Improving Dimensional Stability of Cotton Knits Through Resin Finishing

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ABSTRACT
The aim of this study was to compare the effectiveness of three different types of resin finishes for improving the dimensional stability of 100% cotton honeycombed pique knitted fabrics. After application of each resin at five different concentrations, it was found that the fabric shrinkage could be effectively controlled by using a suitable type and concentration of the resin. However, the cellulose crosslinking by the resin resulted in some loss in the fabric bursting strength. In a second set of experiments, three different types of softeners were applied, at three different concentrations, in combination with the optimized type and concentration of the resin. It was found that the loss in fabric bursting strength due to cellulose crosslinking by the resin could be minimised with a suitable type and concentration of softener without any deterioration in the fabric pilling properties.

Keywords: dimensional stability; cotton knits; resin finishing; shrinkage control

INTRODUCTION

Knitted structures offer several advantages over woven fabrics including better stretch and recovery, resilience, porosity, air permeability, softness, and warmth. Due to better extensibility in structure, knitted fabrics provide better fit and comfort to the wearer [1]. However, the most challenging shortcoming of knitted structures is their lower dimensional stability [2, 3], owing to the instability in their loop dimensions [4, 5].

There are several factors which may be responsible for the instability of loop dimensions and consequently the poor dimensional stability of knitted fabrics. Fabric shrinkage may result due to fiber swelling under moist or wet conditions and relaxation of internal stresses which the fibers may undergo during different manufacturing phases [6, 7]. Yarns having higher spinning tensions result in knitted fabrics with inferior dimensional stability [8, 9]. Knitting tensions along with other knitting parameters (such as tightness factor) and fabric wet processing parameters also affect the dimensional stability of knits [10, 13]. Migration of loops and changes in loop shapes in wet environments are also causes of lower dimensional stability in cotton knits [2]. For dry finished fabrics, lower elasticity of fibers may result in reduced dimensional stability of the fabric, which is because of inferior recovery of fibers from distortion.

Many techniques have been suggested to improve the dimensional stability of knitted cotton fabrics. Some studies suggest that shrinkage of cotton fabrics could be minimized by any treatment that prevents cotton fiber swelling on wetting. [14, 15]. Knitted fabrics made from open-end rotor yarns are reported to have better dimensional stability than those made from ring spun yarns [16]. However, open end yarns are usually not available in higher fineness and result in lower bursting strengths than ring spun yarns, thus limiting their use in knitted fabrics [17, 18].

Fabrics with improved dimensional stability can also be achieved by decreasing their loop length and by use of elastomeric yarns [16, 21]. Decreasing loop length is possible only to a certain extent beyond which knitting machines may not run properly. Cotton knits generally have considerable shrinkage even at lowest possible loop lengths. The use of elastomeric yarns may be a good option for improving dimensional stability, but such an option is not always availed due to cost considerations of the elastane and additional heat-setting process. Decreased wales spacing is another potential option for improving the width-way shrinkage of knitted cotton fabrics [7], though knitting machines restrict this opportunity to a certain range.

Mercerization is also one of the approaches for improvement in dimensional stability of cotton knits [20]. Apart from the cost, limited availability of appropriate mercerization techniques for knits and quality control issues limit the use of the mercerization process for controlling dimensional stability of knitted cotton fabrics [21]. Use of mechanical compactors also decreases the shrinkage in knitted fabrics. This technique has been employed successfully for improving dimensional stability, but with limited shrinkage control, which may not last after 4-5 washes. Tumble drying after washing may also be very efficient in controlling the dimensional stability of garments made from knits [22, 23], but lower production of tumble driers and batch to batch quality variations limit their use for improving dimensional stability.

The application of typical easy-care crosslinking agents is another possible solution of the dimensional stability problem of the cotton knits [24]. This study suggests an optimum combination of resin and softener for attaining maximum dimensional stability in cotton knits, with minimum loss in fabric bursting strength and pilling resistance.

