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Effect of Slub Yarn Ratio on Single Jersey Knitted Fabric Properties

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Abstract

Slub yarns are widely used in Single Jersey knitted fabrics to improve their appearance. This research aims to study the influence of slub yarn ratio on physical and mechanical properties of Single Jersey knitted fabric. Ten single jersey knitted fabrics were produced using four different ratios of slub yarns at two levels of ground yarn counts. Physical properties of knitted fabric were measured such as fabric density, thickness, shrinkage, spirality, color properties and thermal comfort properties. Also, mechanical properties of knitted fabric were measured including bursting strength and abrasion resistance. Results showed that increasing percentage of slub yarns used up to 50% improved fabric density, spirality and shrinkage after repeated washing, while the weight loss percent due to abrasion decreased. Fabric thermal resistance increased and air permeability decreased; while there were no significant changes observed in other measured properties.

Keywords: Slub yarns; Image analysis; Matlab program; Color; Thermal comfort; Bursting; Single Jersey knitted fabric; Abrasion resistance properties

Introduction

Ground slub yarn is a simple fancy yarn whose slub appearance is gained by the variation of yarn linear density during spinning process and no additional yarn or process is required. Slub yarns could be produced by modifying ring spinning frame, such that the intermittent acceleration of the rollers will cause varying degrees of draft to be applied [1].

The usage of slub yarn was spread especially in woven fabric in order to improve its aesthetic appearance with lowest possible cost [2]. At the beginning, it was used as a weft yarn then as warp and weft yarns. Recently, it has been used on circular knitting machines to improve Single Jersey knitted fabrics. Of course, because of the novelty of use, there is scarcity of researches that focus on studying the impact of the use of these yarns on produced fabric properties. This necessitates studying the effect of using such yarn on knitted fabric properties particularly thermal comfort, fabric strength and abrasion resistance after improving its appearance and also optimizing the usage ratio of these yarns to obtain the best fabric quality.

The effect of weft slub yarn parameters including relative thickness, slub length percent and number of slubs per meter on plain woven fabrics geometrical and physical properties were studied. In addition, fabric texture was also investigated using image analysis. Using slub yarns as weft threads in plain woven fabrics resulted in higher fabric bulkiness, higher smoothness, higher tear strength in warp direction and increase in the fabric assistance especially at the higher weft densities. Fabric stiffness increased by the increase in number of slubs per meter and decreased by the increase in slub relative thickness [3].

For Single Jersey knitted fabrics, at constant loop length, as yarn gets finer, yarn diameter decreases and courses spaces increases, hence, courses density decreases theoretically and experimentally. At constant stitch length, as yarn diameter increases, fabric thickness increases, fabric tightness increases and air permeability decreases [4].

Image analysis is applied in detecting fabric defects and extraction of fabric information such as weave, fabric density, yarn count, etc. Two different approaches based on Gabor filters for extracting slubs were studied and compared. The constructed slub extraction technique considers a very important part in the development of a denim fabric recognition system. Denim fabric with slub yarn as warp is quite popular and this fabric recognition system is welcomed by many denim manufacturers [5].

Single Jersey knitted fabric spirality is one of the phenomena which could cause goods to be rejected. In addition to the number of knitting machine feeders, yarn twist liveliness which emerges from increasing twist factor is a key factor that affects this phenomena. Also this phenomena is influenced by fabric tightness, where fabric spirality angle increases by increasing fabric tightness [6].

The dimensional, physical, and visual properties of Single Jersey knitted fabrics manufactured from Chenille yarns were investigated. These parameters were studied, yarn count, pile length, laundering, and dry-cleaning. The surface properties such as softness, smoothness, and luster become much better as the component yarn count becomes finer and the pile length becomes longer. Tumble drying satisfied the end-user's expectations for knitted goods from fine chenille yarns and long pile [7].

Experimental work and tests methodology

The specifications of the used machine are: ALBI circular Single Jersey knitting machine, Gauge 28, Diameter 17 inch and number of feeders are 34. Three different combed waxed yarn counts were spun using 100% Giza 86 Egyptian cotton and 3.6 English twist factor. The conventional yarns are 26 Ne, 32 Ne.

