DEPENDENCE OF YARN AND FABRIC STRENGTH ON THE STRUCTURAL PARAMETERS

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Abstract:

Strength of the fabric is an important property that decides and influences all other performance properties of the fabric. But though we all understand the importance of the strength of the fabric in daily wear, a systematic approach is required to correlate various strength properties with that of the yarn and fabric construction parameters. We are all aware of the effect of the individual factors like twist, count and cover factor on the strength behaviour of the fabric. However it is necessary to study the effect of all these parameters in combination with each other to ultimately influence the strength of the fabric. Such a study is also useful for designing of the fabric, depending upon the end use and the customer requirement as it is gaining importance in the recent fierce competitive scenario. In this study we have evaluated the strength properties of the fabric with respect to tensile, tear and bursting strength and correlated the results with respect to the yarn count, Twist Multiplier and picks per inch of the fabric using regression equations.

Keywords:

Tensile strength, tearing strength, bursting strength. regression analysis, obliquity effect

Introduction

Strength of the fabric is an important property that decides and influences all other performance properties of the fabric. Consideration of the strength of the fabric is very essential while selecting the appropriate fabric for the intended garment. But though we all understand the importance of the strength of the fabric in daily wear, a systematic approach is required to correlate various strength properties with that of the yarn and fabric construction parameters. We are all aware of the effect of the individual factors like twist, count and cover factor on the strength behaviour of the fabric. However it is necessary to study the effect of all these parameters in combination with each other to ultimately influence the strength of the fabric. Such a study is also useful for designing of the fabric, depending upon the end use and the customer requirement as it is gaining importance in the recent fierce competitive scenario.

In this study we have evaluated the strength properties of the fabric in terms of tensile, tear and bursting strength. The tensile strength deals with the force required to break a large number of yarn simultaneously in either warp or weft direction. The tear strength is usually a measure of the force required to propagate a tear, and is often used to give a direct assessment of serviceability, whereas bursting strength deals with the strength of the fabric when a multidirectional force is applied on it. The predictions were done using regression equations[1-5]. The advantage of the system lies in the fact that an empirical model could be developed which can then be used to design fabrics with the desired properties. A further comparison was sought by replacing the conventional ring spun yarn by rotor yarns of equivalent count and twist multiplier.

Materials and methods

Both ring and rotor yarns of 20^s and 24^s were produced with a twist multiplier (T.M.) of 3.6 and 4.0. The total of eight yarns were used for manufacturing the fabric with two different picks per inch (PPI) i.e. 52 and 60 giving a total of sixteen different combinations of the fabrics.

The yarn count was checked by gravimetric method. The yarn diameter was determined with the help of Digital Microscope RSC-5T, using the manual mode of measurement.

The Tensile Strength of both the yarn and the fabric was measured on Instron Tensile Strength Tester, Table Model (Metric) TM-M. The distance between the jaws for the testing of yarn was 10 cm and the speed of the lower jaw was 10 cm/min. For the fabric, the distance between the two jaws was 20cm and the speed of the lower jaw was 20 cm/min. The testing was done by the raveling strip method[5].

The tearing strength of the fabric was determined as per the method (ASTMD 1424) using the tearing strength tester manufactured by Kamal Metal Industries, Model No_A,Sl No.-2903.

The Bursting strength was determined using Rossari Labtech machine as per the method (ASTMD 3786).

Experimental design

For the yarn, a 2^2 full factorial design was used. For both the types of yarn namely ring and rotor spun, the variables being count and T.M., the strength and yarn diameter were predicted based on the above variables. For the fabric, a 2^3 factorial design was used and, the variables were Yarn Count, T.M., and P.P.I.

Table 1. Experimental plan for variables used for yarn (Ring and Rotor).

Combination No.	Level of Variable	
	Count (x_1)	T.M(x_2)
1	-1	-1
2	-1	+1
3	+1	-1
4	+1	+1

Table 2. Actual values corresponding to coded levels in yarn.

Level	Variable	
	Count (x_1)	T.M.(x_2)
-1	20	3.6
+1	24	4.0

Table 3. Experimental plan for variables used for fabric (Ring and Rotor).

Combinations Sr. No.	Variables		
	Count (x_1)	T.M.(x_2)	P.P.I.(x_3)
1	-1	-1	-1
2	-1	-1	+1
3	-1	+1	-1
4	-1	+1	+1
5	+1	-1	-1
6	+1	-1	+1
7	+1	+1	-1
8	+1	+1	+1

Table 4. Actual values corresponding to coded levels in fabric.

