Effect of Plain Rib Direction on fabric properties

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Abstract:

The plain weave can be extended in the warp, weft or both directions in order to derive new weaves. Frameworks to evaluate the plain weave derivatives properties were definitive and couldn’t perfectly cover changing into fabric properties due to extension of floated threads in a one direction. This paper empirically investigated tensile properties, tearing and fabric thickness that were applied on woven experimental polyester samples varying in the direction of rib weave, weave type and weft densities. The significant effects of independent on tested properties were concluded by the 3d analysis of variance test.

Breaking strength and elongation in of rib weaves were affected by the weave factor and the number of plain intersection. The warp breaking strength, weft breaking elongation, warp tear strength and thickness rates of horizontal ribs were significantly increased compared with vertical ribs. On the contrary the weft breaking strength, warp breaking elongation, weft tear strength rates of vertical ribs were significantly increased compared with horizontal ribs.

Keywords:

Plain weave, Plain rib, Warp rib, Weft rib, Fabric properties

1- Introduction:

The plain weave is the simplest weave structure among all of the design of woven fabrics. Most of the woven fabrics are manufactured by this weave.

The elementary weaves are defined as those having two floats in the weave repeat, they typically include plain weave, simple twill weaves and satin/sateen weaves. The elementary weaves can be manipulated to derive new weaves. The plain weave can be extended in the warp, weft or both directions in order to derive new weaves. Extending the plain weave in the warp direction will result in warp rib weaves and extending in the weft direction leads to weft rib weaves[3].

Warp rib results in a design that has ribs or texture ridges across the fabric in warp direction which caused by grouping of filling yarns, on the contrary weft rib results in a design that has ribs or texture ridges across the fabric in weft direction which caused by grouping of threads[1].

In rib weaves with long floats it is often difficult to prevent adjoining yarns from overlapping. Weft ribs also tend to be expensive to weave because of their relatively high picks per unit length which reduces the production of weaving machine unless two picks can be inserted at the same time[6].

In both the warp and weft rib weaves, the appearance of the cloth depends on respective thread settings, and to achieve good effect, it is necessary to weave a weft rib with a high number of picks per inch and a comparatively low number of ends per inch. Similarly the warp rib effect can be enhanced with a high number of ends per inch and comparatively low number of picks per inch. The prominence of the rib can be increased by suitable use of coarse and fine yarns[5].

Plain rib weaves are influenced by extended floats in one direction and the plain interfacings; it is important to consider the nature of the float, its arrangement, the interlacing of adjacent threads etc. The previous investigations established that the best way to evaluate weave is to use weave factor[11]. The weave factor is useful in translating the effect of weave on fabric properties. In some weaves, the number of intersections of each thread in the weave repeat is not equal. In such cases, the weave factories obtained by dividing the sum number of threads per repeat / sum number of intersections per repeat of the cross thread[12].

As weave factor increases, elongation at break has a tendency to decrease; breaking force of fabrics in weaves with evenly distributed floats is lower than those in horizontally striped weaves[9].

Textile serviceability is often likely determinates by the physical performance. Among various kinds of physical behavior, tearing and tensile are two main domains of interest of research. However, only rupture caused by tearing is much more closely related to real life usage. Previous researches and studies all showed that tearing of textile is a complicated phenomenon[8].

It is a well known fact that weave structure affects most of the mechanical properties of woven fabric. Although some isolated studies were made in the past to correlate the weave structure to the mechanical properties of woven fabrics, they were incomplete and did not provide any useful information[14].

The studies about plain rib in one direction are definitive. This paper investigates tensile properties, tearing and rib fabric thickness. The rib weave type and weft densities were used to confirm plain rib direction.

2- Experimental Work:

Thirteen experimental samples were shown in table (1), they were woven according three independed variables:

1- Rib direction (horizontal and vertical rib)
2- Weave type (plain 1/1, rib 3/3, rib $\frac{2\ 1}{2\ 1}$, $\frac{3\ 1}{1\ 1}$).
3- Weft density (55 and 70 picks per inch)

All Experimental samples were tested in the Textile Lab of National Institute for Standards. The tensile strength Test was applied according to ISO 13934-1 [7] by Tenius Olsen instrument model (H5KT) - made in USA, the X-force load was controlled to 2N (set by a photo cell) and the tested speed was fixed to 100 mm/min. The same instrument was used for estimating the tear strength according to ASTM, D2261-96, the X-force load was controlled to 1N (set by a photo cell) and the tested speed was fixed to 300 mm/min. The fabric thickness rates were measured by a Teclock device according to ASTM, D17777-96[2], under 2 kilonewton / m^2 disc pressure.