EXPERIMENTAL

Fabric

A 100% cotton honeycombed pique knitted fabric was used in this study. The fabric of 170 g/m^2 areal density was knitted on 24 gauge knitting machine with 30 inch diameter using 26 Ne (22.7 tex) combed yarn, 0.28 cm stitch/loop length, and 17.0 tightness factor (K).

Chemicals and Auxiliaries

Fixapret ECO: A modified crosslinker based on dimethylol dihydroxyethylene urea (DMDHEU), methanol and diethylene glycol, supplied by BASF; unlike self-crosslinking agents, it is a reactant crosslinker; it contains extremely low level of un-combined free-formaldehyde. Arkofix NZF: A modified dihydroxyethylene urea (DHEU) by Clariant; it is a formaldehyde-free crosslinking agent, comprising only the dihydroxyethyelene groups and no methylol groups. Fixapret CPF: A methylolation product of glyoxalmonourein by BASF; it is a concentrated aqueous solution of a reaction product of urea, glyoxal and formaldehyde often referred to as dimetylol dihydroxyethylene urea (DMDHEU) or glyoxal resin; it is the most commonly used cost-effective crosslinking agent and contains higher levels of free-formaldehyde. Magnesium Chloride ($MgCl_2$, commercial grade), was used as catalyst. Siligen SIE (aminofunctional polysiloxane softener by BASF), Basosoft FF-EUK New (cationic fatty acid product by BASF), and Perapret Additive F-PEB New (a non-ionic secondary polyethylene dispersion by BASF) were used as softeners.

Fabric Pre-treatment

The pre-treatment of the fabric was done in industrial-scale jet dyeing machine at 110°C for 15 minutes using 2g/l hydrogen peroxide, 2 g/l caustic soda, 0.7 g/l wetting agent (Rucowet VL by Rudolf Pakistan) and 0.5 g/l anti-creasing agent (Rucoline JES by Rudolf Pakistan). The bleached fabric was then thoroughly washed, rinsed and neutralized by using 1.5 g/l acetic acid.

Fabric Dyeing

The bleached fabric was dyed in jet dyeing machine using exhaust method with 0.64% (o.w.f.) Synazol Navy Blue KBF, 0.195% (o.w.f.) Synazol Turquoise Blue HFG, 0.163 % (o.w.f.) Everzol Yellow 3RS H/C reactive dyes using 40 g/l sodium sulphate, 20 g/l soda ash, 0.5 g/l leveling agent (Sera Gal P-LP by Dyestar) and 0.5 g/l anti-creasing agent (Rucoline JES by Rudolf Pakistan). The dyeing process was completed by setting the time/temperature profile as per the dye manufacturer’s recommendations. The dyed fabric was then rinsed and washed-off using 1.5 g/l non-ionic detergent (Hostapal NI Extra by Clariant Pakistan), followed by neutralization with 1 g/l acetic acid.

Resin Finishing

In the first set of 15 experiments, the three selected crosslinking agents/resins were applied on the knitted cotton samples at five different concentrations, viz. 20, 50, 75, 100 and 125 g/l. The recipes were prepared with the specified amount of the resins and $MgCl_2$ catalyst (20% of the amount of resin used). The application of the recipes was done on the laboratory stenter at 75% pick-up, followed by drying at 120°C for 2.5 minutes and curing at 160°C for 2 minutes.

In the second set of 9 experiments, the type and amount of resin was fixed at 100 g/l along with the required amount of $MgCl_2$ catalyst, while introducing three different types of softeners in the recipes, each at 20, 40 and 60 g/l concentration. The application of the recipes was done again on the laboratory stenter following the already mentioned curing parameters.

Testing of the Treated Fabric

All the treated fabric samples were subjected to conditioning according to ASTM D1776 prior to testing. The length and width-way shrinkage of the samples was determined after washing the samples according to AATCC TM-135. The bursting strength of the samples was tested according to ASTM D3786, and the pilling resistance of the samples was assessed according to ASTM D4970 using Martindale tester after 1000 cycles.

