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Title: **Effect of Jacquard Structures on the Tensile Strength Property of Weft Knitted Fabrics**

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Effect of Jacquard Structures on the Tensile Strength Property of Weft Knitted Fabrics

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ABSTRACT The goal of this study is to examine the effects of jacquard knit structures (Twill, Stripe, Net and Net1*2) on the tensile properties of knitted fabrics. The relationship between the jacquard knit effect and fabric tensile properties was evaluated through experimentation and analysis. V-bed flat knitting machines were used in the study to manufacture knit samples that were entirely made of 87.3 Tex acrylic yarns. The finding indicates that there are unique relationships between fabric tensile characteristics and jacquard effect structures. Tensile characteristics like tensile strength and elongation percent at break of jacquard effect knitted fabrics vary substantially from one another. The knit structure has a considerable impact on the length wise and width-wise tensile strength of jacquard-effect knitted fabrics at Sig. 0.000 and Sig. 0.000, respectively. Additionally, the interaction of fabric structure and weight, as well as fabric structure and thickness, affects the tensile property of the jacquard effect knitted fabric.

INDEX TERMS elongation at break, jacquard effect, tensile strength

I. INTRODUCTION

Knitted fabrics play a crucial role in the textile industry, offering a blend of comfort, functionality, and style [1]. Knitted fabrics exhibit various properties based on their composition and manufacturing methods. Knitted fabrics mechanical and physical characteristics are crucial in a variety of ways [2]. The tensile strength property is one of the most important properties, and the tensile characteristics of knitted fabrics are significantly influenced by the fabric structure [3]. The fabric's modulus, strain, and tensile strength are all influenced by many knitting parameters [4],

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including loop length [5], kind of yarn [6], and density of stitches [7]. And also, the direction in which the force is applied in relation to the fabric structure might affect the tensile characteristics [8]. Because of the way loops are arranged, fabrics frequently behave differently in the wale (length-wise) direction than in the course (width-wise) direction [9]. Without any slippage, extension, or lateral compression of the yarn, the resistance to extension was wholly caused by a change in the yarn's configuration within the knitted loop [10]. A knitted fabric's tensile characteristics can also be affected by its weight and thickness. In comparison to lighter and thinner fabrics, heavier and thicker materials often offer better tensile strength but lower elongation [11]. Tensile characteristics can be impacted by the number of stitches per unit area, which is commonly described as stitches per inch (SPI) or courses per inch (CPI). Due to more yarns being entangled per unit area, textiles with a higher stitch density typically have higher tensile strength and lower elongation [12].

Knitted fabrics with jacquard patterns offer a variety of qualities that are essential for numerous applications. These structures are useful for clothing, healthcare, and safety protection because of their functional qualities, which include lightweight, heat conduction, compression resistance, moisture permeability, and air permeability [13]. Additionally, developments in jacquard knitting technology have made it possible to create complex patterns with continuous motifs and smooth surfaces, improving the fabric's quality and visual appeal [14]. The effects of various knit structures on the tensile properties of knitted fabrics have been analyzed by many researchers, [15], [16]–[18]. The current study specifically focuses on how the jacquard effect knit structure affects the tensile strength property of knitted fabrics. To the best of our knowledge, there have been limited studies examining the impact of jacquard knit structure on the knitted fabric's tensile qualities. Four jacquard effect structures-the twill effect, the net effect, the net1*2 effect, and the stripe effect were created in order to achieve the study's objective of determining the impact of certain knit structures on the tensile fabric property under constant processing conditions. And, the jacquard effect fabrics are double-layer fabrics, which is an intriguing subject for research on how knit structure affects tensile strength. These fabrics consist of two layers of knitted fabric. By examining the connection between knit structure and tensile strength in double-layer fabrics, this work seeks to close this gap.

II.METHOD

A. MATERIALS

1) YARN

All sample fabric constructions were made using 100% acrylic yarn that was staple spun and had an 87.3 Tex. The yarn was obtained from vendors of textile yarns suppliers.

