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THE PERFORMANCE OF KNITTED FABRICS PRODUCED FROM COTTON/MODAL BLENDED YARNS

أداء أقمشة التريكو المصنعة من الخيوط المخلوطة من القطن والمودال

By

S. H. El Gholmy & A. A. Badr
Textile Eng. Dept., Faculty of Engineering, Alexandria University, Egypt
Sh_gholmy@yahoo.com

الملخص العربى

تعتبر المظهرية والراحة الميكانيكية من أهم الخواص التى يطلبها المستهلك من الملابس أثناء الإستخدام فى الحياة اليومية. ولسنوات عديدة فإنة تم دراسة و التنبؤ بخواص القماش لتقييم أدائة أثناء إستخدامة. ولهذا فإن هذا البحث يهدف الى معرفة الخواص الفيزيائية و الميكانيكية لأقمشة التريكو بإستخدام تحليل الإنحدار لكى يتم التوصل الى تقييم اداء هذة الأقمشة أثناء الإستعمال. تم إنتاج أربعة أقمشة مختلفة بخلطات قطن و مودال مختلفة على نفس ماكينة التريكو. أيضا تم تجهيز الأقمشة الناتجة بطريقتين مختلفتين، الأولى هى تجهيز القماش وهو فى الصورة الإسطوانية (على المقفول) و الثانية تجهيز القماش وهو مفتوح (أى على العرض الكلى للقماش). و أخيرا تم إستخدام الأداء الوظيفى فى معرفة الخصائص التى تم دراستها. و قد أظهرت تحليل النتائج أنة يفضل إستخدام الأقمشة التى تحتوى على نسبة عالية من المودال فى فصل الصيف، حيث أنة لة القدرة على إمتصاص العرق بسهولة و السماح للهواء بالمرور نتيجة لنفاذيتة العالية للهواء.

Abstract

Both fabric appearance and garment comfort are considered the most important wearing characteristics demanded by consumers during daily life use of garments. For many years, predicting fabric properties have been investigated to evaluate the performance of fabrics during wearing. Therefore, this research work aims to investigate the physical and mechanical properties of knitted fabrics using step wise regression to be able to estimate the performance of these fabrics during wear. Four different fabrics with different yarn blends of Egyptian cotton and modal were produced on the same knitting machine. The fabrics were finished by two different techniques the first one in the tubular form (rope form) and the second one in the open width form. Step wise regression was used to estimate the performance of these fabrics during wear. Finally, the desirability function was used to optimize the multiple response properties. The analysis of results shows that the modal is perfect to wear in summer; as it absorbs the sweat easily and allows the air flow due to its high air permeability.

Key words: Modal, knitted fabric, finishing method, Step Wise Regression, Desirability function and Radar area.

1-Introduction:

The selection of the clothing by customers is mainly based on appearance and fashion. Fabric performance is in turn depends on fabric physical and mechanical properties, and fabric characteristics. In other words, the fabric performance is perfectly obtained from the correct analysis of the fabric characteristics and properties both physical and mechanical. Some research works have studied the relation between fabric properties and their performance in clothing production in order to predict the fabric performance based on the mechanical properties under low stress as measured by Kawabata [1] KES-FB system and the Fabric Assurance by Simple Testing FAST [2]. Recently, garment processes become more automated and consumers require more varieties of fabric types. [3] This made the evaluation of the fabric by subjective

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measurement not objective one, thus several researches developed a quantitative methods to evaluate fabric properties. [4]. Therefore, the aim of this research is to evaluate the physical and mechanical properties of knitted fabrics produced from cotton-modal blended yarns to estimate the performance of these fabrics during wear.

The modal fibers have been closely investigated during spinning in several researches. Nazan et al [5] investigated the properties of vortex yarn spinning system, conventional ring and open-end rotor spun yarns produced from different counts of cotton, viscose and 50/50 cotton–modal blended fibres. These yarns were manufactured on a single jersey circular knitting machine. The results show that; viscose fiber was preferred for inner and outer knitwear products for its comfort and visual characteristics. It was also found that, the use of vortex spun yarns, produced from viscose fibres, were recommended for products when comfort and good appearance are required.