RESULTS AND DISCUSSION

Effect of Different Resins on Dimensional Stability of Knitted Fabrics

A summary of the treatment results with different resins/crosslinking agents is given in *Table I*. *Figure 1* illustrates the effect of different crosslinking agents on shrinkage of the knitted fabrics treated with different concentrations. Without any treatment, the fabric's lengthways and widthways shrinkage values were 16.5% and 7% respectively. Treatments with crosslinking agents resulted in significant decrease in shrinkage values. The shrinkage values were found to decrease steadily with increase in the concentrations of all the three types of crosslinking agents used. However, modified Dihydroxy Ethylene Urea (DHEU) was found to be slightly less effective in shrinkage reduction as compared to the other crosslinking agents. This may be attributed to less number of crosslinks formed by DHEU within the cellulose structure because of the absence of methyl or methylol groups as compared to the other two resins.

TABLE I. Effect of Different Resins on Shrinkage and Bursting Strength of Knitted Fabric.

No.	Resin Type	Concentration (g/l)	Fabric Shrinkage (%)		Fabric Bursting Strength (N)
			Lengthways	Widthways	
1	NIL	0	16.52	7.10	76.25
2	Modified Dimethylol Dihydroxy Ethylene Urea (DMDHEU)	25	8.88	6.47	53.00
3		50	5.71	3.96	37.00
4		75	4.90	2.32	33.00
5		100	3.84	1.91	30.75
6		125	3.45	1.32	27.75
7	Methylolated Glyoxyl Monourien	25	9.87	6.80	55.00
8		50	6.71	5.10	52.00
9		75	5.26	3.16	49.00
10		100	4.34	2.04	45.00
11		125	3.90	1.36	40.50
12	Modified Dihydroxy Ethylene Urea (DHEU)	25	11.09	6.90	61.75
13		50	8.56	6.10	57.75
14		75	7.29	4.31	55.25
15		100	6.88	3.88	53.00
16		125	6.35	3.06	51.00

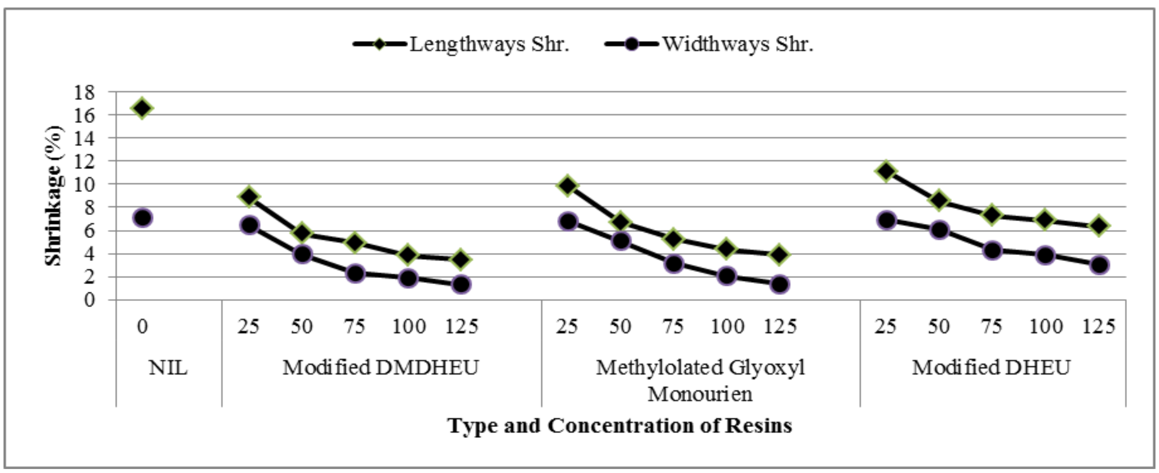

FIGURE 1. Effect of different resins on fabric shrinkage.

