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Research Article

Comparative analysis of physical properties of 1 × 1 rib and plain interlock fabrics knitted with same knitting parameters

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ABSTRACT

Double jersey knitted fabric's (rib and interlock) properties such as bursting strength, stiffness, Gram per Square Meter (GSM), and stitch density have a great influence on its end-use. The aim of this research is to investigate on physical properties of double jersey (rib and interlock) fabric having the same stitch length, yarn type, and count and which were produced in the knitting machines of the same gauge and diameter. The effect of different knit structures on bursting strength, stiffness, GSM, stitch density, and width of the fabric was found out. The results revealed that interlock fabrics have higher GSM, stitch density, and bursting strength values than rib fabrics while the rib fabrics have a higher width than interlock. It is also found that interlock fabric is stiffer than rib fabric which means rib fabric has better flexibility and drapability that significantly effects on customers end use preference. Hence, plain interlock structure is heavier, thicker, narrower, stronger, and stiffer than 1 × 1 rib structure.

Keywords: Bending length, bursting strength, draping and stiffness, fabric width, flexural rigidity, gram per square meter, interlock, rib fabric, shrinkage, stitch density, stitch length, thickness

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INTRODUCTION

Knitted fabric possesses high stretch and recovery, providing greater freedom of movement and outstanding comfort qualities for which they have been preferred as fabrics in many kinds of clothing for a long time.[1] The key to understanding a knitted structure lies within its basic element, the single knitted loop.[2] There are four primary base weft knitted structures – plain, rib, interlock, and purl. Each of these structures shows different properties such as Wales per inch (WPI), course per inch (CPI), stitch density, gram per square meter (GSM), fabric width, bursting strength, and stiffness taking yarn type, count, and machine setting constant.

Knitted fabrics are exposed to multiaxial forces not only during their dry and wet processing in the factory but also during their end-use. Due to their distinct structural features, tensile and tear strength testing as applicable to woven fabrics is not suitable for the knitted fabrics. Therefore, bursting strength of knitted fabrics is conducted to assess the fabric's ability to withstand multiaxial stresses without breaking off.[3]

Bending length is the length of fabric that will bend under its own weight to a definite extent. It is the measure of stiffness of a fabric. The stiffness of fabric constitutes the basic feature determining their suitability for a specific use. The bending stiffness of fabric is an important parameter which determines the drapability, handle, and esthetic appeal of fabric.[4] The drapability of textiles in physical terms is a result of mutual interaction between the bending stiffness and fabric weight.[5]

Literature Review

- As highlighted by pierce, the handle of fabric has judged the sensations of stiffness or limpness, hardness or softness, and roughness or smoothness which are all made use of. Among all of them, fabric stiffness is a key factor in the study of handle and drape.[6]

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- Davis and Edwards have developed a perspective which identifies that the texture of fabric is stiffened by inserting more courses per inch; the bursting pressure and tension increase while the extension remains approximately constant.[7]
- Hamilton and Postle have developed a perspective which identifies that the bending characteristics of weft knitted fabrics are determined by fabric thickness, fabric weight, fabric tightness, stitch type, fabric directions, fabric face and back, and overall construction.[8]
- Gibson and Postle have developed a perspective which identifies that overall fabric construction also determines bending characteristics. They measured the frictional bending moment and the flexibility of several types of knitted fabrics. Plain knits had very low frictional bending moments and high flexibilities. However, generally, plain knits were similar to double knits.[5]
- Using meta-analysis, De Araujo *et al*. stated that to increase the stiffness of knitted fabrics, and therefore their capacity to resist deformation from applied loads, pre-tensioning techniques or the introduction of straight yarns in various directions is required. To increase the resilience of knitted fabrics, and therefore their capacity to absorb energy, a relaxed stretchable loop structure is required.[9]
- As highlighted by Jo, the effect of different factors on the bursting strength of knitted fabrics. The bursting strength increases by increasing knitted fabric density (GSM).[3]

MATERIALS AND METHODS

Machines

Enlisted machines of Table 1 have been used for producing the main material-rib and Interlock fabric.