A ground slub yarn is formed of a single structure that has two parts: slub part and base yarn part as shown in Figure 1 [3]. The basic geometrical parameters of slub yarn are slub length (SL), slub distance (SD), base thickness (d) and slub thickness (D). So the slub yarn properties is (32 Ne, Slub relative thickness 3 (D/d) as shown in Figure 1,

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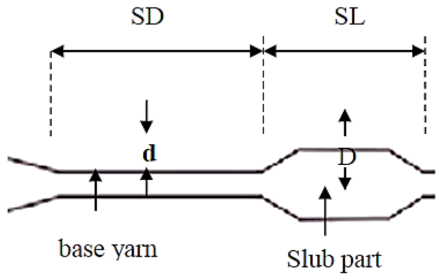

Figure 1: Illustration of the basic geometrical parameters of the slub yarn.

Arrangement (4)		Arrangement (8)		Arrangement (12)		Arrangement (17)	
Feeder No.	Slub Cone	Feeder No.	Slub Cone	Feeder No.	Slub Cone	Feeder No.	Slub Cone
1		1		1		1	
2		2		2	■	2	■
3		3		3		3	
4		4	■	4		4	■
5		5		5	■	5	
6		6		6		6	■
7		7		7		7	
8	■	8		8	■	8	■
9		9	■	9		9	
10		10		10		10	■
11		11		11	■	11	
12		12		12		12	■
13		13	■	13		13	
14		14		14	■	14	■
15		15		15		15	
16		16		16		16	■
17	■	17	■	17	■	17	
18		18		18		18	■
19		19		19	■	19	
20		20		20		20	■
21		21	■	21		21	
22		22		22	■	22	■
23		23		23		23	
24		24		24		24	■
25	■	25		25	■	25	
26		26	■	26		26	■
27		27		27		27	
28		28		28	■	28	■
29		29		29		29	
30		30	■	30		30	■
31		31		31	■	31	
32		32		32		32	■
33		33		33		33	
34	■	34	■	34	■	34	■

Table 1: Slub cone arrangement on knitting machine feeders.

Slub length 5:8 cm and Slub length percent 20%). Thus, the final slub yarn count is 22.65 Ne, total length 16 m, slubs per meter 3.131.

Two controller single jersey knitted fabrics were knitted by conventional 26 Ne for all feeders (this count is approximately equivalent to slub yarn count) and by conventional 32 Ne for all feeders (this count is similar to base count of slub yarn). Then 4 ratios of slub yarns were used (4, 8, 12 and 17 cones) for each conventional yarn count (26 and 32 Ne). Slub yarns were arranged on knitting machine feeders as shown on Table 1.

All fabrics were finished, the 140/3 Luft Rotoplus Thies Jet dyeing machine was used to half bleaching and dyeing of single jersey knitted fabrics. The bleaching solution contained the following ingredients for 200 kg knitted fabrics:

- Sequestering agent for iron (1.5 kg).
- Soap (2 kg).
- Sodium Hydroxide (3 kg).
- Hydrogen peroxide 50% (6 kg).
- Acetic acid (4.5 kg).
- Sequestering agent for water (1.5 kg).
- Leveling agent (1.5 kg)
- Reactive dye S_2G (2.622 kg).
- Softener (8 kg).

Total of 10 samples were knitted keeping the same stitch length and yarn tension. All samples were washed in a home laundering machine for three consecutive washing cycles. The washing process was carried out on (A) program for cotton fabrics at 90°C. Then fabric shrinkage and spirality were tested.

L1956A HP Scanjet scanner was used to investigate only the fabric surface appearance with 4800x9600 dpi, hardware resolution, which works according to light reflection. All samples were captured and analyzed using Matlab software to find the actual light permeability and fabric cover. For this purpose, an EOS450D Canon camera with Lens EF100 mm f/2.8L Macro IS USM, 12.8 Megapixels was used. The camera was fixed at right angle to the Single Jersey knitted samples in order to focus on the fabric sample that is fixed on a lighting box. 40x40 cm fabric samples were weighed 5 times using a digital balance of two decimal digits accuracy.