In another research Farag et al. [6] studied the effect of blending ratio of cotton and modal fibers. It was found that the modal fibres are harmonic with the cotton fibers and add advantages to cotton fibers like processing propensity, besides their extra fibre length and fineness.

On the other hand the properties of knitted fabrics produced from modal and other regenerated cellulose fibers were studied by Gun et al. [7]. Results show that the weight, thickness and air permeability values were independent of the fiber type. Plain knitted fabrics produced from modal/cotton blended yarns have the highest bursting strength values. Plain knitted fabrics produced from bamboo/cotton blended yarns tend to pill less.

Also Marmarali et al [8] studied the thermal comfort of knitted fabrics made from new generated yarns. Results show that mixing natural and synthetic fibers gives warmer feelings.

Many ways and means were carried out to minimize shrinkage and to obtain fabrics having an acceptable level of shrinkage. Recently, new finishing machines, and methods are used for challenging to lessen construction shrinkage and to overcome processing shrinkage. These methods include relaxation drying, compactors and chemical processes. There are many factors that relate to shrinkage. These include the fiber type, the yarn size and type, wet processes, finishing procedures, apparel manufacturing techniques, and garment care methods. The problem in cellulosic fibers is that, they are not easily stabilized like the thermoplastic synthetics, because they cannot be heat set to attain stability. Finishing procedures may reduce or increase the dimensional stability of the fabric. If relaxation dryers, compactors, and/or crosslinking agents are used, then the residual shrinkage after wet processing can be reduced [9].

Badr and El Nahrawy [10] studied the effect of two different finishing methods on the different properties of cotton and cotton modal knitted fabrics. They found that the finishing process has a significant effect on the widthwise shrinkage, loop length and wales density.

2-Experimental work:

In this research work a design of an experiment was carried out to study the effect of blending ratio of cotton and modal fibers and the effect of finishing process on the performance of the produced garment. In order to reach the optimum blend ratio and the suitable finishing process to meet the required end use.

2-1 Material and fabric production:

Four different fabrics, with different blend ratios were produced on the same knitting machine under the same yarn tension. It equals to 5 gm. 100% modal, 70% modal-30%cotton, 50% modal-50% cotton and 100% cotton with yarn count 30/1 and loop length 2.8mm which is commercially used. Then they were finished with two different methods open width form and close width or rope form. Finishing method with open width form means that the finishing process line will be as follows: starting with knitting process then the fabric will be slit by using slitting machine before processing through Stenter machine in the grey state, and then sewn using sewing machine followed by dyeing, centrifugal squeezing and relaxation dryer machines and finally the fabric is manually un-sewn before entering again to the Stenter machine.

While for the other finishing method with close width form, the finishing line will be as follows: Starting with knitting process then the fabric will be dyed followed by balloon squeezing and relaxation dryer machines and at last the fabric is then calendared through compactor machine.

All the fabric samples were produced on Mayer and Cie, S4-3.2 single jersey circular knitting machine, with 26 inch diameter, 24 gauge, 84 feeders and total number of needles is 1944. The loop length was kept constant at 2.8 mm which represents a medium fabric. The following tables (1. 2) show the main specification and properties of the yarns and knitted fabric samples used in this research work.

Table (1) Specifications of used yarns

	Modal 0%	Cotton 100%	Modal 50%	Cotton 50%	Modal 70%	Cotton 30%	Modal 100%	Cotton 0%
Ne	29.6		29.5		29.3		29.7	
TPI	21		19		20		20.1	
Irregularity (CV%)	12.8		11.4		10.3		10.4	
Thin places (-50%)	3		0		0		2	
Thick places (+50%)	19		11		11		6	
Neps	36		20		20		18	
RKM (Kg$_f$*Nm)	20		21		22.6		24.5	
Elongation %	6		5.7		7.1		11.6	
Hairness (H)	7.4		7		6.6		5.9	

