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Comparative Study of the Properties of Plain Knitted Fabrics Made of the Ring and Hybrid Cotton Folded Yarns

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Abstract: The objective of present study was to compare plain knitted fabrics comfort properties realized with hybrid and ring cotton folded yarns formed of two single yarns. The quality of the knitted fabric is determined by adiathermic power, air permeability and abrasion resistance. The results indicate that the plain knitted fabrics properties made of hybrid folded yarns are similar to those made of ring folded yarns. In addition to that, we notice that the yarn linear density and the folding twist factor have the most important effect on plain knitted fabrics properties realised with hybrid and ring folded yarns. This result is of a great industrial interest because the hybrid folded yarns costs less dearly than the ring folded yarns. In present study, Statistical models of the prediction are being presenting describing the variation of knitted fabric characteristics with the spinning and folding parameters and single yarns properties.

Key words: Hybrid and ring folded yarns, folding twist factor, Jersey knitted fabric, air permeability, adiathermic power, abrasion resistance

INTRODUCTION

The folded yarn is produced by folding two or more singles yarns together. Folded yarns are used extensively in the textile industry. Many woven and knitted fabrics use folded yarns.

The consumption of knitted fabric is constantly growing in the clothing industry because the knitted structure offers several advantages, such as extensibility, drape, wrinkle recovery and cheap production cost.

The study of the properties of the knitted fabric was published by Manich *et al*. (2001) who studied the abrasion kinetics of woven fabrics. He showed that the knitted fabrics properties depend on the yarns characteristics.

Cannon and Onal (2002) presented the abrasion properties of knits made from open end and ring spun yarns. He showed that the abrasion resistance of the fabrics depends on the fiber properties, yarn and fabric structures.

Cheikhrouhou *et al*. (2001) indicated the influence of stitch length on the adiathermic power of the knit for two yarns of different linear density, also that the adiathermic power increase with the stitch length because the number of air inside the knit increases, which reduces the thermal exchange with the outside and thus improves the calorific retention capacity.

Ceken and Eylûl (2001) investigated the pilling properties of plain knitted fabrics, he concluded that not only yarn properties that have some effect on pilling, which occurs on fabric surfaces during washing and wearing of wool and wool blend flat knitted fabrics, but also fabric tightness.

Slah *et al*. (2006) used the neural network to foresee the global quality of the knitted fabric from the fiber, yarn and knitting parameters. He estimated the quality of the knit by the properties of comfort, permanency, usefulness and the mechanical resistance properties.

In the following study, we try to estimate the effect of the spinning and folding parameters and the linear count of folded yarns on the quality of knitted fabrics using the experimental design method and linear regression. And to compare the comfort properties such as the adiathermic power, the air permeability and abrasion resistance of plain knitted fabrics made of hybrid and ring folded yarns.

MATERIALS AND METHODS

Production of the cotton folded yarns: In this study, we used three ring spun yarns (R) and three rotor yarns (OE) of different linear density Yd (tex) with respectively three spinning twist factor (α_{SNm}).

The value of twist factor α_{SNm} obtained when the twist is multiplied by the square root of the linear density of the yarn. It presented by the following formula:

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$$\alpha_{SNm} = T \times \sqrt{\frac{Yd(tex)}{1000}}$$

Where:

α_{SNm} = The spinning twist factor.
T = Twist in turns per meter.
Yd (tex) = Linear density in tex.

Two types of folded yarns are discussed: the first, the ring folded yarn (F-R) is composed of two ring spun yarns and the second, the hybrid folded yarn (F-OE/R) is formed with one ring spun yarn and one Open End yarn.

Three folding twist factor (α_{FNm}) were tested. α_{FNm} is given by the following formula:

$$\alpha_{FNm} = T \times \sqrt{\frac{2Yd(tex)}{1000}}$$

Where:

α_{SNm} = The folding twist factor.
T = Twist in turns per meter.
Yd (tex) = Linear density in tex.

Practical studies showed that it is a rapport between the spinning and the folding twist factors for the folded yarns. In that, (Dréan and Renner, 1994) presented the relationship between the value of spinning and folding twist for the cotton folded yarns. He concluded that in knitting, the folding twist value of folded yarns is the half of the spinning twist value in order to have more voluminous folded yarns favoured in knitting.