2) KNITTING MACHINE

The four distinct types of jacquard effect knitted fabrics were produced using a STOLL CMS 502 HP V-bed knitting machine with electronic controls set to the knitting carriage's speed of 0.9 m/min, with a take-down tension of 3.5. Additionally, the back loop lengths measured 10.4mm and front loop lengths were10.3mm.

B. SAMPLE PRODUCTION

A STOLL CMS 502 HP V-bed knitting machine was used to create the jacquard knitted sample fabric, which are named Twill, Net, Net 1*2, and Stripe. And the sample was manufactured at Ethiopian institute of textile and fashion technology (EiTEX) integrated textile factory.

C. FABRIC EVALUATION

After knitting, various physical properties of the fabric samples were analyzed in accordance with the relevant guidelines. The textile industry claims that the materials selected for the study are widely utilized in garment fabrics and are easily obtained on a commercial basis. All of the fabrics were pre-conditioned for 24 hours in a conditioning chamber at 20°C and 65% relative humidity before each test. Each samples of the fabric was measured for each structure in the test, and the average outcome was analyzed.

D. TENSILE STRENGTH

Testing for tensile strength offers important information about how a material behaves under tensile loading circumstances. Using a MESDAN TENSO Tensile tester with a clamp speed of 300 mm/min, a sample length of 75 mm, a load cell of 5 kN, and a pretension of 0 N, the experiments were conducted in compliance with ASTM D5035-instructions 95.

E. FABRIC WEIGHT (GSM)

GSM, is the unit of measurement used to determine the weight of fabrics. The testing was carried out in accordance with ISO 3801. It was measured with a cutting tool (round, 100 cm2) and a digital measuring balance made by Metler.

F. FABRIC THICKNESS MEASUREMENT

In accordance with ASTM D1777-96, the thickness of the fabric samples was measured using a digital thickness gauge (MESDAN, model D-2000). The experiment was carried out at100 KPa.

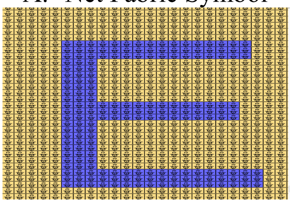
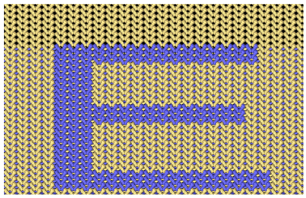
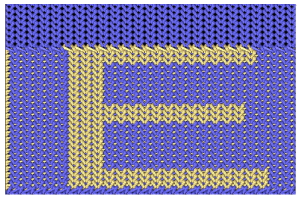
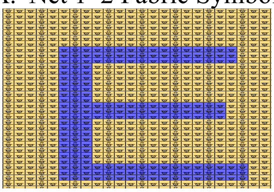
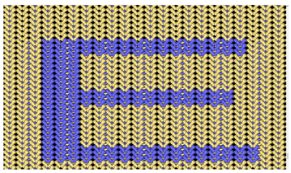
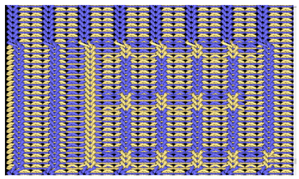
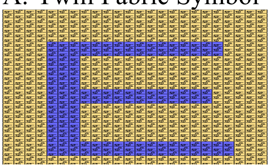
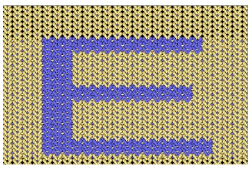
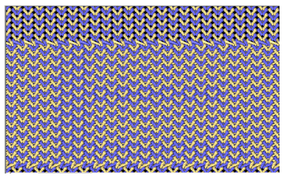
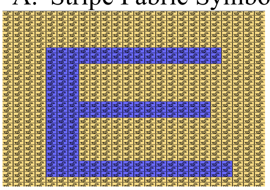
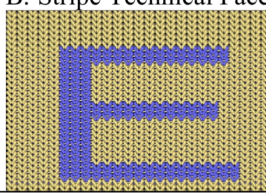
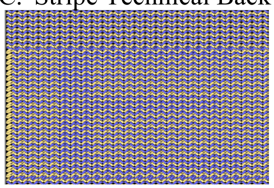
A. Net Fabric Symbol 	B. Net Technical Face 	C. Net Technical Back 
A. Net 1*2 Fabric Symbol 	B. Net 1*2 Technical Face 	C. Net 1*2 Technical Back 
A. Twill Fabric Symbol 	B. Twill Technical Face 	C. Twill Technical Back 
A. Stripe Fabric Symbol 	B. Stripe Technical Face 	C. Stripe Technical Back 