Level	Variable		
	Count(x_1)	T.M.(x_2)	P.P.I.(x_3)
-1	20	3.6	52
+1	24	4.0	60

Table 5. Response surface equations for ring and rotor spun yarns.

Response	Response Surface Equation
Ring Yarn Tenacity, cN/Tex	$17.54-0.23x_1+2.4700x_2+0.22.x_1x_2$
Rotor Yarn Tenacity, cN/Tex	$11.0400-0.8100x_1+0.1600x_{2+}0.0100x_1x_2$
Ring Yarn Diameter, µm	$217.8-28.25x_1-5.43x_2+4.29x_1x_2$
Rotor Yarn Diameter, µm	$242.81-37.29x_1-6.65x_2+1.33x_1x_2$

Results and discussion

Statistical analysis

The response surface equations for the yarn strength and the fabric strength are shown in Tables 5 and 6. The negative coefficient of a variable in a response surface equation indicates that the particular property decreases with the increase in that variable, while a positive coefficient indicates that a particular property increases with the increase in that variable[4]. But the sign and magnitude of the coefficients of the interaction between the variables, again modify this trend. The relationship between response and variable are shown with the help of 3-D graphs (Figs 1-7).

Yarn Tenacity

It has been observed that the yarn count has a negative effect on the yarn tenacity, while the T.M. (in the considered range) positively influenced the yarn tenacity (refer Tables 5 & 7and Figure 1) which is attributed to the increased cohesion between the fibres resulting in greater binding of the fibres into the body of the yarn. The obliquity effect seemed to be negligible as compared to the resistance to slippage in the considered range of T.M. Although this trend was observed for both the ring and the rotor yarns, the ring yarns were stronger than rotor yarns (Fig. 1) due to better orientation of the individual fibres into the yarn structure, as a result of the ring spinning process. This is also evident from the comparison of the response surface equations for tenacity of the two types of yarns. The response surface equation for the ring yarn has a larger constant term as compared to the rotor yarn indicating that the ring yarn possesses higher tenacity value.

Yarn Diameter

Both the yarn count and the T.M. seem to have a negative influence on the diameter of yarns (refer Tables 5 &7) which may be attributed to individual fibres getting more closely tucked in the yarn body at higher count and a higher twist multiplier. The rotor yarns were generally bulkier (higher diameter) than the ring yarns, which is due to the loosely held wrapper fibres resulting in a bulkier structure, and it was clearly apparent in the microscopic examination.

Tensile Strength of the Fabric

The response surface equations for tensile strength (refer Table 6,8 & 9 and Figures 2a-2c, 3a-3c) show, that in both the warp and the weft direction, the count exerts a negative effect on the tensile strength, whereas the T.M. and P.P.I. had a positive effect on it. The changes in the weft yarn brought

Table 6. Response surface equations for ring and rotor spun yarn fabrics.

Response	Response Surface Equation
Tensile strength, Warp wise (Ring)	$37.113-1.413x_1+1.587x_2+1.337x_3+0.413x_1x_2-0.138x_1x_3+0.862x_2x_3+0.037x_1x_2x_3$
Tensile strength, Weft wise (Ring)	$37.163-2.887x_1+0.763x_2+1.812x_3-0.988x_1x_2-0.138x_1x_3+0.513x_2x_3+0.263x_1x_2x_3$
Tensile strength, Warp wise (Rotor)	$34.431-1.369x_1+0.631x_2+0.231x_3-0.369x_1x_2+0.731x_1x_3+0.231x_2x_3-0.269x_1x_2x_3$
Tensile strength, Weft Wise (Rotor)	$33.050-1.725x_1+1.350x_2+1.250x_3+0.475x_1x_2+0.175x_1x_3+0.250x_2x_3+0.475x_1x_2x_3$
Tear strength, Warp wise (Ring)	$3205.9-140.1x_1+467.9x_2+301.4x_3-32.6x_1x_2-51.6x_1x_3+5.9x_2x_3-18.6x_1x_2x_3$
Tear strength, Weft wise (Ring)	$3135.4-479.4x_1-64.9x_2+344.4x_3+167.4x_1x_2-43.9x_1x_3-45.4x_2x_3-18.6x_1x_2x_3$
Tear strength, Warp wise (Rotor)	$2685.8-101.2x_1+64.8x_2+271.2x_3-53.8x_1.x_2+63.3x_1.x_3-78.7x_2.x_3+39.7x_1x_2x_3$
Tear strength, Weft wise (Rotor)	$2525.8-170.7x_1+88.5x_2+314.0x_3+39.5x_1.x_2+12.5x_1.x_3-21.3x_2.x_3-27.8x_1x_2x_3$
Bursting Strength, (Ring)	$11.6538-0.5662x_1+0.0088x_2+0.3087x_3-0.0213x_1x_2-0.0963x_1x_3+0.0538x_2x_3-0.0913x_1x_2x_3$
Bursting Strength, (Rotor)	$10.8188-0.5688x_1+0.2188x_2+0.2812x_3-0.1438x_1x_2+0.0437x_1x_3+0.0563x_2x_3-0.0063x_1x_2x_3$