This result verifies the choice of the value of the spinning and the folding twist factors. The combination of the linear count, the spinning and folding parameters are arranged according to a fractional set (9 experiments) (Table 1).

Ring spun yarns (R) were produced on spinning machine type Zinser 321 in Sitex Industry/Sousse/Tunisia. Autocorner Schlafhorst -338 was used for the winding operation. Rotor yarns (OE) were produced by using Autocoro Schlafhorst of type ACO 240U/288. Assembly and folding operation were carried out, respectively on "SSM" machine and the Two-for-one yarn folding machine Volkmann of the VTS-07 type.

The mechanical properties of single and folded yarn were tested by the Uster Tensorapid. Unevenness and hairiness were controlled by using the Uster Tester 3 (Table 2).

Production of Jersey knitted fabrics: The ring and hybrid folded yarns were knitted using a Protti PV 92SX flat knitting machine with the English gauge E7 in Textile Research Unit of ISET Ksar Hellal/Tunisia.

We estimated the abrasion resistance of the knitted fabrics by measuring the loss of weight (LW(g m^{-2})) after 2500 rounds, this operation is made on Martindale abrasiometer according to the standard NFG 07 121.

The adiathermic power (PA) is the property of a fabric to conserve the body heat that it surrounds, which permits to measure the protective calorific power of the knit. The French Norm NFG 07-108 makes use of the following formula for calculating this parameter.

Table 1: Levels and factors used in fractional set

Level of factor	Yarn linear density Yd (tex)	Spinning twist factor (α_{SNm})	Folding twist factor (α_{FNm})
1	40	100	50
2	80	110	55
3	100	120	60

Table 2: Ring (F-R) and hybrid (F-OR/R) folded yarns properties

Test yarn	Type of folded yarns	Yd (tex)	α_{SNm}	α_{FNm}	Unevenness Cv (%)	Hairiness	Elongation (%)	Tenacity (CN/Tex)
1	F-OE/R	80	100	50	11.51	12.28	6.987	12.218
2	F-OE/R	80	110	55	11.02	11.40	7.213	12.352
3	F-OE/R	80	120	60	10.52	11.81	7.658	13.012
4	F-OE/R	160	100	55	8.21	16.43	12.840	16.060
5	F-OE/R	160	110	60	8.25	14.00	12.860	16.390
6	F-OE/R	160	120	50	8.27	16.10	11.980	14.610
7	F-OE/R	200	100	60	7.88	17.52	11.320	15.891
8	F-OE/R	200	110	50	7.30	16.19	11.684	16.621
9	F-OE/R	200	120	55	8.07	14.77	12.368	17.413
10	F-R	80	100	50	11.43	13.92	7.603	13.245
11	F-R	80	110	55	11.67	13.42	7.765	14.336
12	F-R	80	120	60	11.88	11.85	7.963	14.392
13	F-R	160	100	55	8.68	18.55	11.870	13.261
14	F-R	160	110	60	8.67	16.37	12.040	15.618
15	F-R	160	120	50	8.82	15.03	12.620	16.172
16	F-R	200	100	60	8.03	18.91	10.454	14.926
17	F-R	200	110	50	7.88	16.51	10.094	13.167
18	F-R	200	120	55	7.82	15.23	11.062	13.277

F-OE/R: Hybrid folded yarn; F-R: Ring folded yarn

PA = 17.4 Log $((E^2/Ms)\times100)$, with E: The thickness of the knitted fabric (mm); Ms: The specific mass of the knitted fabric in (g m^{-2}).

Air Permeability of a knitted fabric is given by the following formula:

$$P = Qv/A, \text{ with } Qv:$$

The average debit of air in m^3 sec^{-1} measured by the air permeabler SDL with reference to standard ISO 9237 (1995); A: The surface of the test tube (m^2).

RESULTS AND DISCUSSION

The quality of the knitted fabric is determined by its comfort properties, for example the adiathermic power, the air permeability and the abrasion resistance (Table 3).