FIGURE 1. Effect of (A, fabric symbol, B, fabric technical face, and C, fabric technical back) of the four jacquard effect knitted fabric designs offered by Stoll M1Plus

FIGURE 2. Fabric sample of the four jacquard effects on both sides (A. fabric front effect and B. fabric back effect)

III. RESULTS AND DISCUSSION

Table I displays various characteristics of the knitted fabric made with 87.3 Tex acrylic yarns that has a jacquard effect on stripes, twill, net, and net1*2.

The table includes measurements for thickness, GSM, maximum breaking force in lengthwise and widthwise directions and elongation at break in the lengthwise and widthwise direction.

TABLE I
CHARACTERISTICS OF VARIOUS KNITTED STRUCTURES IN FABRICS

Fabric Structure	Fabric weight (g/m^2)	Thickness (mm)	Max. Breaking Force in N		Elongation % at Break	
			Lengthwise Direction	Widthwise Direction	Lengthwise Direction	Widthwise Direction
Stripe	766.0	2.72	492.60	179.00	75.23	83.73
Twill	902.0	2.75	486.60	339.40	83.06	88.02
Net	1019.0	2.67	365.00	369.20	151.19	94.56
Net1*2	794.0	2.58	328.40	249.00	83.86	109.37

TABLE II
TENSILE PROPERTY OF JACQUARD EFFECT KNITTED FABRIC ANOVA RESULT IN THE WIDTHWISE DIRECTION

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	112890.55	3	37630.18	73.48	.000
Within Groups	8194.00	16	512.13		
Total	121084.55	19			

TABLE III
TENSILE PROPERTY OF JACQUARD EFFECT KNITTED FABRIC ANOVA RESULT IN THE LENGTH WISE DIRECTION

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	105540.95	3	35180.32	18.26	.000
Within Groups	30831.60	16	1926.97		
Total	136372.55	19			

A. EFFECT OF KNIT STRUCTURE ON TENSILE STRENGTH

Tensile strength, which indicates a material's capacity to tolerate, stretching pressures, is an essential mechanical characteristic in textiles. Tensile strength is significantly influenced by the fabric's structure, which includes elements like yarn type, knit pattern, and yarn density [19]. Tensile strength of jacquard effect knitted fabrics made from 100% acrylic yarns notably differ one from the other. The length wise and width wise tensile strength of jacquard effect knitted fabrics are significantly influenced by knit structure at Sig. = 0.000 and Sig. 0.000, respectively (Table II and III).

However, the tensile property of jacquard effect knit structures has different significant effect between knit structures in length and width wise property of knitted fabrics. Table 1 presents the results of tensile strength tests result for four types of jacquard effect knitted fabrics highlighting differences among them. The tensile strength of stripe effect made from 100% acrylic has an average breaking force of 492.66N along the length of the fabric and an average of 179N across the width of the fabric. This disparity underscores the greater tensile strength along the wale direction compared to the course direction. The reason for this is that all of the constituent loops in knit materials share the applied force in the same direction, as they are composed of loops along the wale direction [20]. On the other hand, when the force is applied along the direction of the course, the loops get separated and then return as yarns. This causes the force to be distributed exclusively by yarns, resulting in a decreased tensile strength along the course direction [21]. And its tensile strength value along the length wise direction has relatively higher value and along the width direction it has relatively lower value than other knit structures. These fabrics are produced using two sets of yarns, one for each layer of the fabric to create a pleated jacquard pattern and the two sets of yarns form a pleated fabric with tight yarn interlocking, the jacquard knit structure of stripe effect and twill effect has denser yarn arrangements. As a result, the tensile strength value of stripe and twill are more than net and net1*2 jacquard effect fabric. More load distribution and yarn interlacement resulted in improved tensile strength for fabrics with tighter knit structures.