Equipment

Enlisted major equipment's of Table 2 are used for the mentioned subsequent process.

Sample Fabric Preparation

The fabrics were produced in a double jersey circular knitting machine at Dulal Brothers Ltd. 3 kg of 1 × 1 rib fabric produced in circular rib knitting machine and 3 kg of plain interlock fabric produced in a circular Interlock knitting machine. 40Ne 100% cotton combed yarn was used to produce the fabrics. Both the machines were set of same knitting parameters. Machine gauge, diameter, and no. of needles of the dial and cylinder were 18G, 40" and 4536, respectively. Stitch length of the sample was 3.14 mm.

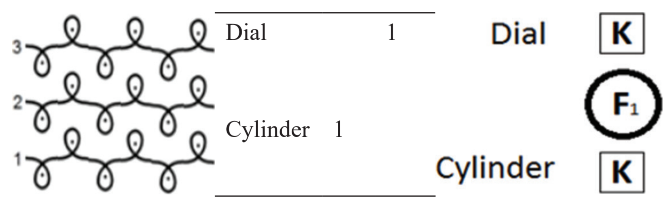
- Before knitting, machine servicing was done properly. All the setting points were checked and yarn tension was adjusted
- After production of the samples was conditioned for 48 h to reach them at a dry relaxed state
- Then, yarn count was tested using scale and precision electronic balance in AUST knitting lab and values of yarn count were found 40Ne for both which has been mentioned at Table 3.

Fabric Specification of the Produced Samples

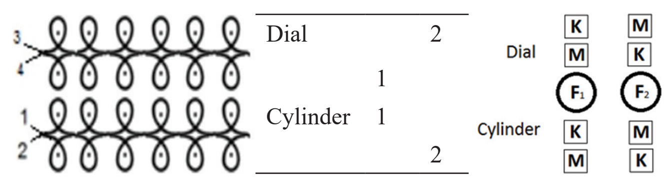
1×1 rib fabric:

Diagrammatic Notation Needle Set out Cam arrangement

Plain interlock fabric:



Diagrammatic Notation Needle Set out Cam arrangement



Test Procedures

Measurement of WPI, courses per inch, fabric width, and stitch density

Testing standard: BS 1051:1981

The test samples should be sufficiently large to enable courses and Wales to be counted at 20 different places over a

Table 1: Specifications of double jersey rib and interlock knitting machine

Name of the machine	Circular rib knitting machine	Circular interlock knitting machine
Brand	Fukuhara	Fukuhara
Machine gauge (needles per inch)	18×18	18×18
Cylinder diameter	40"	40"
No. of feeder	82	82
Total no. of needles	2268×2268	2268×2268
Needle timing	4 needle delay	4 needle delay
Type of needle	Latch needle	Latch needle
R.P.M.	25	20

Table 2: Specifications of major equipment's used in fabric parameter measurement and evaluation

Equipment	Manufacturer	Model	Country of origin	Used for
Precision electronic balance	AND Gulf	EK 600 Dual	UAE	Weight
GSM Cutter	James H. Heal	-	England	GSM
Hydraulic bursting strength tester	Laboratory Supply Co. Ltd.	-	Germany	Bursting strength test
Shirley stiffness tester	SDL International and Co. Ltd.	-	England	Stiffness/Bending length test

Table 3: Specifications of produced fabrics

Sample No.	Fabric type	Yarn type	Yarn count (Ne)	Stitch length (mm)
1.	1×1 rib	100% cotton	40/1	3.14
2.	Plain interlock	100% cotton	40/1	3.14