Significant effects of independent variables were statistically concludes by 3d analysis of variance test.

3- Results and Discussion:

Results of breaking strength and elongation in both directions were displayed in table (2). Results of tear strength in both directions and fabric thickness were displayed in table (3).

The three independent variables used to analyze the tested results (weave, rib direction, and weft density).

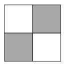
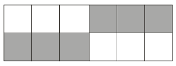
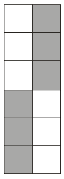
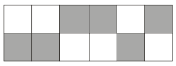
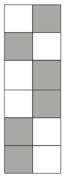
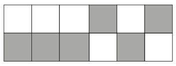
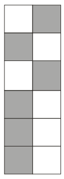
3-1- Effect of weave on tested properties

There was a significant effect of the weave on all tested properties. Tables (4-a) and (4-b) show the f test and the significance effect on 5% level. Rates of Breaking Tensile Strength, Elongation, tear strength in both directions and fabric thickness. The significant effect of each independent variable, the double interactions and all over interactions were displayed in the later tables.

The plain weave 1/1 mean rates with the lower weft densities were the highest in most results of breaking tensile strength and elongation in both directions due to decreasing the weave factor (Weave factor = number of yarn repeat/number of intersections) of plain weave among all weaves; the slippage resistance increased and the break load increased to most far values. This approaching implied that yarn failure mechanism in the fabric is dominated with slippage interlacement changes the contact area between warp and weft yarns. So contact friction between warp and weft yarns of plain increased and provided more resistance to tensile load[10].

The mean differences among the woven ribs is clearly significant. The rib weaves $\frac{3\ 1}{1\ 1}$ in both directions were the highest compared with the rib weaves $\frac{2\ 1}{2\ 1}$ in both directions and rib weaves 3/3 in both directions as shown in table (5); decreasing the weave factor of compound rib weaves caused increasing tensile properties compared with simple rib weave 3/3. Although the weave factor of the two compound rib weaves were congruous but tensile breaking strength and elongation in both directions of rib weaves $\frac{3\ 1}{1\ 1}$ significantly increased more than those of rib weaves $\frac{2\ 1}{2\ 1}$ due to increased of plain intersection which overcome the small difference in float length. The increase in evenly distributed float cause more possibilities to break the floats, this may agree with Kumpikaitė' opinion that Fabrics with evenly distributed floats broke at the weakest part of the fabric[9]. The plain weave 1/1 mean rates with the lower weft densities were the lowest in all results of tear strength in both directions due to increasing restrictions facing tear load.

Table (1). Experimental Samples Specifications

Sample No.	Yarns Specs.		yarns/inch		Weave Structure
	Warp	Weft	Warp	Weft	
1				55	 Plain weave 1/1
2				70	 Horizontal rib 3/3
3				55	
4				70	 Vertical rib 3/3
5				55	
6				70	 Horizontal rib $\frac{2\ 1}{2\ 1}$
7	Polyster 150 Denier 10 bond/m	Polyster 150 Denier 10 bond/m	55	55	
8				70	 Vertical rib $\frac{2\ 1}{2\ 1}$
9				55	
10				70	 Horizontal rib $\frac{3\ 1}{1\ 1}$
11				55	
12				70	 Vertical rib $\frac{3\ 1}{1\ 1}$
13				55	

The breaking elongation in both directions decreased influenced increasing the short plain interlacing; this may increase the thread crimps so the extensibility increased

The weft tear strength rates of vertical rib 3/3 were the highest among all vertical ribs due to collecting the wefts in supporting treble groups to resist the applied tear load. The warp tear strength rates of vertical rib 3/3 were the highest among all vertical ribs due to decreasing compression constrains of plain intersections in weft direction.

The same result could be concluded for the warp tear strength and weft tear of horizontal rib 3/3. Dhamija's [4] study approached that on going the fabric with longer floats generally exhibits higher tearing strength due to greater ease of yarn slippage and fabric distortion, causing more yarns to share the load.

The considered significance difference concerned to tear strength in both directions of rib weaves indicated that the rib structure is sensitive to changing in float length and its effect on the opening of the woven structure and the thread freedom to withstand tear loads.

The regular increasing in float length of rib weave 3/3 leaded to a significant increase in fabric thickness. The float over three yarns made significant increasing of rib weaves $\frac{3\ 1}{1\ 1}$ between the rib weaves $\frac{2\ 1}{2\ 1}$ and plain 1/1.