Fabric cross section was analyzed to find the differences in fabric thickness due to using slub yarns. For this purpose, Fabric was coated with transparent silicon layer, then the sample was cut, and fabric cross-section was captured by the camera. During wales density test, two needles were removed and there was a span of 288 needles. Distance between the two removed needles was measured in the finished fabric and wales density was calculated by equation (1) [4],

$$(WPC) = \frac{288}{distance\ between\ the\ removed\ needles(cm)} \quad (1)$$

Courses density was measured by inserting a different yarn color during knitting and the length of ten repeats was measured. The courses density of finished fabric was then calculated by equation (2) [4]:

$$(CPC) = \frac{№\ of\ feeders \times 10}{length\ of\ ten\ repeats\ (cm)} \quad (2)$$

Bursting strength was tested on Tinius Olsen Material Testing Machine 500, according to ASTM D3787-2001 applying 50 kgf (N) load range, 95 mm extension range, head speed of 305 mm/min, 90 mm endpoint and 0.1 kgf preload. Abrasion resistance test was performed using Martindale instrument according to ASTM 4966. A color property was measured using Data color 100 spectrophotometer according to ASTM E1164. Thermal comfort characteristics were measured. Alambeta instrument was used to measure thermal conductivity, fabric thickness, dry thermal resistance, and thermal absorptivity values. These parameters were tested according to ISO

EN 31092-1994. Relative water vapor permeability was measured on Permetest instrument based on similar skin model principle as given by ISO 11092. Air permeability was measured on Metefem instrument according to ASTM D737. The working pressure was 100 Pa using 20 cm^2 fabric samples. Five readings for each fabric sample were recorded. Results were statistically analyzed using SPSS software to test the significance of slub yarn ratio on all Single Jersey knitted fabric tested properties. Table 2 shows the statistical significance results at 95% confidence level, after uses of Univariate Analysis of Variance by SPSS Program (Two Way ANOVA).

Results and Discussion

Fabric Structural analyses

Figure 2a shows fabric knitted from one yarn count 32 Ne while Figure 2b shows fabric knitted from 50% conventional yarns and 50% slub yarns. It is clear from figure and by observing light reflectance, that fabric typical appearance has been improved as shown in Figure 2b compared to Figure 2a.

Figure 3 shows the real fabric images and binary images that were processed in order to find the actual values of covered area for each sample and to investigate the influence of slub yarn usage ratio on fabric light permeability which is an indication for air permeability and water vapor permeability. Figure 3a shows image of controller fabric sample knitted from 32 Ne conventional yarns, while Figure 3b shows this image after processing. It can be seen that light cover ratio is 91.48%. While Figure 3c and 3d also shows the original and processed image for fabric knitted using 50% slub yarns. It can be observed that light cover ratio increased up to 94.94% and this is expected as a result of bigger yarn diameter. All samples were analyzed and processed at same conditions and settings.

Figure 4 shows the effect of both increasing slub yarn ratio and

Property	Slub yarn percent	Ground yarn count
Weight	0.000	0.000
Thickness	0.000	0.000
Shrinkage	0.000	0.000
Spirality	0.000	0.921
Thermal conductivity	0.063	0.002
Thermal absorptivity	0.382	0.000
Thermal resistance	0.000	0.007
Air permeability	0.008	0.000
Vapor permeability	0.341	0.003
Bursting strength	0.238	0.000
Abrasion resistance	0.000	0.027

Table 2: Statistical significance of slub yarn ratio and ground counts on fabric properties.