TABLE IV
COMPARISON OF TENSILE PROPERTIES ACROSS JACQUARD EFFECT KNITTED FABRICS IN THE LENGTHWISE DIRECTION

(I) Knit Structure	(J) Knit Structure	Mean Difference (I-J)	Std. Error	Sig.	95% CI	
					LL	UL
Stripe	Twill	6.00	27.76	.996	-73.43	85.43
	Net	127.60*	27.76	.002	48.17	207.03
	Net1*2	164.20*	27.76	.000	84.77	243.63
Twill	Stripe	-6.00	27.76	.996	-85.43	73.43
	Net	121.600*	27.76	.002	42.17	201.03
	Net1*2	158.200*	27.76	.000	78.77	237.63
Net	Stripe	-127.60*	27.76	.002	-207.03	-48.17
	Twill	-121.60*	27.76	.002	-201.03	-42.17
	Net1*2	36.600	27.76	.565	-42.83	116.03

Net1*2	Stripe	-164.20*	27.76	.000	-243.63	-84.77
	Twill	-158.20*	27.76	.000	-237.63	-78.77
	Net	-36.60	27.76	.565	-116.03	42.83

In comparison to the twill effect, the stripe effect has fewer gaps and tighter patterns between stitches, resulting in relatively better tensile strength properties. According to as per the Post Hoc test result from Table IV, there is no significant effect test result (sig. 0.99) between the tensile property of the stripe effect knit structure and a twill effect knit structure, which have the tensile breaking force N of 492.6 and 486.6 respectively. However, the stripe effect knit structure has a significant difference tensile property in the length-wise direction between the net and net 1*2 knit structure, with a significant value of 0.002 and 0.00 respectively.

That is because the two sets of yarns do not interlock; instated, they only create two distinct layers from each set of yarn. This might not reduce localized stress concentration, so that knit structures distribute tensile forces less equally across numerous layers, and it gives a possibility of yarn breakage or fabric failure.

Additionally, there is no significant effect test result (sig. 0.56) between the tensile property of, net effect and net1*2 effect knit structure, which has a tensile breaking force N of 365.0 and 328.4 respectively. The yarns in the net1*2 structure are not compressed like those in the net effect structure due to the missing stitch, which may lower the tensile property of the former over the latter. And in all cases, the maximum breaking force N in lengthwise direction is higher than widthwise with direction, because the orientation of the loop legs and the direction of force are the same direction and the number of yarns that bear the tensile force on the longitudinal tensile is more than that of the transverse tensile [22]. The elongation at the break of the net1*2 effect has 151.19% along the length of the fabric. And its elongation at break% value along the length wise direction has relatively higher than the other three structures. Tensile strength, which is measured as the maximum braking force on, newton, and elongation percent (%) at the break, is inversely proportional. Higher breaking force is consumed for low elongation percent at the break and the reverse is also true. The dependence of elongation at maximum force (elongation at break) on the knitting structure is a basic structure distinguished for the greatest elongation at break (and similarly for the maximum force to rupture) in a course direction. It is because the loops have more potential to deform in the course direction [23].

B. EFFECT OF FABRIC STRUCTURE AND THICKNESS ON TENSILE STRENGTH PROPERTY

Fabric thickness and structure have a significant impact on tensile strength; thicker fabrics frequently exhibit higher strength values, and certain structural configurations have an impact on mechanical performance. Figure 3 shows that tensile strength test result demonstrates that the four jacquard effects knitted fabrics have different values. The tensile strength of a twill-effect knitted fabric has a maximum breaking force along the length and the width of the fabric. Due to, its thickness value higher compared to net and net 1*2 fabrics, contributing to its superior tensile properties. Thick materials usually offer higher tensile strengths because they are more volumetric and can tolerate deformation. As the loops come closer to each other due to the increase in course density, overlapping of loops takes place, which enhances the higher fabric thickness [24]. However, according to the Post Hoc test result from Table IV, there is no significant effect test result (sig. 0.99) between the tensile properties of the stripe effect knit structure and the twill effect knit structure that have the tensile breaking force N of 492.6 and 486.6, respectively. But, the thickness value of twill is slightly greater than that of the stripe effect, which might be due to the presence of alternate interlocked of the two yarns in the twill effect, which could marginally reduce its tensile strength compared to the stripe effect.