Table (2) Fabric Specification

Blend Ratio	Courses /cm	Wales/ cm	Fabric Weight (g/m2)	Loop Length (mm)	Thick ness (mm)	Courses/ cm	Wales/ cm	Fabric Weight (g/m2)	Loop Length (mm)	Thickn ess (mm)
	Close Width Samples for 30/1 Ne					Open Width Samples for 30/1 Ne				
100%M	19.2	13.95	117.8	2.815	0.331	18.98	13.65	117	2.82	0.337
70%M/30%C	19.2	14.9	127.5	2.803	0.367	19.45	13.6	123	2.82	0.361
50%M/50%C	20.6	14.5	135.3	2.815	0.384	19.213	13.625	120	2.82	0.3486
100%C	20.5	14.8	135.5	2.818	0.409	19.21	13.63	120	2.82	0.349

2-2 Methodology:

In order to predict the performance of fabrics produced with different blended yarns of Egyptian cotton and modal fibers and with different finishing process. Step wise regression was used to estimate regression equations for each fabric property under study. In the second part of this research work the desirability function was used to reach the optimum quality value for the studied properties. The desirability function was used to combine multiple responses into one response value (desirability function) by choosing a value from 0 (for properties characteristics that were desired to be minimum) to 1 (for properties characteristics that were desired to be maximum). The inputs were the mean response estimates for properties studied. This involves transformation of each estimated response variable Y_j to a desirability value d_j, where $0 \leq d_i \leq 1$. The value of d_i increases as the "desirability" of the corresponding response increases [11-13].

2-3 Fabric Tests:

In this research the bursting strength was measured according to ASTM D3786 and pilling was measured according to ASTM D3512 and air permeability by ASTM D 737. The color difference was measured on the data color instrument. The 100% cotton sample at open width form was taken as a reference sample during measurement. The most important property that affects the fabric end use in the garment is the fabric handle force, which was measured by the fabric hand-meter using the principle of the withdrawing the fabric sample through a circular ring where the force generated during withdrawing the sample through this ring. The maximum value of the force occurs when the whole specimen has almost passed through the ring. The forces included in the initial deformation are related to the bending modulus and the shear stiffness of the fabric. As the test continues, forces due to compression have a larger effect as the fabric sample is pressed to the dimensions of the ring [14-15].

3-Results and Discussion:

The following table (3) shows the Design of Experiment of the studied factors and the results obtained from the fabric testing. As for the fabric properties the different color shade (ΔE), Bursting strength, pilling resistance, Air permeability and fabric shrinkage were measured.

Where:

C: Finishing process: 1= open width form, -1= close width form

B: Blend ratio: 1=100% modal, 0.4= 70% modal, 0=50% modal and -1=0% modal.

Table (3) Design of Experiment and fabric results

Sample number	Finishing process(C)	Blend Ratio	Color shade (ΔE)	Bursting Strength ($lb/inch^2$)	Handle force (g)	Pilling Grade	Air Permeability ($ft^3/m^2/sec$)	Lengthwise Shrinkage %	Widthwise Shrinkage %
1	1	1	2.11	57.29	336.6	3.5	605.3	7.625	10.13
2	1	0.4	1.71	71.49	707.1	4	442.3	10.88	11.13
3	1	0	2.135	83.18	949.2	4	362	8.875	10.38
4	1	-1	0.273	95.63	1483	3.5	216.3	5.875	11
5	-1	1	2.79	61.37	306	4	545	11.25	4.75
6	-1	0.4	2.648	76.16	605.7	3.5	371.5	11.63	5.875
7	-1	0	2.513	84.28	837.8	3.5	302.8	8.625	7.125
8	-1	-1	1	92.82	1574	3.5	182	5.75	6.625
Average			1.897	77.78	849.9	3.688	378.4	8.813	8.375
Maximum Value			2.79	95.63	1574	4	605.3	11.63	11.13
Minimum Value			0.273	57.29	306	3.5	182	5.75	4.75
Difference			2.518	38.34	1268	0.5	423.3	5.875	6.375

3-1 Color Shade:

The following equation was estimated to predict the color shade of the produced fabric with R^2 = 0.916.The 100% cotton fabric at open width form was taken as a reference sample other samples were compared according to it.