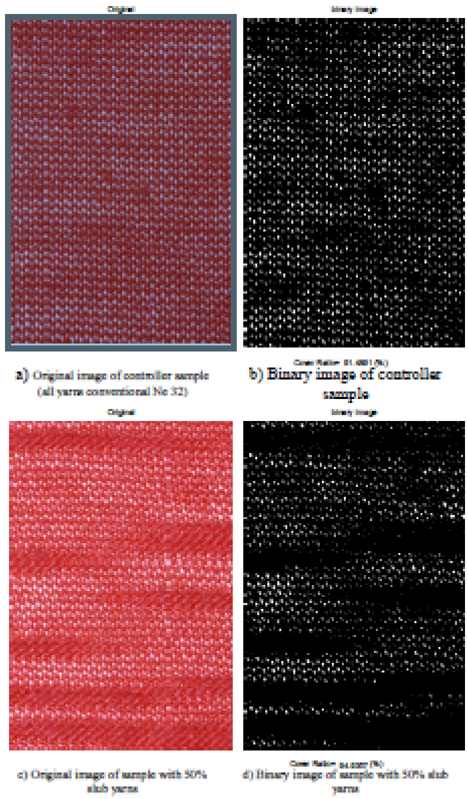

Figure 3: Original and Binary images of different Single Jersey knitted samples based on light permeability.

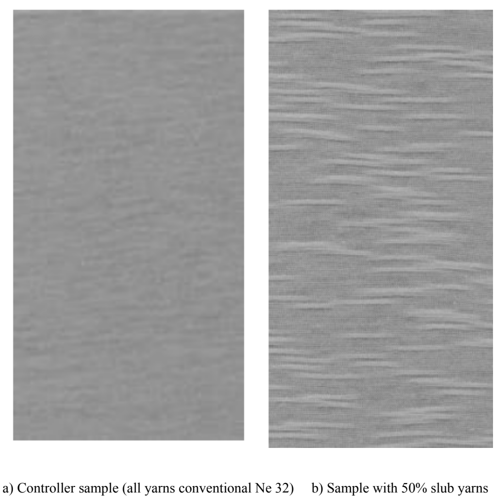

Figure 2: Images of different Single Jersey knitted samples based on light reflection.

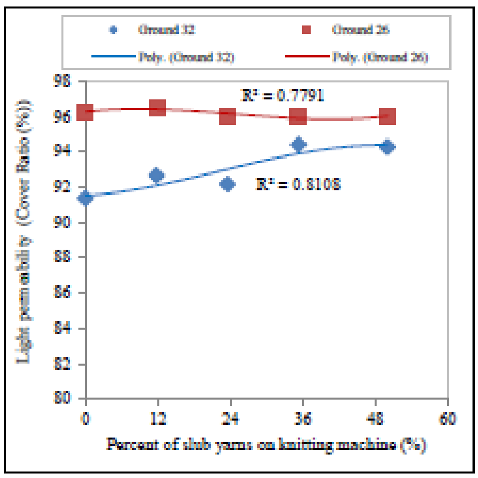

Figure 4: Effect of slub yarn ratio on light permeability of Single Jersey knitted fabric at different ground yarn counts.

ground yarn count on light cover ratio of Single Jersey knitted fabric. By increasing slub yarn ratio from 0 to 50%, values of light cover ratio. Increase by a ratio up to 6% particularly if ground yarn count is equal to slub yarn base count. While the light cover ratio does not change by increasing slub yarn ratio if ground yarn is coarser than base of the slub yarn count. Due to this change in light cover ratio. It is expected that all fabric characteristics are affected especially air permeability and water vapor permeability.

Fabric geometry

Figure 5 explains the influence of slub yarn ratio on fabrics wales and courses density after finishing and repeated washing. Wales density decreases slightly by 3% as slub yarn ratio increases from 0 to 50% either in finished or washed fabrics, however, it is not affected by ground yarn count.

Courses density increases as slub yarn ratio increases and this is due to increasing yarn count with constant stitch length. As yarn diameter increases courses spaces decrease, consequently density increases. It can be seen from the figure that as yarn count decreases from 32 to 26 Ne, courses spaces decrease and density increases by a ratio up to 6.5% for both finished and washed fabrics. Therefore, as slub yarn ratio changes from 0 to 50%, courses density increases by a ratio up to 10%.