C. EFFECT OF FABRIC STRUCTURE AND FABRIC WEIGHT ON TENSILE STRENGTH PROPERTY

The effect of fabric weight on tensile strength, has revealed a positive correlation between fabric weight and tensile strength, with heavier materials frequently displaying greater strength values [25]. The explanation for this link is that fabrics with a larger weight typically include more fiber and yarn, which enhances their mechanical properties and increases their resistance to deformation. Many factors, like fabric construction, yarn type, and fiber type, affect the relationship between fabric weight and tensile strength.

Figure 4 illustrates that the net effects have higher weight values compared to twill, net1*2, and stripe effect structures. Knit structures with high GSM generally have higher stitch densities. Higher stitch densities result in heavier fabrics because more yarn is required to create the stitches. The fabric has a comparatively higher weight than other constructions due to the net effect, which is a double knit fabric. The two layers are generated simultaneously by the front needles knitting with one yarn and the back needles knitting with the second yarn.

And also, the net 1*2 effect fabric has a double layer, but the back layer has a loose structure, which makes it makes low weight as compared to net effect fabric. Because compared to missing stitches, knit stitches result in a denser fabric structure. A compact and closely knit fabric is produced when the yarn is drawn tightly to form a loop during the formation of a knit stitch. However, the stripe effect fabric has higher tensile property than net effect, even if the net effect fabric has greater fabric weight than stripe effect. It might be the nature of fabric, because to produce these fabrics the knitting machine uses two sets of yarns, one for each layer of the fabric, to create a pleated jacquard pattern. But, in the stripe effect structure the two sets of yarns form a pleated fabric with tight yarn interlocking, it gives the jacquard knit structure of stripe effect has denser yarn arrangements. Therefore, fabrics with tighter knit structures typically had higher tensile strength because of increased load distribution and yarn interlacement [26].

TABLE V

COMPARISON OF TENSILE PROPERTIES ACROSS JACQUARD EFFECT KNITTED FABRICS IN THE WIDTHWISE DIRECTION

(I) Knit structure	(J) Knit structure	Mean Difference (I-J)	Std. Error	Sig.	95% CI	
					LL	UL
Stripe	Twill	-160.40*	14.31	.000	-201.35	-119.45
	Net	-190.20*	14.31	.000	-231.15	-149.25
	Net1*2	-70.00*	14.31	.001	-110.95	-29.05
Twill	Stripe	160.40*	14.31	.000	119.45	201.35
	Net	-29.80	14.31	.201	-70.75	11.15
	Net1*2	90.40*	14.31	.000	49.45	131.35
Net	Stripe	190.20*	14.31	.000	149.25	231.15
	Twill	29.80	14.31	.201	-11.15	70.75
	Net1*2	120.20*	14.31	.000	79.25	161.15

	Stripe	70.00*	14.31	.001	29.05	110.95
Net1*2	Twill	-90.40*	14.31	.000	-131.35	-49.45
	Net	-120.20*	14.31	.000	-161.15	-79.25