Table 4: Widths of rib and interlock fabrics

Obs.	Rib fabric		Interlock fabric	
	WPI	Width in inch	WPI	Width in inch
1.	52	87.23	60	75.60
2.	52	87.23	58	78.21
3.	52	87.23	60	75.60
4.	53	85.59	60	75.60
5.	54	84.00	60	75.60
6.	52	87.23	58	78.21
7.	54	84.00	60	75.60
8.	52	87.23	60	75.60
9.	53	85.59	60	75.60
10.	52	87.23	60	75.60
11.	54	84.00	58	78.21
12.	54	84.00	60	75.60
13.	54	84.00	60	75.60
14.	54	84.00	58	78.21
15.	52	87.23	60	75.60
16.	52	87.23	60	75.60
17.	54	84.00	60	75.60
18.	52	87.23	60	75.60
19.	52	87.23	60	75.60
20.	52	87.23	60	75.60
Mean±SD		85.94±1.54		76.12±1.07
C.V%		1.79		1.41

WPI: Wales per inch

minimum measuring distance of 3 cm, spaced to give a good representation of sample avoiding selvedges and center creases.

For this procedure, counting glass and pin are required. Before test, the test samples were conditioned for 48 h under the standard atmosphere.

- First of all, samples were laid horizontally on a flat surface to make the samples relaxed
- The edge of the counting glass was positioned such way that it is parallel to the line of Wales
- Courses were counted along a Wale and Wales were counted perpendicular to the Wales line
- The number of courses and WPI was counted
- Step 3 was repeated for another 19 different places on the sample
- Test results were presented in Table 5 for discussion
- Fabric widths were calculated using the following formula. Values of fabric width presented in Table 4

$$\text{Fabric width in inches} = \frac{\text{Total no. of needles knitting in the machine}}{\text{No. of wales per inch}}$$

- Stitch density was calculated using below formula and results were presented in Table 5.

Stitch density per inch^2 = WPI × CPI

Measurement of GSM

Testing standard: BS 2471:1978

GSM stands for gram per square meter (g/m²). GSM sample cutting method is given below:

- Test sample was cut by GSM cutter from several places of the fabric
- Then, the samples were weighed by electronic balance
- As the cutting area of the cutter was 100 cm^2, the weighed results were multiplied by 100 to convert the result into g/m^2
- Twenty samples were measured for each structure. Test reading was presented in Table 6.

Measurement of bursting strength

Testing standard: ISO 13938-1:1999

The British standard describes a test in which the fabric to be tested is clamped over a rubber diaphragm by means of an annular clamping ring and increasing fluid pressure is applied to the underside of the diaphragm until the specimen bursts. The operating fluid may be liquid or gas. Two sizes of specimen are in use, the area of the specimen under stress being either 30 mm diameter.

Table 5: Stitch density of rib and interlock fabrics

Obs.	Rib fabric			Interlock fabric		
	WPI	CPI	Stitch density	WPI	CPI	Stitch density
1.	52	33	1716	60	43	2580
2.	52	33	1716	58	43.5	2523
3.	52	33	1716	60	43	2580
4.	53	34	1802	60	43	2580
5.	54	33	1782	60	43	2580
6.	52	34	1768	58	43	2494
7.	54	33	1782	60	43.5	2610
8.	52	34	1768	60	44	2640
9.	53	32	1696	60	43.5	2610
10.	52	33	1716	60	44	2640
11.	54	35	1890	58	42	2436
12.	54	34	1836	60	43	2580
13.	54	34	1836	60	44	2640
14.	54	34	1836	58	43.5	2523
15.	52	35	1820	60	43	2580
16.	52	34	1768	60	43.5	2610
17.	54	35	1890	60	44	2640
18.	52	34	1768	60	43	2580
19.	52	34	1768	60	43.5	2610
20.	52	34	1768	60	43	2580
Mean±SD			1782.1±56.16			2580.8±52.62
C.V%			3.15			2.04

