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An approach to improve the elasticity of rib fabric through mechanical and chemical finishing

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Article

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ABSTRACT

In recent years, the demand for knit fabric has increased significantly due to some of its unique properties like comfortability, stretchability, easy care, excellent wrinkle resistance and a high degree of fashion features. Among the different types of knit fabric, rib fabric is very popular for its elasticity. There is a demand for more elasticity of rib fabric in manufacturing apparel like sportswear. A common practice is to use elastane yarn along with native yarn to increase the knit fabric's elasticity. Elastane fibres are synthetic fibres which are not comfortable. Elastane yarns are costly and cause a few difficulties during knitting. In this study, a combination of mechanical and chemical finishing processes has been introduced to increase the elasticity of 100% cotton rib fabric. The best possible finishing route was incorporated to maximize the rib fabric elasticity. It was observed that rib fabric elasticity can be increased up to 1.5 times from its native value. The material cost between the new proposed process and the existing elastic fabric manufacturing process was compared. It was found that the new process is much cheaper. This is an approach to finding an easy, industrially applicable and cost-effective method to maximize rib fabric elasticity without using any elastane yarn.

KEYWORDS

rib fabric, elastomeric softener, mechanical finishing, shrinkage, elastic recovery

INTRODUCTION

Elasticity is one of the most important properties of knit fabric. Elasticity is measured in terms of elastic recovery. However, if fabric possesses more elasticity, users feel more comfortable as well as perfectly fit with the body [1]. A good elastic fabric shows good dimensional stability [2,3]. Knit fabrics with a desirable elasticity are suitable for manufacturing apparel like compressor garments, sports apparel like swimwear, and athletic and active wear [4-18]. Three types of knit fabric such as single jersey, rib and interlock are popular throughout the world based on their end use. Among them, the rib fabric provides a higher elasticity than single jersey or interlock fabric due to its construction [19–21]. The single jersey fabric provides moderate elasticity and the interlock fabric provides the lowest elasticity according to their construction. On the other hand, rib fabric has better elasticity and it is used in socks, cuffs, waistbands and collars. Normally, the elastane yarn is used along with the native yarn during the knitting to add more elasticity to the knit fabric [22–26]. But these elastane yarns are costly and cause a few difficulties during knitting. Another common practice is that by changing a few knitting parameters (for example loop length) the knit fabric elasticity can be increased. However, this technique does not improve a significant amount of elasticity [27–30]. That is why the elasticity increment of the knit fabric without using the elastane yarn remains challenging yet.

On the other side, finishing processes play the most crucial role to improve the dimensional stability of knit fabrics [31]. Among all types of knit fabrics, it is extensively difficult to control the dimension of rib fabrics. Feed speed, over-feed and under-feed percentage, and set the width of the machine at the feed of finishing machines like stenter, open dryer and compactor are the key parameters to dominate the dimensional properties. However, these finishing machines are capable of adjusting spirality, shrinkage and finally the mass per unit area of the knit items [32]. Therefore, elastane yarn is commonly used to improve the elasticity of knit fabrics following the mentioned finishing route [33]. Overall, without elastane yarn, significant elastic recovery cannot be obtained yet following the knitting parameter variation and finishing parameters.

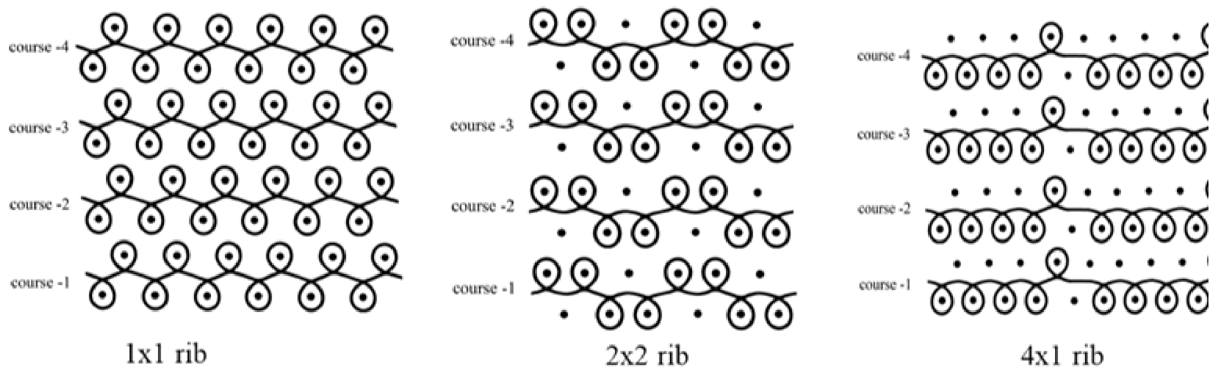
This research aimed to find a method to increase the elasticity of rib fabric without using any elastane yarn which is cost-effective and easy to apply.