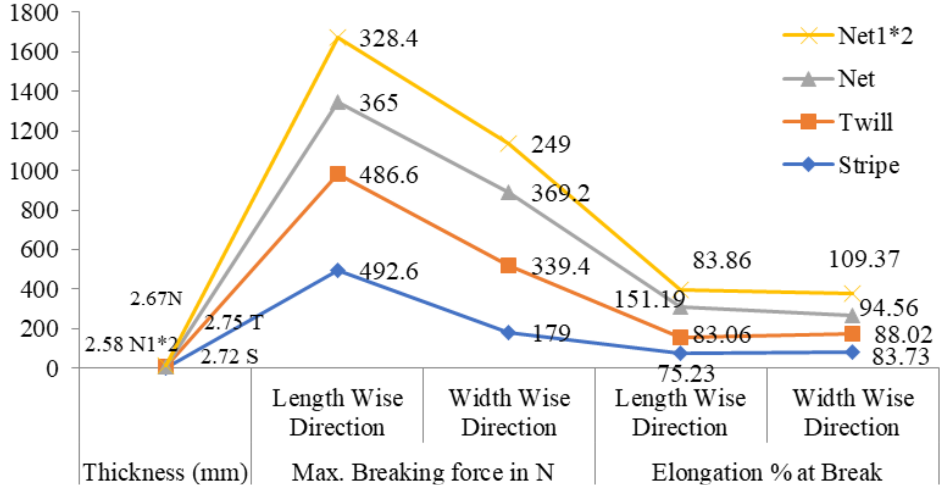


FIGURE 3. Effect of fabric structure and fabric thickness on tensile strength property

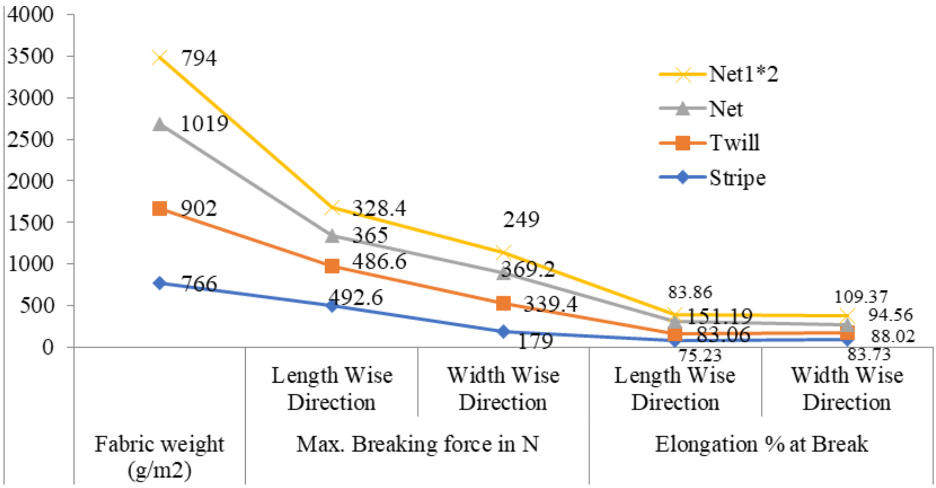


FIGURE 4. Effect of fabric structure and fabric weight on tensile strength property

IV.CONCLUSION

This study focuses on examining, the tensile characteristics of jacquard effect knitted fabrics. Tensile characteristics like tensile strength and elongation percent at break of jacquard effect knitted fabrics created from 100% acrylic yarns differ greatly from one another. Knit structure has a considerable impact on the lengthwise and widthwise tensile strength of jacquard-effect knitted fabrics at Sig. = 0.000 and Sig. 0.000, respectively. The tensile strength of a 100% acrylic stripe-effect has maximum breaking force of 492.66 N along the fabric's length and an average of 179 N across the fabric's width. And compared to other knit structures, its tensile strength value is comparatively higher along the lengthwise direction and lower along the widthwise direction. Also, net effect has maximum elongation at break of 151.19% along the fabric's length, and Net1*2 effects have maximum elongation at break to the width with direction, whereas the stripe effect knit structure's elongation at break in the lengthwise direction is 75.23%, making it relatively less elongated than other knit structures. And also, the interaction of fabric structure and weight, as well as fabric structure and thickness, affects the tensile property of the jacquard effect knitted fabric.

CONFLICT OF INTEREST

The authors of the manuscript have no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

DATA AVALIABILITY STATEMENT

The data associated with this study will be provided by the corresponding author upon request.

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