$$Y = 2.145 - 0.34C + 0.864B - 0.62B^2$$

P- val= $6*10^{-23}$ $4*10^{-8}$ $6*10^{-14}$ $9*10^{-7}$

(C = Finishing method, B = Blend ratio)

As it can be seen the color shade difference increases as the percent of the Modal fiber increase in fabric. This is due to high absorption capability of the modal fiber due to its non amorphous regions. Practically, this makes the Modal fabric good to wear during summer, as it absorbs the suiting quickly also wicks rapidly making the body feels dry and comfort. Therefore, the Modal fabric will act well in the underwear garments.

3-2 Bursting strength:

The following equation was obtained to predict the bursting strength of the produced fabric with R^2 = 0.954.

$$Y = 82.88 - 17.7B - 2.03CB - 6.19B^2$$

P-val= $3*10^{-37}$ $4*10^{-20}$ 0.01 $1*10^{-5}$

The equation shows that the bursting strength decreases dramatically as the percent of the modal fiber increases in fabric. Although, the strength of modal yarn is higher than cotton yarn, but the smooth surface of modal fibers reduces the inter fiber gripping force leading to sliding of fibers over each other, which may lead to decreasing bursting strength of modal fabrics. For this reason the 100% modal fabric is not recommended for the sportswear, where the severe movement of the body can exerts high stretching force on the cloth and can cause breakage or wear to the product.

3-3 Pilling resistance:

The following equation was estimated to predict the pilling resistance of the produced fabric with R^2 = 0.451.

$$Y = 3.695 + 0.284B - 0.27B^2$$

P- val= $1*10^{-28}$ $4*10^{-4}$ 0.024

As it can be noticed the pilling grade increase as the percent of the modal fiber increases in fabric. This can prove that blending the modal with cotton fiber in riches the cotton fiber properties and overcomes one of the major problems of cotton fiber in knitted fabric, which is pilling ability. Since the R Square is equal to 0.451 which represents a low value, we need to increase the sample size to detect the actual effect of percentage modal fiber.

3-4 Air Permeability:

The following equation shows the factors that affect the air permeability with R^2 = 0.974.

$$Y = 328 + 28.06C + 186.9B + 58.75B^2$$

P-val= $8*10^{-29}$ $3.7*10^{-7}$ $1.6*10^{-23}$ $7*10^{-7}$

The equation proves that the air permeability increases as the modal percent increases. This makes the modal a perfect garment to wear in summer as it allows the air flow through the wide voids and also absorb the sweat rapidly.

3-5 Fabric Handle force:

The fabric handle can be estimated by the following equation with a R^2 = 0.966

$$Y = 910.5 - 606B$$

P- val= $1*10^{-32}$ $1*10^{-23}$

The equation shows that the handle force decreases as the modal fiber percent increases in the fabric. This proves the high drapability of the modal fabric and the low modal initial shear modulus. Moreover, it indicates the low fabric friction which agrees with the results of low bursting strength previously mentioned in this research.

3-6 Fabric Shrinkage:

The following equations were obtained to predict the lengthwise and widthwise shrinkage of the produced fabric where for the lengthwise shrinkage, the R^2 is equal to 0.627.

$Y=9.663 + 2.03B - 0.94CB - 1.95B^2$

P-val=$4*10^{-19}$ $2*10^{-5}$ 0.022 0.004

The lengthwise shrinkage increases as the percentage of the modal increases inside the yarn for the fabric finished with the close width form method, while it decreases for the samples processed through the finishing method with open width form method. The later occurs actually due to compactness effect in the lengthwise direction happened for the fabric during the over feeding action accompanied with thermosetting effect applied at the Stenter finishing machine. While, for the widthwise shrinkage the R^2 is equal to 0.698.

$Y= 8.375 + 2.281C$

P- val= $4*10^{-24}$ $3*10^{-9}$

The widthwise shrinkage resulted from samples processed through open width form method provides extra widthwise shrinkage value than the other finishing method (close width form). The reason of that trend is caused by the more stretchability occurred to the fabric in the lateral direction during processing inside the Stenter machine.