Figure 6 shows the relationship between slub yarn ratio and Single Jersey knitted fabrics weight per square meter. These fabrics are knitted from ground yarns 26 Ne and 32 Ne. As slub yarn ratio increases from 0 to 50%, fabric weight per square meter increases by 28% and this is because average yarn diameter increases generally in produced fabric. Whereas increasing English yarn count results in increasing yarn diameter and fabric weight increases by 38% as shown in Figure 6. Statistical analysis indicates that the effect of ground yarn count and slub yarn ratio is significant.

Fabric shrinkage

Figure 7 shows the relationship between slub yarn ratio and Single Jersey knitted fabric shrinkage in wales and courses direction. As slub yarn ratio increases from 0 to 50%, fabric shrinkage improves in both lengthwise and widthwise approximately by percent 5%. This is because using more yarns with bigger diameter causes an increase in fabric tightness i.e. reduction in fabric pores as shown in Figure 4. Statistical analysis indicates that the effect of slub yarn ratio on fabric shrinkage and ground count is significant.

Fabric spirality

As noticed from Figure 8, when slub yarn ratio increases from 0 to 33%, spirality decreases approximately from 8 to 0.5 degree, and this is due to increase in fabric tightness and light permeability as shown in Figures 3 and 4. Statistical analysis indicates that the effect of slub yarn ratio on fabric spirality is significant while the effect of ground yarn count is non-significant.

Fabric thickness

It is known that fabric thickness is a function of yarn diameter whereas yarn count decreases from 32 to 26 Ne, yarn diameter increases and fabric thickness increases by a ratio up to 10% as shown in Figure 9. It is clear also that increasing the ratio of used slub yarns from 0 to

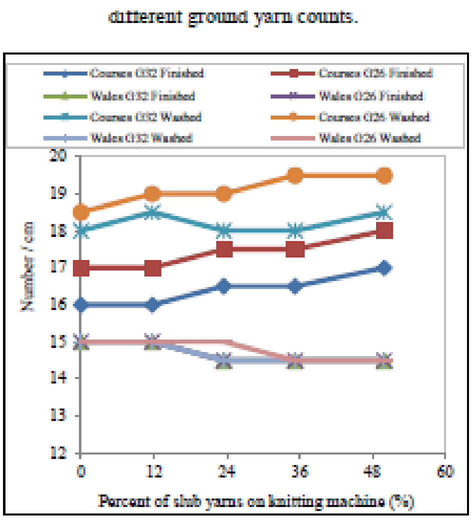

Figure 5: Effect of slub yarn ratio on courses and wales density of finished and washed Single Jersey knitted fabric at different ground yarn counts.

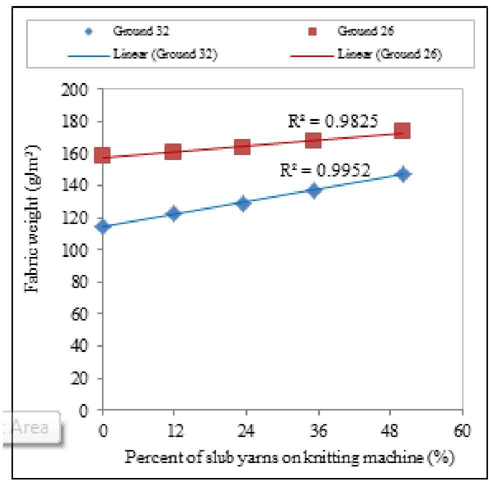

Figure 6: Relationship between slub yarn ratio and weight of Single Jersey knitted fabric at different ground yarn counts.

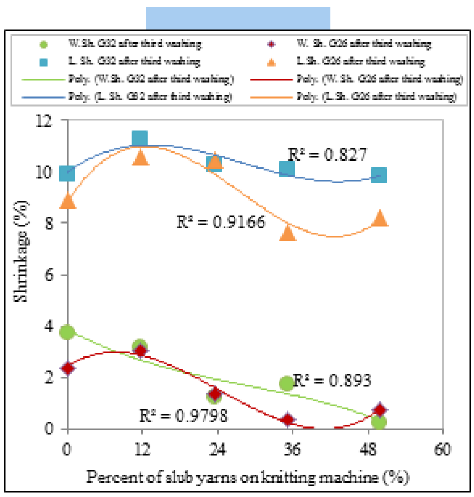

Figure 7: Relationship between slub yarn ratio and shrinkage of Single Jersey knitted fabric at different ground yarn counts.