WPI: Wales per inch, CPI: Course per inch

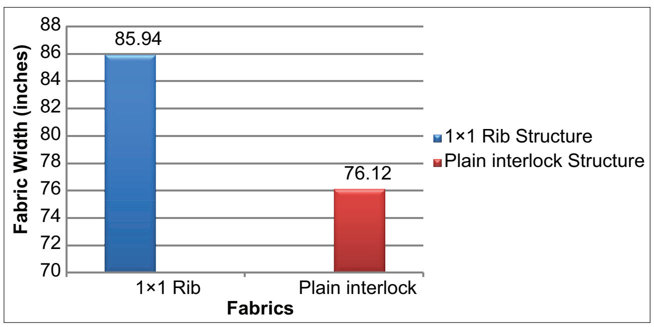


Figure 1: Comparison of fabric widths

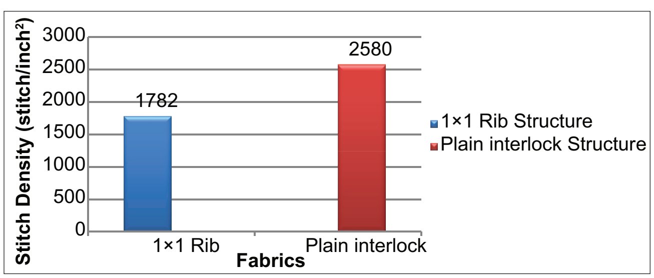


Figure 2: Comparison of stitch density

In this work, the diaphragm bursting test method was used. The specimens for this test were out half-inch greater in diameter than the outside diameter of the clamp ring.

Bursting tester is composed by a cylinder with a flexible rubber diaphragm mounted on its upper part, where it is created pressure read on a double index.

1. The sample between the upper movable ring and lower fixed ring was clamped
2. Both gauge's index (indicator and maximum) were set on zero position
3. Motor was started and pressure increased until sample bursting
4. When the sample was bursted, motor returns to position, pressure decrease, and the apparatus was ready for another test
5. Pressure's maximum value indicated by gauge's index was recorded
6. Above test, procedure was done for two different structures
7. Twenty reading was taken for each structure
8. Test results were presented in Table 7.

Measurement of bending length and flexural rigidity

Testing Standard: BS 3356:1990

For stiffness test, 6” × 1” Wales way direction knitted fabric sample is taken. Since Shirley stiffness tester’s scale dimension is 6” × 1” (sample and scale dimension should be same).

- The test specimens were cut to size 6” × l” with the aid of template
- Both the template and specimen were then transferred to the platform with the fabric underneath
- Then both were slowly pushed forward
- The strip of the fabric initiated to drop over the edge of the platform and the movement of the template and the fabric continued until the tip of the specimen viewed in the mirror cuts both index lines
- The bending length then immediately read off from the scale mark opposite a zero line engraved on the side of the platform

- Each specimen was tested 2 times, at the head end and tail end in Wale direction
- In this way, 20 samples of each structure were tested
- Test results were presented in Table 8 for discussion

Table 6: Areal density (GSM) of rib and interlock fabrics

Obs.	Rib fabric	Interlock fabric
	GSM	GSM
1.	130.75	185.36
2.	127.01	181.31
3.	127.01	185.36
4.	129.49	185.36
5.	135.80	179.24
6.	127.01	179.24
7.	135.80	187.50
8.	127.01	189.69
9.	129.49	187.50
10.	127.01	189.69
11.	135.80	177.17
12.	131.91	185.36
13.	131.91	189.69
14.	131.91	187.50
15.	130.75	185.36
16.	127.01	187.50
17.	135.80	187.50
18.	127.01	189.69
19.	127.01	187.50
20.	127.01	189.69
Mean of GSM±S.D of GSM	130.12±3.46	185.86±3.81
C.V% of GSM	2.66	2.05

- Flexural rigidity was measured using the below formula and result was presented on Table 9.