Further analysis revealed that the effect of increasing concentration of resins on the decrease in shrinkage values was not linear but the slope of the effect decreases at higher concentrations. This may be attributed to engagement of maximum reactive sites of cotton at optimum resin concentration, thus decreasing the rate of increase in crosslinking with increasing resin concentration. This trend is shown in *Figure 2* for Methylolated Glyoxyl Monourien. Second order polynomial equations almost perfectly modelled the lengthways (S_L) and widthways (S_W) shrinkage trends, with very high coefficient of determination R^2 values. These equations/models could be used for predicting the shrinkage control of the treated fabrics at different resin concentrations.

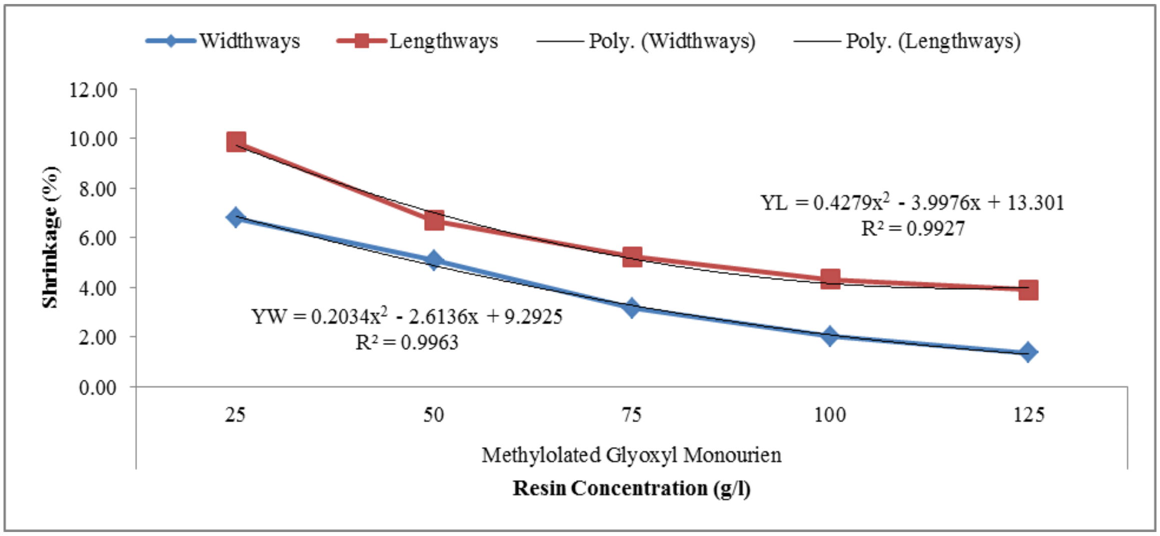

FIGURE 2. Effect of Methylolated Glyoxyl Monourien on shrinkage of knitted fabrics.

