of the yarn to contract and its surface character), the weaving conditions (especially the weaving tension), and the fabric structures (the lower the weave factor, the higher the freedom to migrate).

Apart from the characteristics of the yarns and the weaving conditions (which in this experimental study were the same for all of the fabrics), the parameters which effected on the degree of distortion of each float during relaxation were as follows:

Location of the Free Spaces

The location of the free spaces assigned the direction of the float movement. Indeed, the location of the free spaces (on either side of the float) offered a free way of assigning the direction in which the float (an in-plane lever) could skew. Right hand twills have free zone on right side of the top part and left side of the bottom part of the warp floats offering the warp floats to turn clockwise.

Left hand twills have free zones located on left side of the top part and right side of the bottom part of the warp floats to let them skew counter clockwise (Figure 5).

The Float Length

As the float length gets longer the freedom of the float to contract goes higher (Figure 6). Table 3 comparison of 2/2 twill to 3/3 twill, shows a direct relationship between the float length and the contraction and skewness.

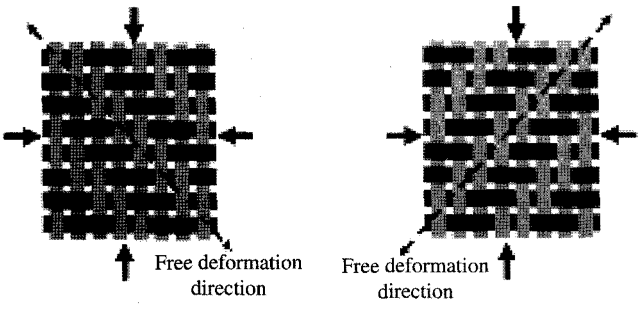


Figure 5. Twill structure and free directions to deform.

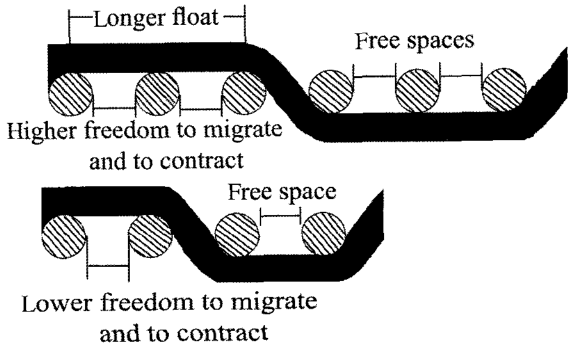


Figure 6. Comparison of float length between 3/3 and 2/2 twill weaves.

The Free Spaces

As the free spaces (voids) increase, the freedom of movement for the yarns goes higher (Figure 6). In other words, the firmness of the fabric reduces. Comparison of 2/2 and 3/3 twill weaves in Table 3 (case 1 and 5 or case 2 and 6) reveals the fact that as free spaces increase, (the longer the floats) the contraction increase making the yarns to get closer and as a result the skewness increases.

Theoretical Estimation and Calculation

Warp Degree of Movement

The angle in which the warp float will migrate (the warp plane movement) is:

$$\tan\alpha = \frac{\textit{warp movement}}{\textit{the warp float length}} = \frac{\textit{weft contraction for each float}}{\textit{the warp float length}}$$

(Figure 7)

Weft Degree of Movement

The angle in which the weft float will migrate (the weft plane movement) is

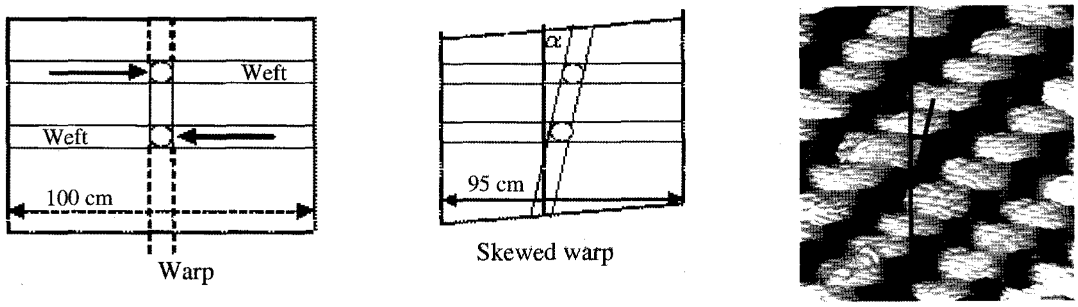
$$\tan\theta = \frac{\textit{weft movement}}{\textit{the weft float length}} = \frac{\textit{warp contraction for each float}}{\textit{the weft float length}}$$

Warp Float Migration (mm)

The movement of the warp float is related to the amount of weft contraction. In other words, warp float migration is the weft contraction per each warp. For example, in a fabric with warp density of 26, if there would be 5 % weft contraction, the maximum possible movement of the warp float is equal to (5 mm/260).