Table 7. Strength parameters for ring and rotor yarn.

Sr. No.	Combination		Ring Yarn Tenacity, cN/Tex	Ring Yarn, Diameter um	Rotor Yarn, Tenacity cN/Tex	Rotor Yarn, Diameter um
	Count	T.M.				
1	20	3.6	15.22	255.77	11.70	288.08
2	20	4.0	20.020	236.33	12.00	272.12
3	24	3.6	14.62	190.69	10.06	210.84
4	24	4.0	20.00	188.40	10.40	200.21

Bursting strength

Bursting strength of the fabric (refer Tables 6,8 & 9 and figures 6a-6c,& 7a-7c) also showed an increase with an increase in T.M. and P.P.I. and a decrease in its value with increase in count. In the case of fabrics with rotor yarns in the weft, the influence of T.M. is more significant than in the case of fabrics with ring yarn as weft, which is also indicated in the higher coefficient of the term in the response surface equation of bursting strength for the fabrics with rotor yarn in the weft.

Table 8. Strength parameters for fabric with ring spun yarn as weft.

Sr. No.	Combination			Tensile Strength Warp Wise, Kg	Tensile Strength Weft Wise, Kg	Tear Strength Warp Wise, Gms.	Tear Strength. Wt.in Weft Wise, Gms	Bursting Strength, Kg/cm^2.
	Count	T.M.	P.P.I.					
1	20	3.6	52	36.7	36.6	2517	3432	11.93
2	20	3.6	60	38.0	40.0	3174	4262	12.45
3	20	4.0	52	37.4	39.6	3469	3021	11.70
4	20	4.0	60	42.0	44.0	4224	3744	12.80
5	24	3.6	52	33.4	33.6	2368	2189	10.85
6	24	3.6	60	34.0	35.4	2893	2918	11.35
7	24	4.0	52	35.6	31.6	3264	2522	10.90
8	24	4.0	60	39.8	36.5	3738	2995	11.25

Table 9. Strength parameters for fabric with rotor spun yarn as weft.

Sr. No.	Combination			Tensile Strength Warp Wise, Kg	Tensile Strength Weft Wise, Kg	Tear Strength Warp Wise, Gms.	Tear Strength. Wt.in Weft Wise, Gms	Bursting Strength, Kg/cm^2.
	Count	T.M.	P.P.I.					
1	20	3.6	52	35.80	32.6	2342	2297	10.85
2	20	3.6	60	33.8	35.2	2995	2998	11.25
3	20	4.0	52	36.8	34.8	2816	2493	11.45
4	20	4.0	60	36.8	36.5	2995	2998	12.05
5	24	3.6	52	31.8	28.8	2200	19.07	9.90
6	24	3.6	60	33.8	30.2	2947	2547	10.45
7	24	4.0	52	32.4	31.0	2300	2150	9.95
8	24	4.0	60	34.25	35.3	2891	2816	10.70

about by changing the count, T.M and P.P.I., exerted a tremendous influence also on the warp wise strength of the fabric. The warp wise tensile strength in the case of fabrics having ring yarn in the weft was dominantly influenced by the P.P.I. of the fabric followed by count and T.M. successively. Fabric with ring yarn in weft showed higher influence of the P.P.I. on the warp wise strength as compared to the fabric having rotor yarn in weft, which can be clearly seen by the higher coefficient of P.P.I. in the response surface equation for the former. It is also to be noted that the fabric with ring yarn in the weft had only slightly higher tensile strength as compared to the one having rotor yarn in the weft, although individual ring yarn had significantly higher tensile strength as compared to rotor yarn.

Tearing strength

The tearing strength (refer Tables 6, 8 & 9 and Figures 4a-4c, and 5a-5c) was found to be the most sensitive of the three different strengths when variations were made in the weft. The fabric with ring yarn in the weft had a higher strength value in general in both the directions as compared to fabrics with rotor yarns in the weft. But for the tearing strength the variations were of a much higher order.