We used the statistic Delta which is the difference between the high and the low effect of each factor in order to classify the most influential factors of folded yarns on the properties of knitted fabrics.

The dominant parameters that influence the air permeability, the adiathermic power and the abrasion resistance of knitted fabric of ring and hybrid yarns, are the yarn linear density Yd (tex) and the folding twist factor (α_{FNm}) (Table 1, 4a and b).

By the value of statistic delta, we can present the significance of the parameters which is revealed as: level of importance: Yd (tex) $\rangle$ $\alpha_{FNm}\rangle\alpha_{SNm}$

By means of this ranking, we can compare the properties of the two kinds of plain knitted fabrics by Fig. 1-6 to give the mean data of properties of plain knitted fabrics and to evaluate the effect of the most significant factors, the linear density and the folding twist factor on the comfort properties.

According to the Table 3, we notice that the plain knitted fabrics properties made of hybrid and ring cotton folded yarns are very similar.

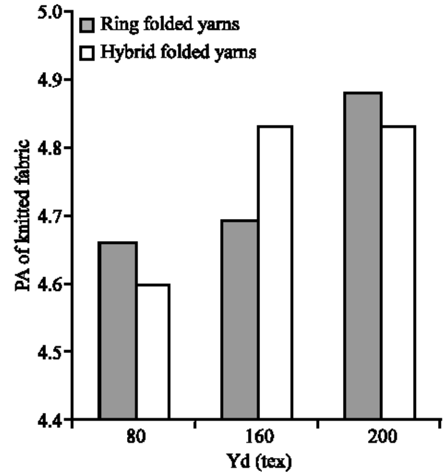

Fig. 1: Relationship between adiathermic power PA and Yd (tex)

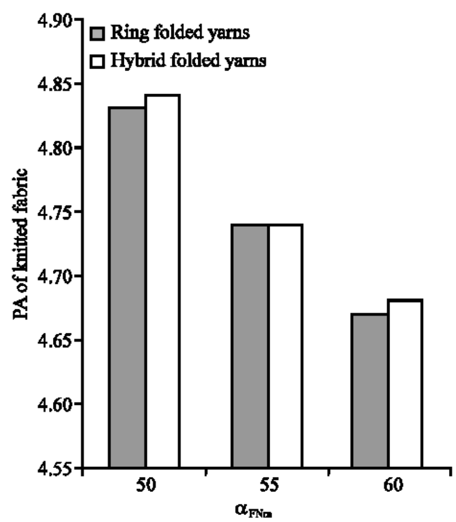

Fig. 2: Relationship between adiathermic power PA and α_{FNm}

Table 3: Table for optimization of the plain knitted fabric quality of cotton

Test knit	Parameters of spinning and folding of folded yarns: Yarn linear density Yd (tex)	α_{SNm}	α_{FNm}	Properties of plain knitted fabric of ring folded yarns: PA	P (m^3 m^2 sec^{-1})$\times10^{-3}$	LW (g m^{-2})	Properties of plain knitted fabric of hybrid folded yarns: PA	P (m^3 m^2 sec^{-1})$\times10^{-3}$	LW (g m^{-2})
1	I	I	I	4.75	0.48	3.72	4.67	0.43	3.68
2	I	II	II	4.68	0.67	3.43	4.61	0.61	3.33
3	I	III	III	4.57	0.53	3.18	4.54	0.53	3.04
4	II	I	II	4.67	0.36	4.46	4.80	0.36	5.33
5	II	II	III	4.63	0.30	4.19	4.79	0.30	4.11
6	II	III	I	4.78	0.44	4.62	4.90	0.43	4.57
7	III	I	III	4.82	0.38	4.76	4.71	0.34	4.71
8	III	II	I	4.96	0.29	5.23	4.97	0.26	5.28
9	III	III	II	4.87	0.21	5.01	4.81	0.21	4.97

From Fig. 1 and 2, we noted that the adiathermic power is not affected by the linear density Yd (tex) and the folding twist factor α_{FNm}. And the plain knitted fabrics made of hybrid folded yarns have an adiathermic power approaching to those made of ring folded yarns.