EXPERIMENTAL

Materials

For the production of fabrics, an English count of 34 Ne was used without any elastane yarn. Two different types of softeners were employed for the chemical treatment. One is an elastomeric softener known as Asumin elast (industry grade, brand: Asutex, Spain), while the other is a cationic softener known as Sapamine CSN (industry grade, brand: Huntsman, Singapore) [34]. Asumin elast is modified polydimethylsiloxane amine (pH 6.5±1) which makes 3D reticulation of the silicone and Sapamine CSN is a fatty condensation product with cationic characteristics having pH 3.5-4.5 at 10% formulation.

The 1×1, 2×2, and 4×1 rib fabrics were used since they are often made in Bangladesh [35,36]. For each 1×1, 2×2, and 4×1 rib, eight identical rolls of cloth from the same batch were taken. There were 24 fabric rolls in all, counting from S01 to S24. S01 to S08 are the first eight rolls for 1×1 rib, S09 to S16 are the next eight rolls for 2×2 rib, and S17 to S24 are the last eight rolls for 4×1 rib fabric. Figure 1(a), (b) and (c) represent the notation diagram of 1×1, 2×2 and 4×1 rib fabric.



a) b) c)

Figure 1. Notation diagram of a) 1x1 rib, b) 2x2 rib and c) 4x1 rib

Fabric Manufacturing

1×1, 2×2 and 4×1 rib fabric were produced in a double jersey circular knitting machine (Mayer & Cie from Germany) having a grey mass per unit area expressed as GSM (gram per square meter) of 130±10 and target GSM was 180. Knitting parameters were selected as below:

Table 1. Knitting parameter of experimental samples

Sl. No.	Rib fabric	Combed Yarn, Ne	Mass per unit area (g/m^2)		Stitch length (mm)	Machine diameter (inch)	Machine gauge (needle/inch)	Target width (inch)
			Grey	Target				
S01-S08	1×1	34	139					70
S09-S16	2×2	34	130	180	2.6	36	18	52
S17-S24	4×1	34	123					64

Finishing process

All the samples were treated with elastomeric softener and cationic softener and each sample was finished with a combination of different finishing routes to measure the optimum elastic recovery. The best method was evaluated and compared with the conventional method based on elastic recovery and cost. The change in shrinkage and GSM of the fabric was also measured with the application of each method.

Four basic mechanical finishing techniques were considered for the finishing process that is: only stenter, a combination of stenter and compacting, only open dryer, and a combination of the open dryer and compacting [37]. Cationic softeners and elastomeric softeners have been used as chemical reagents. Combining both the mechanical and chemical processes eight different criteria were derived for the finishing of the fabric. To facilitate the elastic recovery of fabric, well-established parameters for rib fabrics for 180 finished GSM were well-thought-out. The chemical consumption was considered as 20 g/L as well as the machine speed, machine overfeed and temperature was fixed at 25 m/min, 50% and 140 ^{0}C respectively. Table 2 describes the finishing techniques that have been applied.