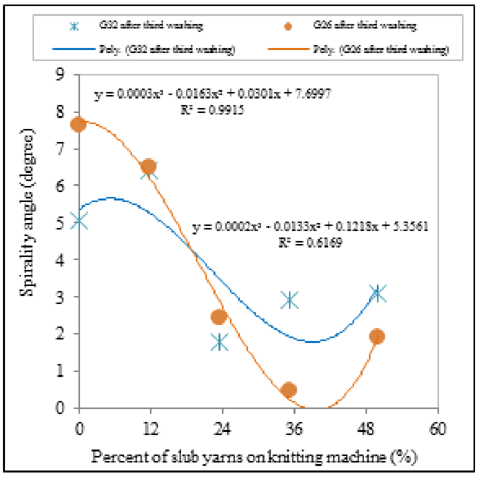

Figure 8: Relationship between slub yarn ratio and spirality of Single Jersey knitted fabric at different ground yarn counts.

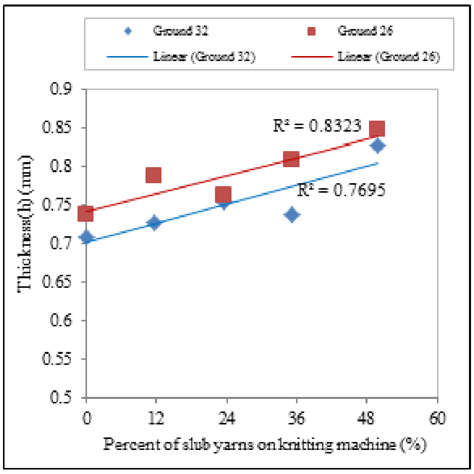

Figure 9: Relationship between slub yarn ratio and thickness of Single Jersey knitted fabric at different ground yarn counts.

Figure 10: Longitudinal cross section of Single Jersey knitted fabrics.

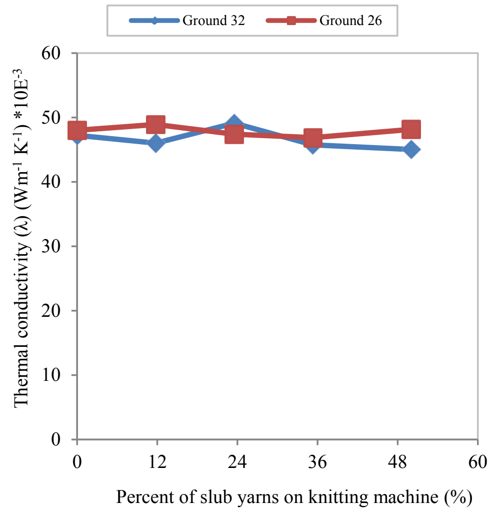

Figure 11: Relationship between slub yarn ratio and thermal conductivity of Single Jersey knitted fabric at different ground yarn counts.

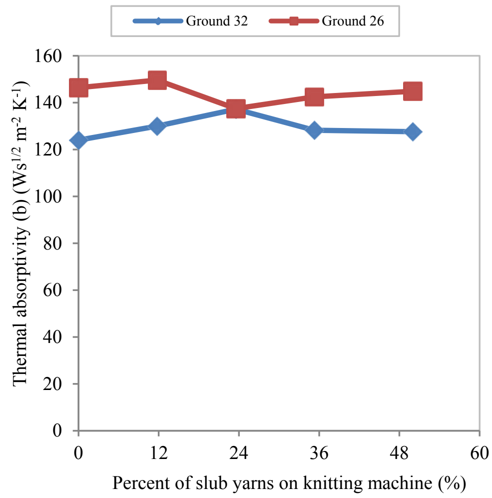

Figure 12: Relationship between slub yarn ratio and thermal absorptivity of Single Jersey knitted fabric at different ground yarn counts.