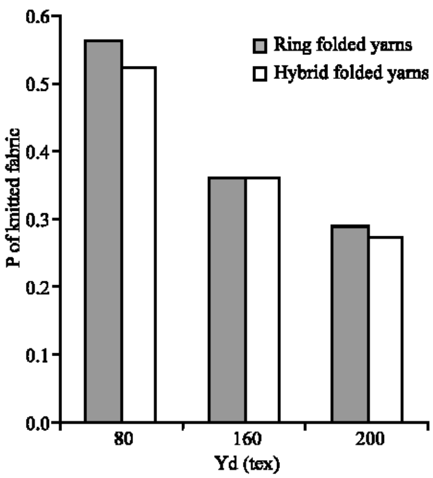

Fig. 3: Relationship between air permeability P and Yd (tex)

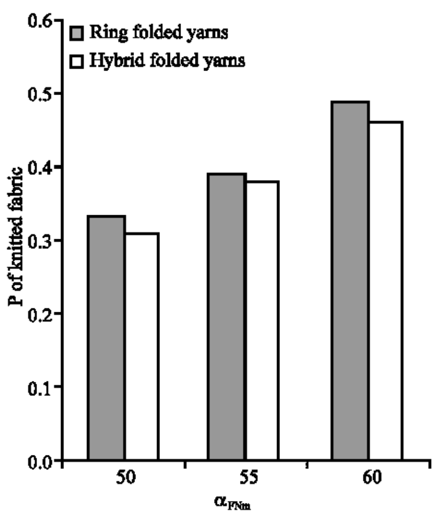

Fig. 4: Relationship between air permeability P and α_{FNm}

Table 4a: Effect of different factors on knitted fabric properties made of ring folded yarns

Properties of knitted fabric		Parameters of folded yarns: Yarn linear density Yd (tex)	α_{SNm}	α_{FNm}
Air permeability (P)	Delta	0.25	0.013	0.14
	Row	1.00	3.00	2.00
Adiathermic power (PA)	Delta	0.22	0.06	0.16
	Row	1.00	3.00	2.00
Abrasion resistance (LW)	Delta	1.63	0.38	0.59
	Row	1.00	3.00	2.00

The Yd (tex) has significant influence on the air permeability and abrasion resistance of the two plain knitted fabrics. As a matter of fact, we notice that when Yd (tex) increases for a constant plain knitted fabric LFA (the yarn length absorbed by stitch), the volume occupied

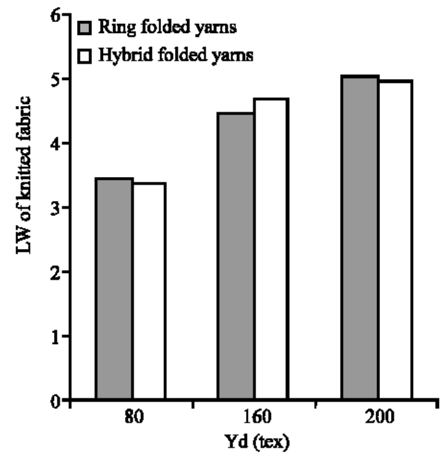

Fig. 5: Relationship between abrasion resistance LW and Yd (tex)

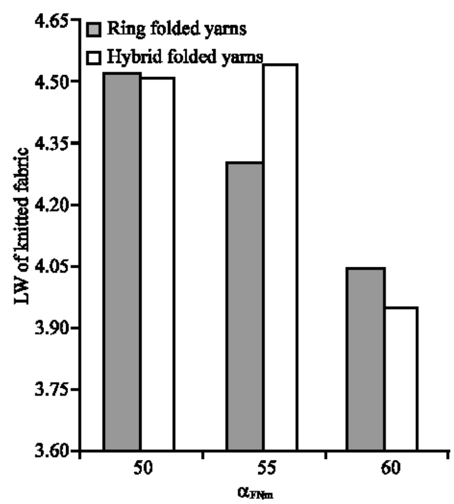

Fig. 6: Relationship between abrasion resistance LW and α_{FNm}

Table 4b: Effect of different factors on knitted fabric properties made of hybrid folded yarns