Table 2. Finishing parameters of the experimental sample

Rib fabric			Finishing Route	Chemical used	Speed (m/min)	Temperature (°C)	Machine over feed (%)	Amount of softener (g/L)
1x1	2x2	4x1						
Sample No								
S01	S09	S17	Stenter	Cationic Softener (Sapamine CSN)	25	140	50	20
S02	S10	S18	Stenter &compacting					
S03	S11	S19	Open Dryer					
S04	S12	S20	Open Dryer &compacting					
S05	S13	S21	Stenter	Elastomeric Softener (Asumin elast)				
S06	S14	S22	Stenter &compacting					
S07	S15	S23	Open Dryer					
S08	S16	S24	Open Dryer &compacting					

Shrinkage and GSM test

All samples were conditioned on a flat surface for at least 24 hours before testing under standard atmospheric conditions at relative humidity (65 ±2) % and temperature (20±2) °C. Fabric shrinkage was tested according to the AATCC-TM 135 method and mass per unit area (GSM) was tested according to the ISO 6330:2012 method.

Elastic recovery test

The elastic recovery test was done by the method of BS EN 14704-1:2005 by a constant rate of elongation (CRE) testing machine. Before performing the test, samples were kept for 20 hours in a fully relaxed condition. All the samples were cut according to the (100×50) mm dimension. The sample was fastened to the apparatus, a 15 N force was applied in the longitudinal direction, and the sample's extended length was measured under these circumstances. After then, the load was taken out of the sample, and after 1 minute and 30 minutes, the remaining length of the sample was measured. The below equation was used to determine elastic recovery:

Elastic recovery R is $$R = \frac{D}{S} \times 100 \quad (1)$$

Where D has recovered elongation in %, and S is the extension percentage

$$D = (100 - C) \times 100 \quad (2)$$

Where C is un-recovered elongation in %

$$C = \frac{Q-P}{P} \times 100 \quad (3)$$

Where P is the initial length of the sample in mm

$$S = \frac{E-P}{P} \times 100 \quad (4)$$

Where E is the extended length after the application of load in mm. The Q is the final length after the removal of the load (mm). There are two values of Q (after 1 minute and 30 minutes).

RESULTS AND DISCUSSION

Finished width, GSM and shrinkage of the samples

From the findings, it is prominent that softeners do not affect fabric shrinkage and GSM whereas these properties are affected by the mechanical finishing process. The stenter is causing the lowest GSM and the highest shrinkage value whereas the open dryer is causing the highest GSM value and the open dryer & compacting is causing the lowest shrinkage value for 1×1, 2×2 and 4×1 rib. The reason behind this result is stenter machine holds the fabrics widthwise throughout the machine, whereas the open dryer and compactor release the fabric before entering the heating chamber. It causes the drying of samples in higher tension for the stenter machine and loose tension for the open dryer and compactor [38]. For this reason, the finished width and shrinkage are higher than the open dryer and compactor. Conversely, the final GSM of the open dryer and compactor is showing a higher value than having used the stenter route.

Table 3. Finished width, GSM and shrinkage value of experimental fabric

Sl. No.	Rib fabric	Finishing route	Chemical used	Final finished width (inch)	Final finished GSM (g/m²)	Shrinkage (%)	
						Length-wise	Width-wise
S01	1x1	Stenter	Cationic Softener (Sapamine CSN)	71	171	-6.8	-6.3
S02		Stenter &compacting		70	174	-4.9	-5.7
S03		Open Dryer		68	184	-6.6	-2.9
S04		Open Dryer &compacting		70	178	-3.5	-5.3
S05		Stenter	Elastomeric Softener (Asumin elast)	71	172	-6.6	-6.4
S06		Stenter &compacting		70	175	-4.5	-5.8
S07		Open Dryer		68	185	-6.4	-2.7
S08		Open Dryer &compacting		70	179	-2.4	-5.5
S09	2x2	Stenter	Cationic Softener (Sapamine CSN)	52	172	-6.4	-6.7
S10		Stenter &compacting		51	174	-5.2	-5.9
S11		Open Dryer		49	185	-6.9	-3.7
S12		Open Dryer &compacting		52	176	-3.8	-5.8
S13		Stenter	Elastomeric Softener (Asumin elast)	53	173	-6.1	-6.5
S14		Stenter &compacting		52	175	-5.0	-5.7
S15		Open Dryer		50	188	-6.4	-3.4
S16		Open Dryer &compacting		52	178	-3.4	-5.7
S17	4x1	Stenter	Cationic Softener (Sapamine CSN)	65	173	-6.9	-6.8
S18		Stenter &compacting		64	177	-5.8	-6.6
S19		Open Dryer		62	186	-6.2	-3.7
S20		Open Dryer &compacting		64	180	-4.4	-5.7
S21		Stenter	Elastomeric Softener (Asumin elast)	65	174	-6.8	-6.7
S22		Stenter &compacting		64	178	-5.4	-6.5
S23		Open Dryer		62	186	-5.9	-3.8
S24		Open Dryer &compacting		64	180	-3.8	-5.6