50%, fabric thickness increases by 17% and this is due to the usage of yarns that have bigger average diameter. This also affects fabric thermal resistance and mechanical properties. Statistical analysis indicates the significance of both variables. To clarify the change in thickness, fabric longitudinal cross section was obtained and captured by high resolution camera and Figure 10 shows the big variation in fabric thickness between the places from ground and slub yarns. Also there is variation in thick places length that is ascribed to the convergence and divergence of thick places between two adjacent slub yarns.

Fabric thermal comfort

Figures 11 and 12 show the relationship between slub yarn ratio, fabric thermal conductivity and fabric thermal absorptivity. It is clear from both figures and from statistical analysis that the effect of slub yarn ratio is insignificant. As shown in Figure 12, fabrics knitted from coarse counts have higher fabric absorptivity values and this is expected because as yarn diameter increases, number of paths in which heat transfers increases causing higher absorptivity.

Regarding fabric thermal resistance, as shown in Figure 13 and by statistical analysis it is evident that slub yarn ratio and ground yarn count affects it significantly, it is clear that when slub yarn ratio increases from 0 to 50%, thermal resistance increases by 20% which is due to greater fabric thickness that is directly proportional to thermal resistance as shown in Figures 9 and 10. While the effect of slub yarn ratio, as shown in Figure 14 and from statistical analysis on relative water vapor permeability is insignificant.

Figure 15 shows the relationship between slub yarn ratio and Single Jersey knitted fabric air permeability. These fabrics are knitted from ground yarns 26 Ne and 32 Ne. As slub yarn ratio increases from 0 to 50%, fabric air permeability increases by a ratio up to 23% and

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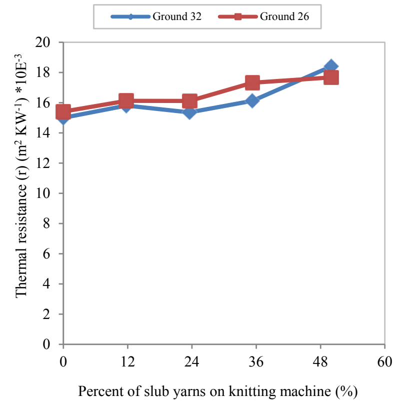

Figure 13: Relationship between slub yarn ratio and thermal resistance of Single Jersey knitted fabric at different ground yarn counts.

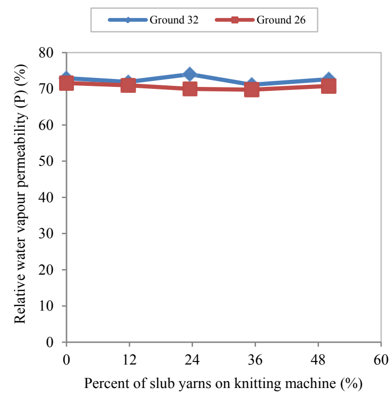

Figure 14: Relationship between slub yarn ratio and relative water vapor permeability of Single Jersey knitted fabric at different ground yarn counts.

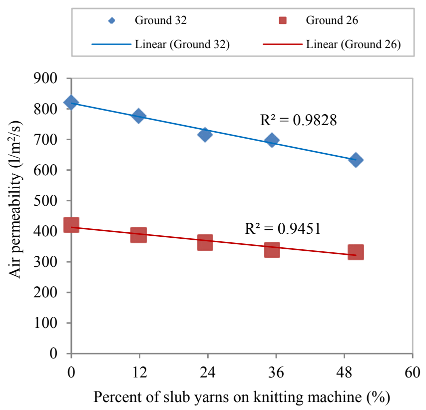

Figure 15: Relationship between slub yarn ratio and air permeability of Single Jersey knitted fabric at different ground yarn counts.

this is because light cover ratio increases by 4% and fabric thickness by 17%. Whereas yarn thickness increases, air permeability decreases. This trend is obvious form Figure 15 where increasing English yarn count from 26 to 32 i.e. reducing yarn diameter, results in increasing air permeability by 95%. And statistical analysis indicates that the effect of both variables on fabric air permeability is significant.