Flexural Rigidity, G = M × C × 9.807 × 10-6 μNm

Where,

M = Fabric mass per unit area (g/m^2)

C = Bending length (mm)

RESULTS AND DISCUSSION

Fabric Width

From Table 4 and Figure 1, it was observed that the 1 × 1 rib knitted fabric was wider than plain interlock fabric in spite of having the same knitting parameters. The widths of rib and interlock fabric were found 85.94” and 76.12”, respectively. In this study, it was seen rib fabric shrunk by 32% and interlock fabric shrunk by 40%. It can be said that the variation in widths depends on the knit structures.

Stitch Density

From the above diagram, it can be seen that the stitch density of plain interlock knit structure is higher than 1 × 1 rib knit structure while other parameters such as yarn type and count, machine gauge and diameter, and stitch length, remains same.

GSM

From Table 6 and Figure 3, it was observed that two different knitted fabric structures had shown different areal density (GSM) in spite of having the same knitting parameters; here, GSM of rib and interlock fabric was found 130.12 and 185.86, respectively. Plain interlock fabric has 43% higher GSM than 1 × 1 rib knitted fabric. Each interlock pattern row often termed an “interlock course”

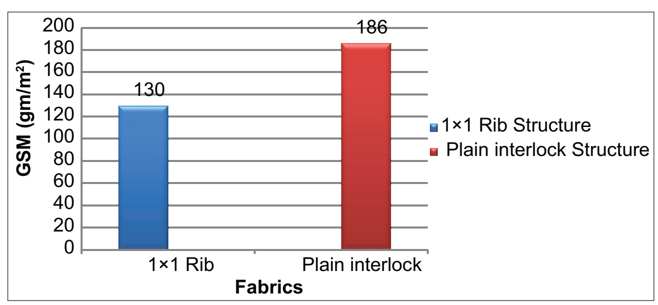


Figure 3: Comparison of GSM

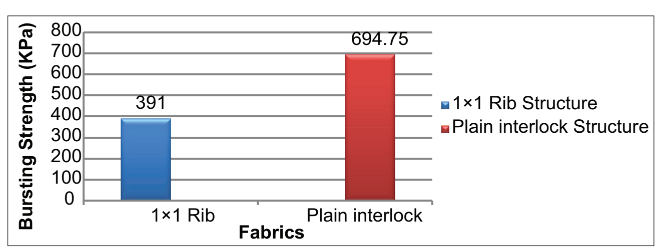


Figure 4: Comparison of bursting strength

Table 7: Bursting strength of rib and interlock fabrics

Obs.	Rib fabric				Interlock fabric			
	Face side		Backside		Face side		Backside	
	Kpa	Time (sec)	Kpa	Time	Kpa	Time (sec)	Kpa	Time
1.	370	26	360	27	660	27	740	26
2.	390	26	350	27	730	28	730	27
3.	400	26	400	26	540	28	680	27
4.	390	26	360	27	690	27	650	26
5.	400	27	340	26	710	26	660	26
6.	400	26	400	26	740	27	700	27
7.	370	27	380	26	650	27	730	26
8.	350	26	360	26	660	28	730	26
9.	350	25	410	26	680	27	670	26
10.	360	26	380	26	730	28	670	27
11.	440	25	380	27	700	27	760	26
12.	420	26	360	26	710	26	660	27
13.	410	26	390	27	690	28	690	26
14.	460	25	350	27	720	27	670	26
15.	460	27	410	26	690	27	750	27
16.	420	26	360	25	690	26	710	26
17.	400	27	400	26	680	28	690	27
18.	440	25	360	26	720	27	740	26
19.	430	26	390	27	670	27	750	27
20.	440	27	400	26	680	26	670	26
Mean±SD	391±31.61				694.75±39.74			
C.V%	8.08				5.72			