3-7 Desirability Function:

The following table (4) shows the mathematical calculations to reach the desirability value d_j for the properties studied. The bursting strength, air permeability and pilling grade responses were to be maximized, while the color shade difference (ΔE), handle force, lengthwise shrinkage and widthwise shrinkage were to be minimized. Finally the Area under each curve in the radar chart was calculated. For each response Y_i, a desirability function d_i assigns numbers between 0 and 1 to the possible values of Y_i, with $d_i = 0$ representing a totally undesirable value of Y_i and $d_i = 1$ representing a wholly desirable or ideal response value. The individual desirabilities are then united using the geometric mean, which gives the overall desirability D: $D = (d_1 \times d_2 \times \ldots \times d_k)^{1/k}$. Where: K indicates the number of responses. If any response Y_i is completely undesirable (d_i= 0), then the overall desirability is zero (11, 12). Figure (1) shows the radar chart for the tested sample properties used in this study.

Table (4) Desirable values and Ranking of each property

Sample number	(ΔE) d_1*100	Strength d_2*100	Handle Force d_3*100	Pilling Grade d_4*100	Air Permeability d_5*100	Lengthwise Shrinkage d_6*100	Widthwise Shrinkage d_7*100	Desirable value D*100	Radar Area	Ranking
1	12.91	59.91	90.91	87.5	100	75.41	46.91	57.88	15886	2
2	15.94	74.76	43.28	100	73.07	52.87	42.7	50.61	10494	4
3	12.76	86.99	32.24	100	59.j81	64.79	45.78	48.54	9431	7
4	100	100	20.63	87.5	35.73	97.87	43.18	59.77	13328	3
5	9.767	64.17	100	100	90.05	51.11	100	60.26	16864	1
6	10.29	79.64	50.52	87.5	61.38	49.46	80.85	50.94	10329	5
7	10.85	88.13	36.52	87.5	50.02	66.67	66.67	49.01	9295	8
8	27.25	97.07	19.45	87.5	30.07	100	71.7	51.57	9637	6

Polygon Area= $((d_1*d_2)+(d_2*d_3)+(d_3*d_4)+(d_4*d_5)+(d_5*d_6)+(d_6*d_7)+(d_7*d_1))*(0.5*(\sin(360/7))$