Fabric color properties

It is evident from Figure 16 and by statistical analysis that the effect of slub yarn ratio and ground yarn count on Single Jersey knitted fabrics color properties (LAB) is insignificant.

Fabric strength

Figure 17 shows the relationship between slub yarn ratio and Single Jersey knitted fabric bursting strength, these fabrics are knitted from different ground yarn counts. It is apparent from statistical analysis and the figure that fabric bursting strength is not affected by slub yarn ratio where it increases slightly if ground yarn counts are equal to the slub yarn count base (32 Ne) and decreases slightly if ground yarn counts are similar to the equivalent slub yarn count (26 N_e).

Fabric abrasion resistance

It is clear from Figure 18 that when slub yarn ratio increases from 0 to 50%, abrasion resistance increases by 60% because as slub yarn ratio increases, the probability of existence of apparent thick areas in fabric increases. These areas resist friction instead of the remaining fabric structure which reduces the percentage fabric weight loss. From statistical analysis, the effect of slub yarn ratio is significant unlike the effect of ground yarn count which is non-significant.

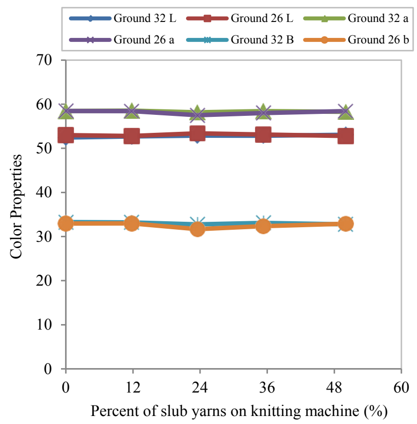

Figure 16: Relationship between slub yarn ratio and color properties of Single Jersey knitted fabric at different ground yarn counts.

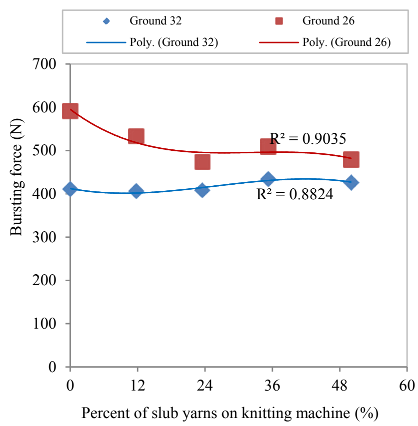

Figure 17: Relationship between slub yarn ratio and bursting strength of Single Jersey knitted fabric at different ground yarn counts.

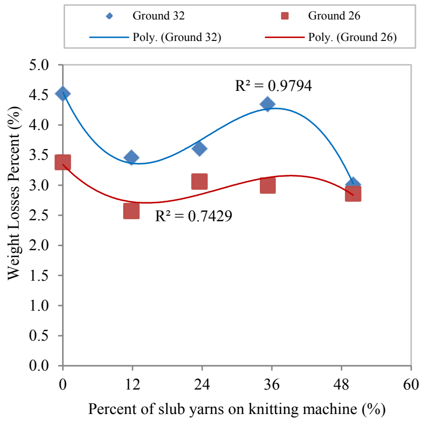

Figure 18: Relationship between slub yarn ratio and abrasion resistance of Single Jersey knitted fabric at different ground yarn counts.

Conclusion

Single Jersey knitted fabric appearance improved after using the slub yarns and its classic texture has changed specially from fabric back side. Fabric weight has increased by 28% and shrinkage ratio has improved by 5%. Also, fabric spirality improved where it reached 0 approximately particularly at 33% slub yarn ratio. Fabric thickness increased by 17% which enhanced thermal resistance by 20% in contrary to fabric air permeability which was reduced by 23%. Finally fabric abrasion resistance improved. While the influence of slub yarn ratio on other tested properties was insignificant.

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