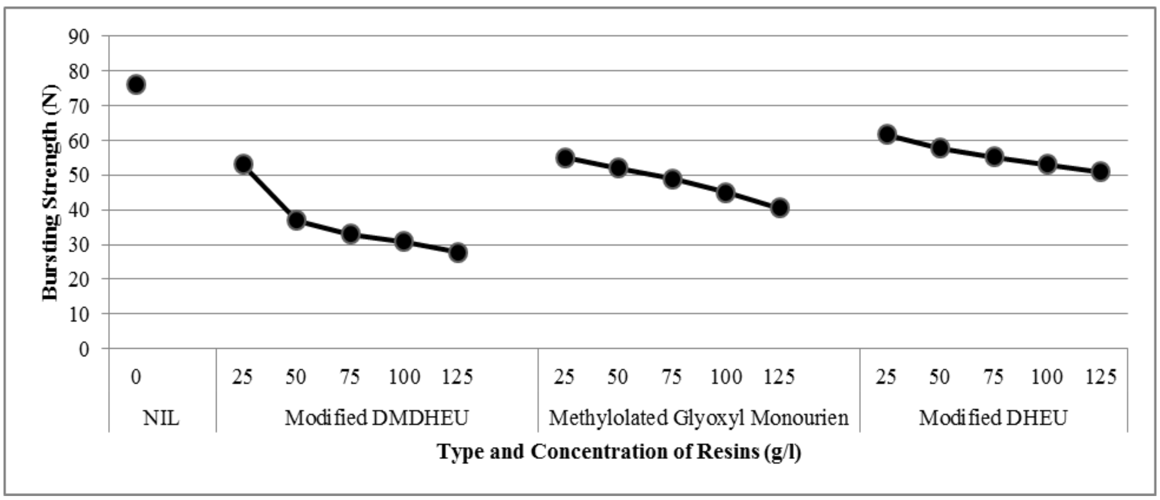

FIGURE 3. Effect of different resins on fabric bursting strength.

Effect of Different Resins on Bursting Strength of Knitted Fabrics

The effect of different resins and their concentration on the bursting strength of the knitted samples is given in *Figure 3*. It is evident that all resins result in decrease in the bursting strength, steadily with the increasing concentration. Modified DMDHEU results in maximum decrease in bursting strength as compared to other resins, which may be attributed to the highest degree of cellulose crosslinking with this type of resin. Methylolated Glyoxyl Monourien results in less loss in the bursting strength while giving good shrinkage control comparable with the modified Dimethylol Dihydroxy Ethylene Urea DMDHEU (*Figure 1 & 3*).

Figure 4 shows a correlation between the decrease in fabric shrinkage and the fabric bursting strength for Methylolated Glyoxyl Monourien. It is clear that the slop of shrinkage % is non-linear while that of the bursting strength is almost linear. With an initial increase in resin concentration, the number of crosslinks within the cellulosic chains rapidly increases, resulting in a drastic reduction in shrinkage %, but later on the rate of crosslinking and the resulting shrinkage control decreases when the available number of hydroxyl groups decrease in the cellulosic fabric. The rate of decrease in the bursting strength does not seem to be entirely dependent on the crosslinking but also on other factors such as fiber embrittlement, fabric stiffening or cellulosic damage during acidic resin finishing conditions.

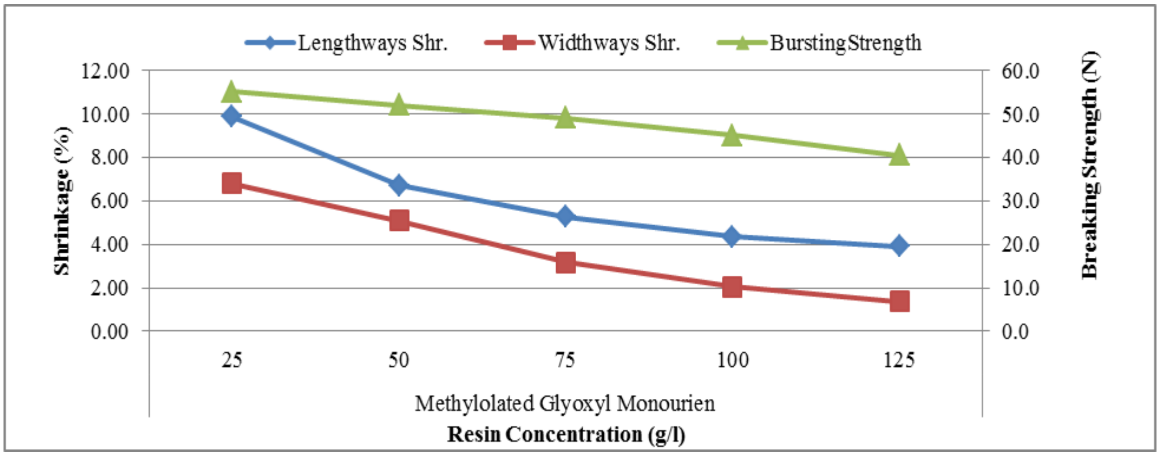

FIGURE 4. Effect of Methylolated Glyoxyl Monourien on shrinkage and bursting strength of knitted fabrics.