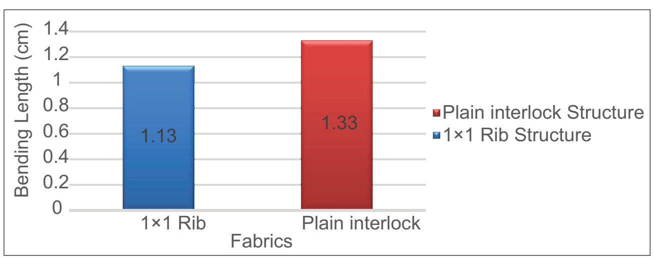


Figure 5: Comparison of bending length

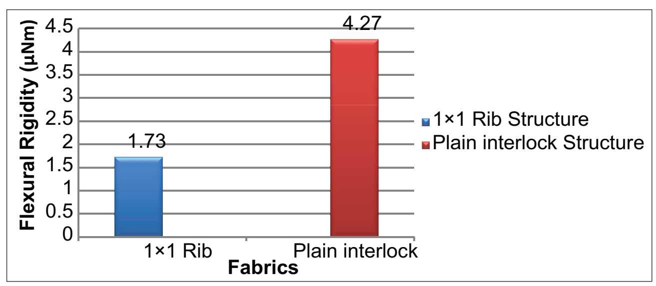


Figure 6: Comparison of flexural rigidity

requires two feeder courses, each with a separate yarn that knits on separate alternative needles, producing two half-gauge 1 × 1 rib courses whose sinker loops cross over each other and shrinkage of plain interlock fabric is greater than 1 × 1 rib knitted fabric which already has shown in and that's why interlock knitted fabrics are heavier and thicker than rib knitted fabrics. It can be said that the variation in GSM depends on the knit structures.

Bursting Strength

From Table 7 and Figure 4, it was observed that structural changes have an effect on the fabric bursting strength in spite of having the same knitting parameters. The bursting strength of rib and interlock was found 391KPa and 694.75KPa. Plain interlock fabric showed 78% higher bursting strength than 1 × 1 rib knitted fabric. Due to stitch density of plain interlock fabric is greater than 1 × 1 rib knitted fabric and the interlock fabrics are compact, thicker, and tighter than rib fabrics, so it shows higher bursting strength values. Increase bursting strength of a knitted fabric may cause from increasing stitch density as well as tightness factor of that fabric.

Table 8: Bending length (cm) of rib and interlock fabrics

Obs.	Rib fabric				Interlock fabric			
	Face side		Back side		Face side		Back side	
	Head	Tail	Head	Tail	Head	Tail	Head	Tail
1.	1.20	1.20	1.18	1.15	1.35	1.35	1.30	1.25
2.	1.15	1.13	1.00	1.13	1.30	1.25	1.45	1.40
3.	1.13	1.10	1.20	1.10	1.30	1.25	1.30	1.35
4.	1.00	1.10	1.15	1.05	1.25	1.35	1.30	1.30
5.	1.18	1.10	1.10	1.05	1.25	1.25	1.40	1.35
6.	1.18	1.05	1.15	1.15	1.30	1.30	1.40	1.35
7.	1.20	1.12	1.05	1.15	1.35	1.25	1.30	1.25
8.	1.35	1.00	1.05	1.20	1.40	1.37	1.30	1.30
9.	1.00	1.05	1.00	1.20	1.45	1.35	1.27	1.25
10.	1.20	1.10	1.20	1.15	1.35	1.40	1.30	1.27
11.	1.15	1.12	1.10	1.05	1.40	1.37	1.40	1.40
12.	1.00	1.10	1.15	1.15	1.35	1.30	1.45	1.30
13.	1.15	1.20	1.20	1.13	1.25	1.40	1.27	1.32
14.	1.18	1.08	1.00	1.10	1.37	1.40	1.35	1.25
15.	1.13	1.15	1.10	1.20	1.30	1.30	1.30	1.35
16.	1.2	1.00	1.20	1.18	1.37	1.37	1.40	1.30
17.	1.35	1.05	1.00	1.13	1.30	1.35	1.30	1.40
18.	1.00	1.10	1.15	1.20	1.40	1.25	1.35	1.32
19.	1.18	1.10	1.20	1.10	1.25	1.35	1.27	1.25
20.	1.13	1.13	1.15	1.15	1.35	1.25	1.45	1.30
Mean±SD	1.13±0.10				1.33±0.08			
C.V%	9.27				6.27			

Bending Length

From Table 8 and Figure 5, it has been shown that the stiffness properties of fabric are affected by different knit structures in spite of having the same knitting parameters. Plain interlock fabric showed a higher bending length than 1 × 1 rib knitted fabric. The bending length of rib and interlock fabric was found 1.13 cm and 1.33 cm, respectively. Lighter fabric had very low frictional bending moments.