3-2- Effect of rib direction on tested properties

There was a significant effect of the rib direction on all tested properties as shown in Tables (4-a) and (4-b). In the warp direction of horizontal ribs the warp threads formed plain intersections with shorter floats so the warp breaking strength rates | increased more than the weft breaking strength,

Table (2).Results of breaking strength and elongation in both directions

Sample No.	Weftsi/nch	Weave	Warp breaking strength (N)	Warp breaking elongation (%)	Weft breaking strength (N)	Weft breaking elongation (%)
1	55	Plain weave 1/1	1152.667	35.247	1109.667	24.500
2	70	Horizontal rib 3/3	1126.333	21.667	1284.333	38.067
3	55	Horizontal rib 3/3	1107.333	21.410	1029.000	33.810
4	70	Vertical rib 3/3	1108.333	41.900	1288.333	19.683
5	55	Vertical rib 3/3	1087.667	39.883	1103.333	21.260
6	70	Horizontal rib $\frac{2\ 1}{2\ 1}$	1175.000	27.600	1376.333	32.060
7	55	Horizontal rib $\frac{2\ 1}{2\ 1}$	1135.000	25.130	1073.667	31.077
8	70	Vertical rib $\frac{2\ 1}{2\ 1}$	1154.000	35.400	1443.000	24.287
9	55	Vertical rib $\frac{2\ 1}{2\ 1}$	1118.667	30.203	1113.333	22.187
10	70	Horizontal rib $\frac{3\ 1}{1\ 1}$	1183.667	24.987	1479.000	35.013
11	55	Horizontal rib $\frac{3\ 1}{1\ 1}$	1144.667	28.307	1176.333	32.733
12	70	Vertical rib $\frac{3\ 1}{1\ 1}$	1164.000	38.380	1469.333	24.773
13	55	Vertical rib $\frac{3\ 1}{1\ 1}$	1130.667	34.810	1126.000	22.343

Table (3). Tear strength in both directions and fabric thickness

Sample No.	Weftsi/nch	Weave	Warp tear strength (N)	Weft tear strength (N)	Fabric thickness (mm)
1	55	Plain weave 1/1	67.367	64.633	.309
2	70	Horizontal rib 3/3	128.867	145.033	.646
3	55	Horizontal rib 3/3	168.167	182.833	.611
4	70	Vertical rib 3/3	116.900	189.300	.620
5	55	Vertical rib 3/3	153.900	205.700	.521
6	70	Horizontal rib $\frac{2\ 1}{2\ 1}$	117.367	96.967	.413
7	55	Horizontal rib $\frac{2\ 1}{2\ 1}$	141.067	108.033	.394
8	70	Vertical rib $\frac{2\ 1}{2\ 1}$	61.967	112.567	.401
9	55	Vertical rib $\frac{2\ 1}{2\ 1}$	95.300	133.967	.386
10	70	Horizontal rib $\frac{3\ 1}{1\ 1}$	151.833	80.367	.486
11	55	Horizontal rib $\frac{3\ 1}{1\ 1}$	179.333	103.267	.469
12	70	Vertical rib $\frac{3\ 1}{1\ 1}$	76.200	181.967	.450
13	55	Vertical rib $\frac{3\ 1}{1\ 1}$	104.767	196.800	.401

Table (4-a). F test and significance effect of independent variables on 5% level related to warp breaking strength and elongation in both directions

Source	Warp breaking strength		Warp breaking elongation		Weft breaking strength		Weft breaking elongation	
	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Weave	442.891	.000	11.082	.000	738.753	.000	7.825	.002
Direction	167.587	.000	1014.18	.000	51.228	.000	1731.27	.000
Density	498.056	.000	20.613	.000	9736.21	.000	40.797	.000
Weave * Direction	.210	.812	106.253	.000	78.427	.000	60.536	.000
Weave * Density	16.663	.000	8.753	.001	130.774	.000	1.289	.293
Direction * Density	1.066	.311	25.693	.000	.023	.000	7.756	.010
Weave * Direction * Density	.673	.519	4.425	.022	36.227	.880	15.814	.000

Table (4-b). F test and significance effect of independent variables on 5% level related to warp and weft tear strength, and fabric thickness

Source	Warp tear strength		Weft tear strength		Fabric thickness	
	F	Sig.	F	Sig.	F	Sig.
Weave	325.608	.000	687.987	.000	4800.78	.000
Direction	1411.79	.000	1137.31	.000	523.926	.000
Density	657.188	.000	190.696	.000	499.129	.000
Weave * Direction	214.227	.000	250.348	.000	74.525	.000
Weave * Density	7.159	.003	4.752	.017	70.016	.000
Direction * Density	1.293	.266	4.511	.043	79.371	.000
Weave * Direction * Density	2.081	.145	9.386	.001	31.129	.000