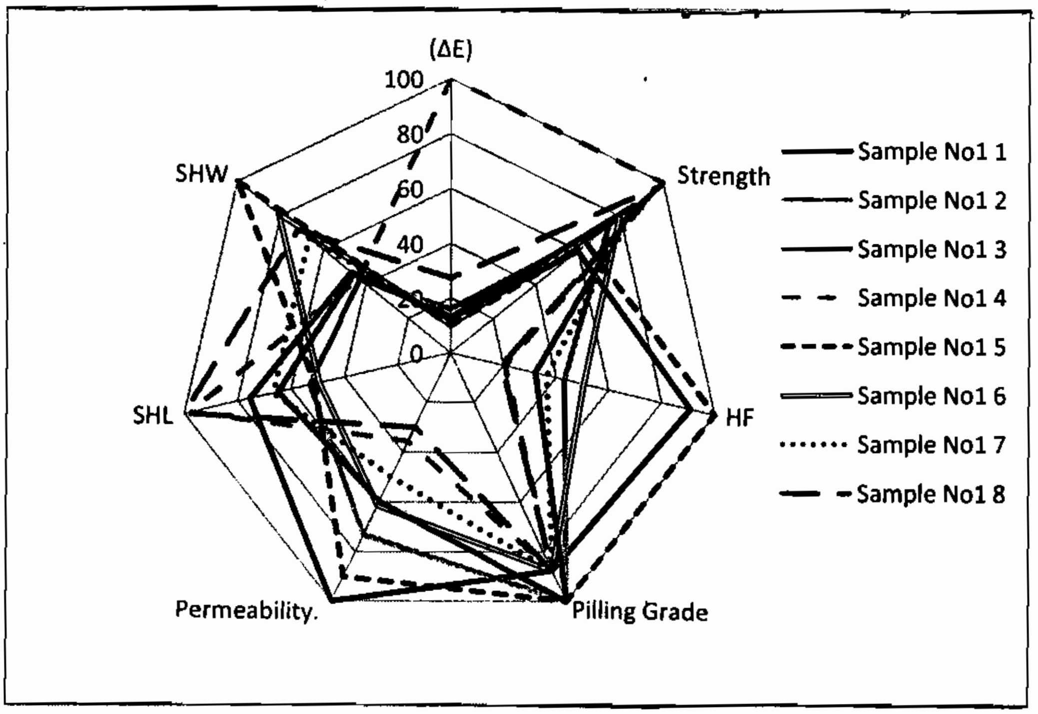

Figure (1) Quality Polygons for fabric properties

As it can be seen from both the D values and the polygon area at table (4) that the best sample in this case is sample number (5), which is 100% modal fabric finished in close width form followed by sample number (1), which is also 100% modal fiber, but finished in open width form.

In the above mentioned case all the properties under study have the same importance for the end use and thus have the same weight assigned to 1. Actually, this is not true, as the importance of each property differs according to the end use. The following table (5) shows the target value for each property and the degree of importance, according to a number consumer's point of view, if the fabric will be used as a summer cloth.

Table (5) Response target weight and importance

Response	Target	Importance	Weight
Color difference	Minimum is better	5	0.5
Strength	Maximum is better	6	0.5
Handle force	Minimum is better	3	1.5
Pilling grade	Maximum is better	4	1
Air permeability	Maximum is better	2	2
Lengthwise Shrinkage	Minimum is better	1	2.5
Widthwise Shrinkage	Minimum is better	1	2.5

The following table (6) shows the desirable value for the properties studied using different weights according to the degree of importance. Where **D=** $(d_1^{0.5}*d_2^{0.5}*d_3^{1.5}*d_4*d_5^{2}*d_8^{2.5}*d_7^{*2.5})^{1/9.5}$

Table (6) the Desirable value and properties ranking

Sample Number	D value	Ranking
1	67.3279	2
2	52.9889	6
3	52.0149	8
4	52.7668	7
5	73.2224	1
6	58.2424	3
7	55.2428	4
8	53.8976	5

As it can be seen from the table (6) that sample number (5) is the best sample which is 100% modal finished in close form and the second sample is sample number (1), which is as well 100% modal fiber, but finished in open width form.

It is also clear that the worth two samples are samples (3) and (4) which they contain 50 and 0% modal respectively. This proves that as the percent of modal fiber increases in the sample, the performance of the sample improves.

4-Conclusion:

Predicting the performance of the cotton and Modal fabric blends has been investigated in order to estimate the durability and the characteristics of the fabric in the end use garment. Results show that the color shade difference increases as the percent of the modal fiber increases in fabric. This is due to high absorption capability of the modal fiber due to large inner surface of voids. The bursting strength decreases dramatically as the percent of the modal fiber increases in fabric, which may be the only week point in the modal fabric, further researches should consider the seam strength of modal fabric. Also results shows that blending the modal with cotton fiber in-rich the cotton fiber properties and overcome one of the major problems of cotton fiber in knitted fabric, which is pilling ability. Additionally, lengthwise shrinkage decreases as the percentage of modal increases for the samples processed through the finishing method with open width form. This is actually due to the compactness effect in the lengthwise direction occurred for the fabric during the over-feeding action accompanied with thermosetting effect applied at the Stenter machine. Finally results show that the handle force decreases as the modal fiber percent increases in the fabric. This proves the high drapability of the modal fabric and the low modal initial shear modulus. Moreover, indicates the low fabric friction .Also, this confirms the low bursting strength of modal fabric previously mentioned in this research.

Optimizing the .response of the studied properties shows that the 100% modal fabric gave the best ranking. From these results it can be seen that the modal fabrics are perfect to wear in summer and will be very comfortable in under wear cloth. Unfortunately, the modal fabrics are kindly week, so they are not recommended for sportswear as they can not withstand the high bursting force which may be exerted at the knee and the elbow.

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