Flexural Rigidity

It was also observed from Figure 6 that the flexural rigidity of interlock fabrics is higher than rib fabrics. . Therefore, rib knitted fabrics are more flexible than interlock fabrics due to interlock fabrics are thicker than rib fabrics. Since stiffness of fabric in bending is very dependent on its thickness, the thicker the fabric, the stiffer it is if all other factors remain the same. Hence, interlock fabric shows higher stiffness properties as a result lower fabrics drape quality because fabrics drape and stiffness are negatively related to each other.

CONCLUSION

This research is an approach to compare some physical properties of knitted cotton fabric such as bursting strength, stiffness, GSM, stitch density, and fabric width between two double jersey knit structures interlock and rib-knit structures of same yarn count, stitch length, machine gauge, and diameter. It was found that fabric structures have a significant effect on these properties. It is apparent that interlock knit structure has higher bursting strength than rib knit structure. However, rib knit structure shows higher flexibility and drapability than interlock knit structure. Therefore, rib structure has higher comfort properties with lower strength than interlock structure. Besides, knitted fabric structure has also an effect on fabric stiffness properties. The results also show that knit structure of fabric has a significant effect on GSM, stitch density, and width of the fabric. From the results, it was found that interlock structure is heavier, thicker, and narrower than rib structure of equivalent gauge of knitting machine.

Table 9: Flexural rigidity (μNm) of rib and interlock fabrics

Obs.	Rib fabric			Interlock fabric		
	M	C	G	M	C	G
1.	130.12	11.82	2.12	185.86	13.12	4.11
2.	130.12	11.03	1.67	185.86	13.50	4.37
3.	130.12	11.32	1.81	185.86	13.00	3.99
4.	130.12	10.75	1.58	185.86	13.00	3.99
5.	130.12	11.08	1.81	185.86	13.12	3.97
6.	130.12	11.32	1.81	185.86	13.38	4.21
7.	130.12	11.30	1.92	185.86	12.88	3.92
8.	130.12	11.50	1.89	185.86	13.43	4.50
9.	130.12	10.62	1.52	185.86	13.30	4.32
10.	130.12	11.62	1.96	185.86	13.30	4.38
11.	130.12	11.05	1.79	185.86	13.93	4.69
12.	130.12	11.00	1.72	185.86	13.50	4.47
13	130.12	11.70	2.07	185.86	13.10	4.18
14.	130.12	10.90	1.68	185.86	13.43	4.45
15.	130.12	11.45	1.92	185.86	13.12	4.11
16.	130.12	11.45	1.87	185.86	13.60	4.63
17.	130.12	11.32	1.93	185.86	13.38	4.40
18.	130.12	11.12	1.71	185.86	13.3	4.38
19.	130.12	11.45	1.87	185.86	12.80	3.86
20.	130.12	11.40	1.85	185.86	13.38	4.45
Mean±SD			1.73±0.18			4.27±0.26
C.V%			10.42			6.04

Suggestion for Future Study

In this research, work simplest derivatives structure of both knit structures that are 1 × 1 rib and plain interlock was studied. Hence, a similar effect can be measured using different derivatives structures of rib and interlock fabric.

Here, all other factors such as yarn count, stitch length, and machine gauge were kept constant by varying these factors; some researches can be done.

Different researches can be done using a different type of yarn such as Polyester Cotton (PC), Chief Value of Cotton (CVC), and mélange yarn instead of cotton yarn.

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