The elastic recovery of the samples

The initial value (before chemical and mechanical finishing) of elastic recovery for 1x1, 2x2 and 4x1 rib fabric was 9.4%, 9.2% and 8.8% respectively. Both chemical and mechanical finishing has a significant impact on elastic recovery. It was detected that the stenter process with the cationic softener provides the lowest elastic recovery after 30 minutes of observation ranging from 11.70% to 13.11% whereas the open dryer & compacting process with elastomeric softener provides the highest elastic recovery ranges from 25.84% to 26.04% for 1x1, 2x2 and 4x1 rib fabric maintaining the same during of observation which is around 2.5 times higher than that of the initial value.

Open dryer and compacting process with cationic softener provide the second highest elastic recovery ranges from 23.44% to 25.54% for 1x1, 2x2 and 4x1 rib fabric which are shown below table and graph:

Table 4. Elastic recovery properties of experimental samples

Sl. No.	Rib fabric	Finishing route	Chemical used	P, initial distance (mm)	Width-wise Elongation (%)						
						After 1 Minute			After 30 Minutes		
					S, extension (%)	C, un-recovered elongation (%)	D, recovered elongation (%)	R, elastic recovery (%)	C, un-recovered elongation (%)	D, recovered elongation (%)	R, elastic recovery (%)
S01	1x1	Stenter	Cationic softener (Sapamine CSN)	100	197	81	19	9.60	76	24	12.18
S02		Stenter & compacting			190	75	25	13.16	69	31	16.32
S03		Open Dryer			215	70	30	13.95	63	37	17.21
S04		Open Dryer & compacting			209	57.7	42.3	20.24	51	49	23.44
S05		Stenter	Elastomeric softener (Asumin elast)		197	75	25	12.70	71	29	14.72
S06		Stenter & compacting			190	70	30	15.77	66	34	17.89
S07		Open Dryer			215	64	36	16.75	58	42	19.53
S08		Open Dryer & compacting			209	51.3	48.7	23.30	46	54	25.84
S09	2x2	Stenter	Cationic softener (Sapamine CSN)		183	85	15	8.20	76	24	13.11
S10		Stenter & compacting			180	79	21	11.67	73	27	15.00
S11		Open Dryer			200	75	25	12.50	68	32	16.00
S12		Open Dryer & compacting			184	60	40	21.74	53	47	25.54
S13		Stenter	Elastomeric softener (Asumin elast)		188	79	21	11.17	73	27	14.36
S14		Stenter & compacting			185	75	25	13.51	68	32	17.30
S15		Open Dryer			205	72	28	13.66	65	35	17.07
S16		Open Dryer & compacting			192	57	43	22.40	50	50	26.04
S17	4x1	Stenter	Cationic softener (Sapamine CSN)		188	85	15	7.98	78	22	11.70
S18		Stenter & compacting			185	79	21	11.35	72	28	15.14
S19		Open Dryer			207	73	27	13.04	65	35	16.91
S20		Open Dryer & compacting			197	60	40	20.30	53	47	23.86
S21		Stenter			194	78	22	11.34	72	28	14.43

Sl. No.	Rib fabric	Finishing route	Chemical used	P, initial distance (mm)	Width-wise Elongation (%)						
						After 1 Minute			After 30 Minutes		
					S, extension (%)	C, un-recovered elongation (%)	D, recovered elongation (%)	R, elastic recovery (%)	C, un-recovered elongation (%)	D, recovered elongation (%)	R, elastic recovery (%)
S22	4x1	Stenter & compacting	Elastomeric softener (Asumin elast)	100	189	72	28	14.81	66	34	17.99
S23		Open Dryer			210	69	31	14.76	64	36	17.14
S24		Open Dryer & compacting			200	55	45	22.50	48	52	26.00