Properties of knitted fabric		Parameters of folded yarns: Yarn linear density Yd (tex)	α_{SNm}	α_{FNm}
Air permeability (P)	Delta	0.260	0.026	0.16
	Row	1.000	3.000	2.00
Adiathermic power (PA)	Delta	0.216	0.012	0.15
	Row	1.000	3.000	2.00
Abrasion resistance (LW)	Delta	1.550	0.040	0.48
	Row	1.000	3.000	2.00

by the folded yarn in the knitted fabric increases and consequently the air permeability decreases (Fig. 3). In deed, for a Yd (tex) varying from 80 tex to 200 tex, the air permeability knitted fabric decreases of 48.07%.

The hairiness increases with the 2-fold yarn count as shown in Table 2, because the surface area of the yarn will increase with the yarn count and it is likely that the hairiness will increase as well and the abrasion resistance of plain knitted fabrics will decrease (Fig. 5). Consequently, the folded yarns of linear density = 80 tex has a low hairiness. These yarns gives a plain knitted fabrics showing a increase of the abrasion resistance of 32.03% that the plain knitted fabrics by the folded yarns of Yd = 200 tex. The fact that confirms the clarification of Cannon *et al.* (2003).

The folding twist factor α_{FNm} affects the air permeability and the abrasion resistance of plain knitted fabrics. Actually; when α_{FNm} increases the volume occupied by the folded yarn in the stitch decrease and the air permeability increases (Fig. 4). And also by the increase of α_{FNm}, the hairiness decreases (Table 2) and the abrasion resistance increases (Fig. 6).

As a result, working with α_{FNm} of 60 instead of 50 improves the plain knitted fabric air permeability because high folding decreases the diameter of folded yarns and increases the porosity of the realized knitting. This improvement is about 31%.

Figure 6 shows that the abrasion resistance increases as the folding twist increases of 11%.

We noticed also that the comfort properties of knitted fabrics depend with the properties of folded yarns. In fact, we concluded that the spinning twist factor α_{SNm} has not a significant effect on knit properties because this factor influences essentially the properties of the single yarns and not folded yarns ones.

According to results of Table 3, it was difficult to discuss the relationship between each parameter of spinning and folding process and the linear density of folded yarns with the comfort properties of knitted fabrics. Equations describing these relationships were then determined.

By via the data of the Table 3 and the linear regression, six statistical models can be used to describe the effect of the selected parameters on the properties of the plain knitted fabrics.

For the plain knitted fabric realised by the ring folded yarns:

$$PA = 5.41+16\times10^{-4}\ Yd(tex)-33\times10^{-5}\alpha_{SNm}-0.0157\alpha_{FNm};\quad R^2 = 76.7\% \qquad (1)$$

$$P = 1.10+20\times10^{-4}\ Yd(tex)-67\times10^{-5}\alpha_{SNm}-0.0167\alpha_{FNm};\quad R^2 = 85.5\% \qquad (2)$$

$$LW = 5.28+12\times10^{-3}\ Yd(tex)-21\times10^{-4}\alpha_{SNm}-0.048\alpha_{FNm};\quad R^2 = 99.8\%. \qquad (3)$$

For the plain knitted fabric realised by the hybrid folded yarns:

$$PA = 5.25+19\times10^{-4}\ Yd(tex)+11\times10^{-4}\alpha_{SNm}-0.0167\alpha_{FNm};\quad R^2 = 87.7\%. \qquad (4)$$

$$P = 0.829+19\times10^{-4}\ Yd(tex)+67\times10^{-5}\alpha_{SNm}-0.0147\alpha_{FNm};\quad R^2 = 91\%. \qquad (5)$$

$$LW = 7.43+14\times10^{-3}\ Yd(tex)-19\times10^{-3}\alpha_{SNm}-0.0557\alpha_{FNm};\quad R^2 = 90.3\%. \qquad (6)$$

(R^2): The coefficient of the determination of the statistical model

By means of the data of Table 3 and the linear regression, we can obtain the optimum level of the three factors for comfort properties of the plain knitted fabrics by the relationship between each property and each factor.

The optimum spinning and folding condition for the selected folded yarns obtained from the experimental design for the properties of plain knitted fabric which can be defined in Table 5.