Effect of Different Softeners on Dimensional Stability and Bursting Strength of Knitted Fabrics

Effect of different softeners on the shrinkage and bursting strength of knitted fabrics is given in *Table II* and *Figure 5*. It is clear that treatment with softeners results in an improvement in the bursting strength. In other words, some loss in the fabric bursting strength due to resin finishing can be recovered by treatment with softeners. This recovery may be attributed to increase in fiber and yarn slippage within the fabric due to increased lubrication with the softeners. Due to this increased lubrication, fibers and yarns become less brittle and can undergo slippage under the influence of bursting force, thus giving extra support to one another. If we compare the results of the softener-treated samples with that of the control sample in *Figure 5*, which was treated with the resin but not treated with any softener, it is evident that the use of softeners does not appreciably deteriorate the shrinkage control effect of the resin.

However, a serious drawback of some of the softeners became evident when their effect was evaluated on fabric pilling resistance as given in *Figure 6*. The fatty acid based softener and the polyethylene dispersion were found to significantly deteriorate the pilling resistance of the treated fabric. However, aminofunctional polysiloxane softener was less detrimental as compared to its counterparts. This may be attributed to higher surface smoothness, lower surface friction and better abrasion resistance in case of polysiloxane softener as compared to the others.

TABLE II. Effect of Different Softener Treatments on the Properties of Knitted Fabric.

No.	Softener Type	Concentration (g/l)	Fabric Shrinkage (%)		Bursting Strength (N)	Pilling Resistance
			Lengthways	Widthways		
1	NIL	0	4.34	2.04	45.00	5.00
2	Aminofunctional Polysiloxane	20	5.26	1.96	53.00	4.75
3		40	5.25	1.96	56.50	4.50
4		60	5.44	2.19	67.75	4.00
5	Cationic Fatty Acid Product	20	5.31	2.13	52.00	2.25
6		40	5.38	2.16	56.00	2.00
7		60	5.85	2.39	66.00	1.50
8	Polyethylene Dispersion	20	5.12	1.95	51.00	4.00
9		40	5.05	1.90	52.25	3.00
10		60	5.01	1.88	61.75	2.00