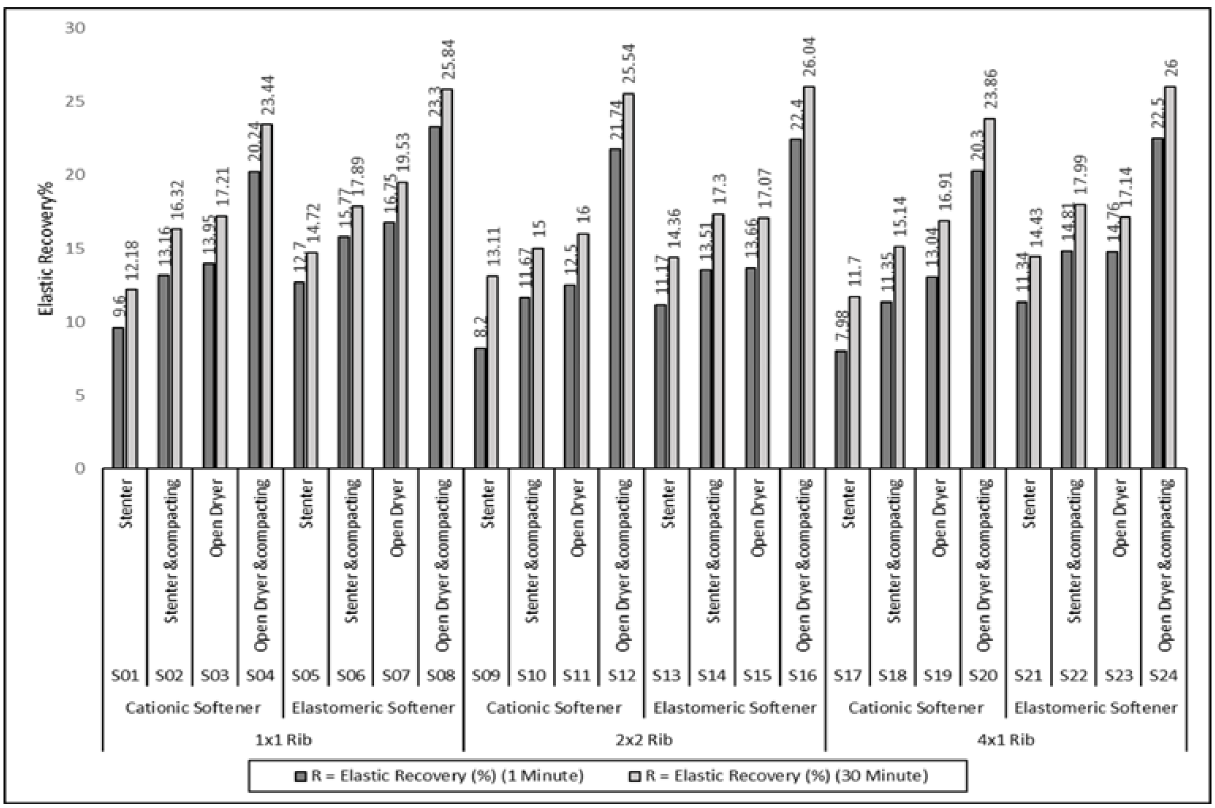


Figure 3. Graphical representation of Elastic recovery properties

The sole difference between S01 and S05's elastic recovery values is that S01 was treated with cationic softener while S05 was treated with elastomeric softener where both the samples were finished through stenter. As it is evident that, S05 offers a more elastic recovery than S01, it is obvious that elastomeric softener provides greater flexibility to rib fabric. The 3D reticulation of silicone-based elastomeric softener imparts an extra recovery tendency than cationic conventional softener [39]. For the same reason, S13 and S21 offer more elastic recovery than S09 and S17 respectively. Similarly, evidence of the superiority of elastomeric softener over cationic softener for other mechanical processes (Stenter and compacting, Open dryer as well as open dryer and compacting) was seen. Compared to alternative mechanical finishing procedures, the open dryer and compacting process allow for the best elastic recovery [38]. Contrasting the elastic recovery values of S05, S06, S07, and S08, it is found that S08 has the highest elastic recovery value where S05, S06, S07, and S08 are elastomeric softener-treated samples; the only difference is in their mechanical finishing procedure. The combination of the open dryer and compacting method helps to offer more elastic recovery value to the rib fabric than that of other mechanical finishing procedures. Likewise, S16 has the best elastic recovery value compared to S13, S14, and S15 and for the same reason, S24 offers the highest elastic recovery value compared to S21, S22, and S23. The fabric's elasticity is not changed by the open dryer procedure which is just a typical drying procedure. On the other hand, by applying heat and pressure during the compacting, the cloth is allowed to pre-shrink to generate a crepey and bulky texture which results in more elasticity than the previous result of its crepey and thick texture of open dryer treated sample. Therefore, it can be claimed that rib fabric exhibits the best elasticity when treated with an elastomeric softener and then finished by an open dryer and compacting machine. At the same time, elastomeric softener (polydimethylsiloxane amine) provides more frictional resistance and improves the fastness properties of its chemical behaviour. Moreover, 3D reticulation of elastomeric softener on the fabric surface might increase the hydrophobicity of the finished rib fabrics [39]. That is why practically rib fabrics finished with elastomeric softener usually retain supreme elastic recovery properties up to at least 10 consecutive washes. Finally, since elastomeric silicone softener is more difficult to remove by washing treatment, it exhibits superior properties than cationic softener [40].