Weft Float Migration (mm)

The movement of the weft float is related to the amount of warp contraction. In other words, weft float migration is the



(a) Yarn under weaving tension (b) Yarn released from weaving tension (c) Warp float skewed in the real fabric

Figure 7. Contraction effecting float skewness.

Table 5. The measurements

Fabric	% contraction		Weave	Free spaces/repeat		Tanα	Tanθ	Skewness	
	Warp	Weft						Estimated	Actual
1	4	4.20	2/2 (R)	**2/4**	**50%**	0.018501	0.024672	4.317	**2.50**
2	4.05	4.16	2/2 (L)	**2/4**	**50%**	0.018340	0.024973	4.331	**2.60**
3	4.95	4.91	3/2 (R)	**3/5**	**60%**	0.018761	0.026444	4.520	**2.75**
4	5.80	5.60	4/2 (R)	**4/6**	**66%**	0.018863	0.027229	4.609	**2.80**
5	6.70	6.50	3/3 (R)	**4/6**	**66%**	0.019652	0.028228	4.785	**3.00**
6	6.80	6.45	3/3 (L)	**4/6**	**66%**	0.019519	0.028634	4.815	**3.05**

warp contraction per each weft.

Fabric Skewness (%)

The fabric skewness angle is the sum of the warp and weft skewness angles. In other words, the fabric skewness is the degree of the warp and weft float distortion (i.e., $\tan(\alpha+\theta) \times 100 = skewness(\%)$).

Based upon the above theoretical suggested estimation, the maximum possible skewness for each fabric is calculated, the values are recorded (Table 5) and compared to the actual measured skewness. The comparison of the estimated and measured values of skewness shows an acceptable agreement (Figure 8).

Please note that, the actual skewness values are always lower than the maximum possible values (Figures 9 and 10). This is due to the resistance of the floats to skew and slippage of the yarns over each other (which is related to the shearing properties of the fabric).

Table 5 shows that the highest skewness (measured and estimated) belongs to the right (case 5) and left-hand 3/3 twills (case 6). The comparison indicates the following facts:

Both fabrics are skewed in their own twill directions due to the location of the free space.

The floats in both directions (warp and weft) are long (ends and picks float over 3 consecutive threads without any interlacing), causing each float to have a better freedom to contract.

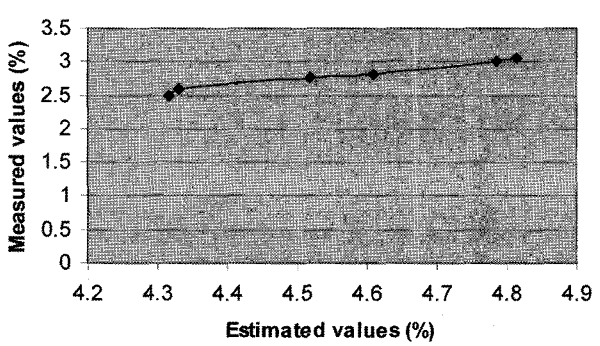


Figure 8. Plot of the measured skewness versus the estimated values.

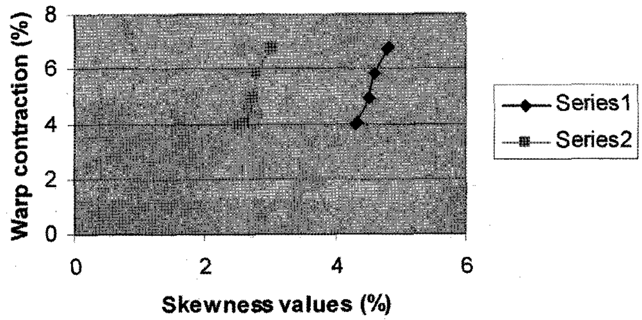


Figure 9. Plot of warp contraction versus the measured (series 2) and estimated maximum possible skewness values (series 1). Series 1: maximum possible skewness, series 2: actual measured skewness.

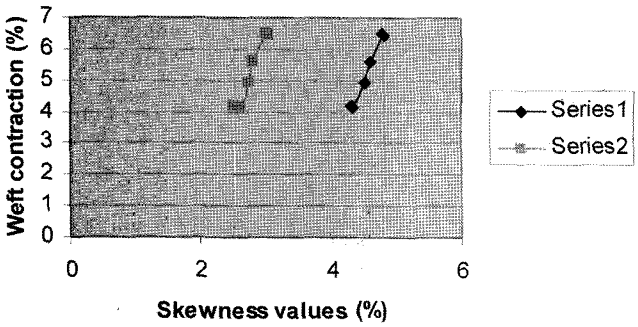


Figure 10. Plot of weft contraction versus the measured (series 2) and estimated maximum possible skewness values (series 1). Series 1: maximum possible skewness, series 2: actual measured skewness.