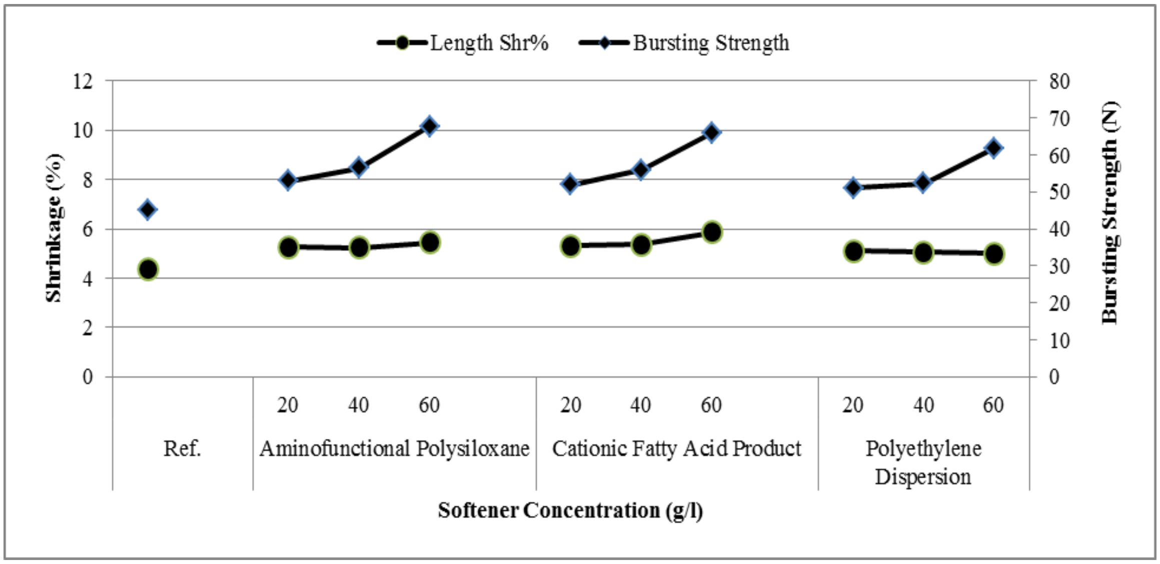

FIGURE 5. Effect of Different Softeners on Shrinkage and Bursting Strength of Knitted Fabrics.

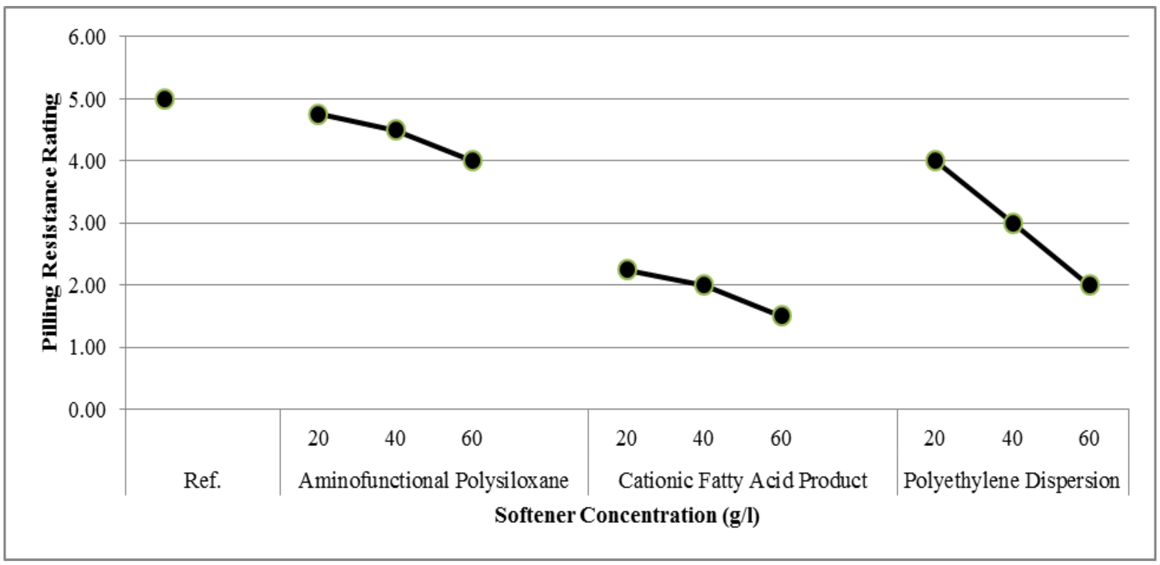

FIGURE 6. Effect of Different Softeners on Pilling Resistance of Knitted Fabrics.

CONCLUSION

The effectiveness of three different types of resins, viz. modified dimethylol dihydroxyethylene urea (DMDHEU), modified dihydroxyethylene urea (DHEU) and a methylolation product of glyoxalmonourein, was compared for improving the dimensional stability of cotton knits. It was found that the modified DMDHEU was the best among the tested resins for improving the fabric dimensional stability, however, accompanied by maximum loss in fabric bursting strength. Three different types of softeners, viz. aminofunctional polysiloxane, fatty acid amide and polyethylene dispersion were compared for their ability to retain fabric bursting strength during resin application. It was found that the aminofunctional polysiloxane softener was the best option for bursting strength retention without deteriorating the fabric pilling resistance.

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