Cost Comparison

Normally fabric elasticity is increased by utilizing elastane yarn with the available yarn. It is necessary to compare the cost between the traditional process (utilization of elastane yarn) and our developed process. Normally, in Bangladesh, 97% cotton and 3% elastane rib fabrics are most frequently produced. The cost of elastane yarn to produce 100 kg of 97% cotton and 3% elastane rib fabric is approximately \$21.75 (Table 5) whereas the cost of cationic softener and the elastomeric softener to treat 100 kg cotton rib fabric is approx. \$6.44 and \$6.10 respectively (Table 6). The developed process is cheaper than the traditional process.

Table 5. Cost calculation for elastane yarn

Fabric type	Required elastane yarn to produce 100 kg fabric (kg)	Price of elastane yarn per kg ($)	Total cost of elastane yarn ($)
97% cotton and 3% elastane	3.00	7.25	7.25 × 3.00 = 21.75

Table 6. Cost calculation of softeners

Fabric type	Chemical name	Required chemical for 100 kg fabric (kg)	Chemical price per kg ($)	Total cost of chemical ($)
100% cotton rib	Cationic softener	2.00	3.22	3.22 × 2.00 = 6.44
100% cotton rib	Elastomeric softener	2.00	3.05	3.05 × 2.00 = 6.10

CONCLUSION

Elastic recovery improvement of rib fabric used in sportswear is a vital area of research for textile industries. The main objective of this study was to improve the elastic properties of rib fabric with the combined application of chemical and mechanical finishing. The findings confirm that elastic recovery increased mostly with the application of an elastomeric softener along with the use of an open dryer and compactor. It is also suggested that these softeners can be an excellent replacement for elastane yarn. In comparison, the elastomeric softener shows greater benefits such as cost, softness, and comfort than the cationic softener. Textile industries can adopt this technique to improve the elastic properties without using elastane yarn.

Author Contributions

Conceptualization – Hossain MS, Islam MM, Islam MA; methodology – Hossain MS, Islam MM, Islam MA; formal analysis – Islam MM, Smriti SA; investigation – Hossain MS, Dey SC, Islam MA; resources – Islam MM, Dey SC; writing-original draft preparation – Islam MM, Smriti SA; writing-review and editing – Hossain MS, Islam MA; visualization – Islam MM, Smriti SA, Dey SC; supervision – Hossain MS, Islam MA. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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