Table (5). Mean values of tested properties due to rib weave effect

Weave	Warp breaking strength (mean)	Warp breaking elongation (mean)	Weft breaking strength (mean)	Weft breaking elongation (mean)	Warp tear strength (mean)	Weft tear strength (mean)	Fabric thickness (mean)
Rib 3/3	1107.417	31.215	1176.250	28.205	141.958	180.717	.600
rib $\frac{2\ 1}{2\ 1}$	1145.667	29.583	1251.583	27.402	103.925	112.883	.399
rib $\frac{3\ 1}{1\ 1}$	1155.750	31.621	1312.667	28.716	128.033	140.600	.451

the increased number of plain intersections in warp direction inhibit warp threads to completely overcome their crimp so the elongation in warp direction decreased than weft directions shown in table (6). The same explanations in the reverse direction referred to increasing weft breaking strength of vertical ribs than the warp breaking strength and decreasing the elongation of vertical ribs than horizontal ribs.

The significant difference of tear strength rates in both directions influenced by the rib weave direction is clear. According to collecting the yarns in groups, the warp tear strength of horizontal ribs increased than vertical ribs and weft tear strength of vertical ribs increased than horizontal ribs. The warp tear strength rates of horizontal ribs increased 45.6% than weft tear strength rates of vertical ribs while weft tear strength of vertical ribs increased 42.4% than warp tear strength of horizontal ribs.

The past interpretation is similar to Schwartz [15] explanation; thread mobility is an important factor affecting tear strength since it will facilitate the grouping or buckling of threads during tearing and therefore improve the tearing resistance as more than one thread has to be broken at a time. This grouping of threads is made easier if the yarns are smooth and can slip over each other. The vertical cords formed by horizontal ribs leaded to increased rates of fabric thickness compared with those formed by vertical ribs; this may due to the effect of fabric shrinkage in width so the weft floats became more prominent than the warp floats which had tension and friction fatigues effect on their diameters.

3-3- Effect of weft density on tested properties

There was a significant effect of weft density on all tested properties as shown in Tables (4-a) and (4-b). The 70 weft/inch increase the number of intersection in warp direction so the warp breaking strength increased as shown in table (7), the warp and weft crimp increased so the elongation increased. The mean significance differences of breaking strength rates in weft direction of 70 weft/inch obviously increased; meaning the effectiveness of increasing the number of picks per unit to increase the tensile strength in weft directio. Also The major experimental samples appeared a tendency of denser picks to increase breaking elongation in both directions.

The fabric stiffness might be increased and the freedom of yarns restricted due to increasing the number of weft per inch so the tear strength in both directions decreased.

This result agrees with Nassif's empirical work which demonstrated that the weft density increases fabric tearing strength of Micro polyester Woven Fabrics[13].

Table (6). Mean values of tested properties due to rib direction effect

Rib direction	Warp breaking strength (mean)	Warp breaking elongation (mean)	Weft breaking strength (mean)	Weft breaking elongation (mean)	Warp tear strength (mean)	Weft tear strength (mean)	Fabric thickness (mean)
Horizontal	1145.333	24.850	1236.444	33.793	147.772	119.417	.503
Vertical	1127.222	36.763	1257.222	22.422	101.506	170.050	.463

Table (7). Mean values of tested properties due to weft density effect

Weft density	Warp breaking strength (mean)	Warp breaking elongation (mean)	Weft breaking strength (mean)	Weft breaking elongation (mean)	Warp tear strength (mean)	Weft tear strength (mean)	Fabric thickness (mean)
70 weft/inch	1151.889	31.656	1390.056	28.981	108.856	134.367	.503
55 weft/inch	1125.238	30.713	1104.476	26.844	129.986	142.176	.442

4- Conclusion:

This paper empirically investigated tensile properties, tearing and fabric thickness that were applied on woven experimental polyester samples varying in the direction of rib weave, weave type and weft densities. The yarn failure mechanism in the fabric is dominated with slippage interlacement changes the contact area between warp and weft yarns; so contact friction between warp and weft yarns of plain increased and provided more resistance to tensile load. Decreasing the weave factor of compound rib weaves caused increasing tensile properties compared with simple rib weave 3/3. Two reason controlled the tensile breaking strength of compound rib weaves which had congruous weave factor the number increased of plain intersection which overcome the small difference in float length and The decreased in evenly distributed float cause less possibilities to break the floats in weakest part.

Nature of plain rib weave in one direction plays an important role in collecting the yarns in groups and increasing the tear strength in other direction. Tension and friction fatigue of vertical ribs ends decreased their prominent resulted in shrinking compared with horizontal ribs.

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