By means of regression equations of 1 to 6, we estimate the calculated value of the adiathermic power, the air permeability and abrasion resistance of the two types of the knitted fabrics. For testing our models, we used the

Table 5: Optimum level of plain knitted fabrics properties

Knitted fabric type	Plain knitted fabric properties	Factor	Optimum level
Knitted fabric of ring folded yarns	Adiathermic power (PA)	Yd(tex)	200
		α_{SNm}	100
		α_{FNm}	50
	Air permeability (P)	Yd(tex)	80
		α_{SNm}	120
		α_{FNm}	60
	Abrasion resistance (LW)	Yd(tex)	80
		α_{SNm}	120
		α_{FNm}	60
Knitted fabric of hybrid folded yarns	Adiathermic power (PA)	Yd(tex)	200
		αs_{Nm}	100
		α_{FNm}	50
	Air permeability (P)	Tf(tex)	80
		α_{SNm}	120
		α_{FNm}	60
	Abrasion resistance (LW)	Yd(tex)	80
		α_{SNm}	120
		α_{FNm}	60

optimum spinning and folding conditions (Table 5). A comparison of the estimated values from the model with those from the experiment shows very good agreement (Fig. 7-9).

As a result, we can note that the best optimum spinning and folding conditions are $\alpha_{FNm} = 60$, $\alpha_{SNm} = 120$ and Yd (tex) = 80 which presented improvements of the plain knitted comfort properties made of hybrid and ring folded yarns especially for the air permeability and for the abrasion resistance (Table 5).

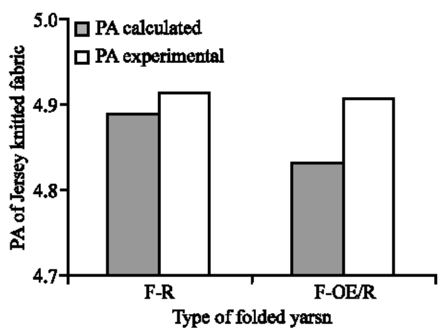

Fig. 7: Comparison between the experimental and calculated PA

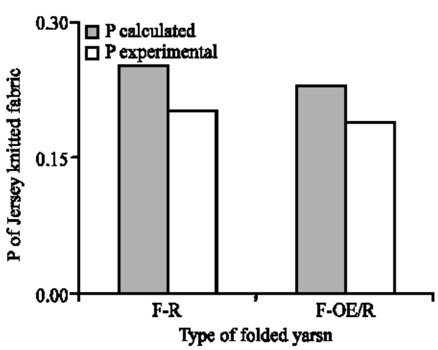

Fig. 8: Comparison between the experimental and calculated P

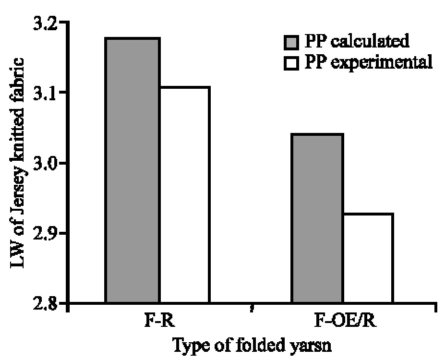

Fig. 9: Comparison between the experimental and calculated LW

CONCLUSIONS

The interest of this study was to compare the two plain knitted fabrics made of hybrid and ring folded yarns properties. It aims also at studying the influences of the linear density, the spinning and the folding twist factors on the characteristics of plain knitted fabrics.

Among the results, we have found that the plain knitted fabrics properties made of hybrid and Ring cotton folded yarns were very close.

In addition to that, we noticed that the linear density and the folding twist factor have a considerable influence, especially on the air permeability and on the abrasion resistance of the plain knitted fabrics. On one hand, these factors have several effects on the Jersey knitted fabrics air permeability and abrasion resistance. On the other hand, they can be influential on other plain knitted fabrics criteria.

Consequently, the prediction equation obtained can be used by the spinner as a guide to evaluate the influence of folding and spinning parameters on the plain knitted fabrics properties.

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