There are maximum numbers of (voids) free spaces giving enough freedom to floats to move.

However in order to test the above analyses, part II of the experimental work was done (Table 3 part II). As one can see, case 1 & 2 "herringbones", yarns do not find one freeway across the width of the fabric to skew (Figure 11). Indeed each weave repeat contains 2 diagonal lines against each other which make the skewness direction reverse causing the fabric to have the lowest amount of skewness (almost zero). In other word; the location of the free space depending upon the twill line is changed (moved from right side of the float to the left side of the float).

Table 3 part II (Case 3 and 4) where the 1/1 plain weave is added to 2/2 and 3/3 weaves caused to reduce the skewness from 2.5 % and 3.0 % to 1.10 % and 1.45 %. This reduction of the skewness is due to the increase of interlacing points which block the freedom of the yarn movement as well as the fabric contraction (Figure 12).

Conclusions

Following observations are the outcome of this experimental research work.

When fabrics are released from the weaving tensions (during relaxation), depending upon the weave structure there is a chance that the fabric will become skewed.

Distortion of the twill weave woven fabrics is dependent upon the behaviour of the floats at the relaxation state.

The twill structures give the fabrics chance to be skewed in twill direction. The reason is, during relaxation (when yarns are shrinking) each float acts like in-plane lever making warp float with the neighbouring weft floats to act like the two arms of a scissor causing elongation of the main diagonal and shortening of the off diagonal making the fabric to shear.

Location of the free space, assigns the direction of the float movement and as a result, the direction of the fabric skewness.

The length of the floats and free spaces between the yarns are important elements affecting the quantity of the skewness.

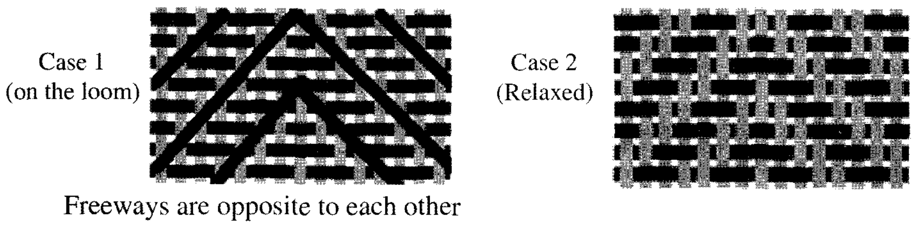


Figure 11. Deformations in herringbone structure.

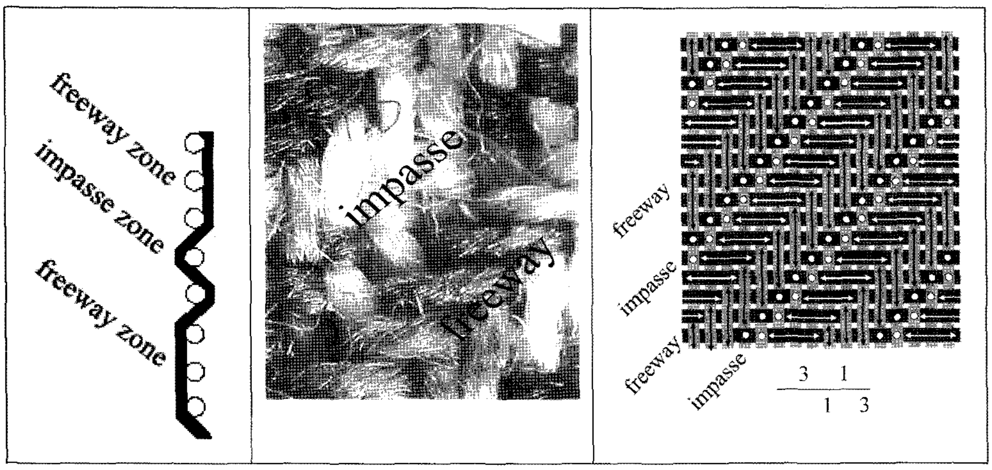


Figure 12. Twill weave.

The longer the floats and the higher the number of the free spaces in one repeat, the more freedom there will be for floats to move and as a result, the higher the skewness.

Adding interlacing points (if possible and accepted) to the structure, could be a way to eliminate the skewness of the woven fabric.

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