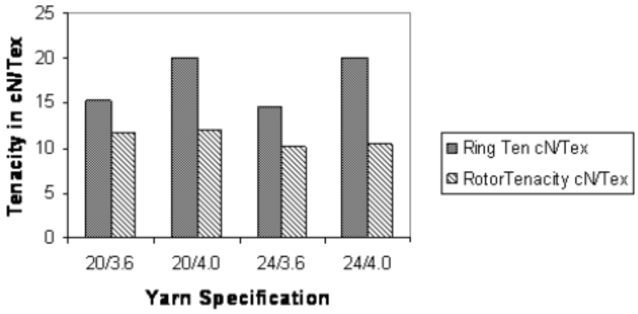
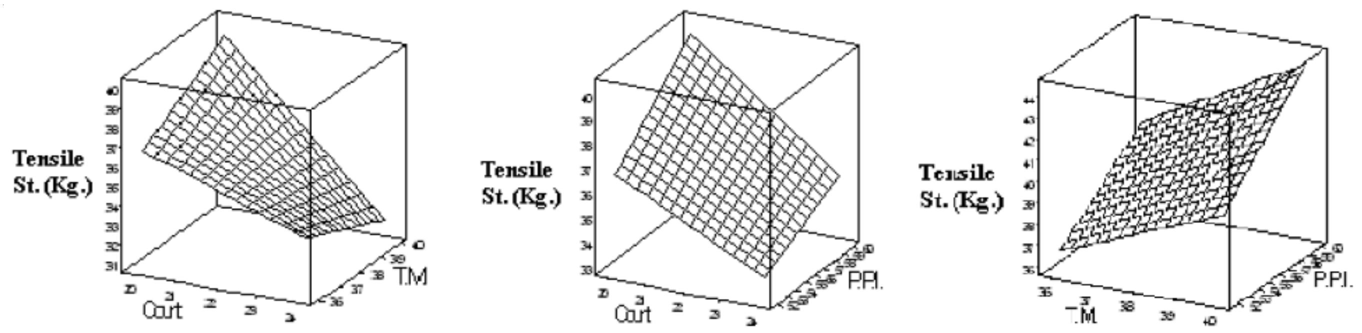


Figure 1. Comparative tenacity of ring vs rotor yarns.

Conclusion

The yarn tensile strength and diameter are dependent on the structural parameters of the yarn such as count and T.M., besides the fibre characteristics. The influence of the count and T.M. varies with the different forms of spinning. An open end or rotor yarn with a similar count and T.M.as that of a conventional ring spun yarn does not have a similar strength profile, due to the difference in the fibre orientation and fibre cohesion in the different yarn systems.

These yarn characteristics further determine the performance properties of the fabric woven from them. It was found that though there was notable difference in the strength properties



a) b) c)

Figure 2. Response surface plot of tensile strenght of fabric in weft direction (weft; ring yarn).

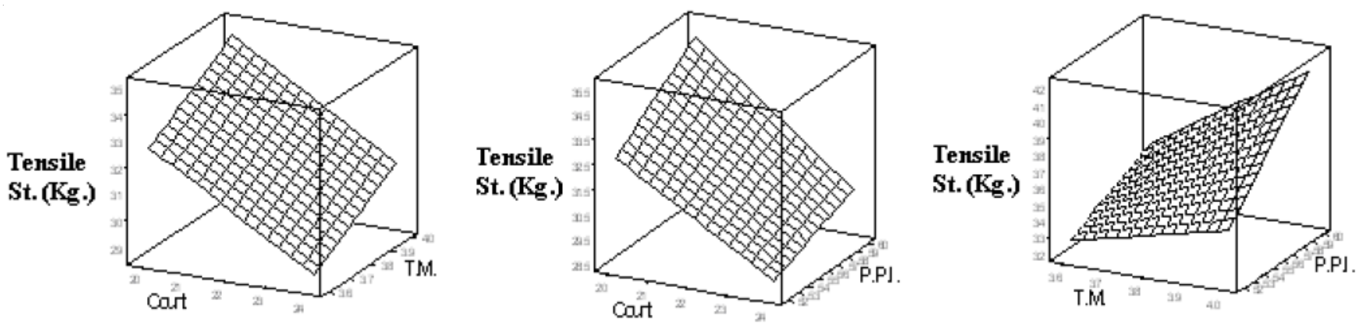


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Figure 3. Response surface plot of tensile strenght of fabric in weft direction (weft; rotor yarn).

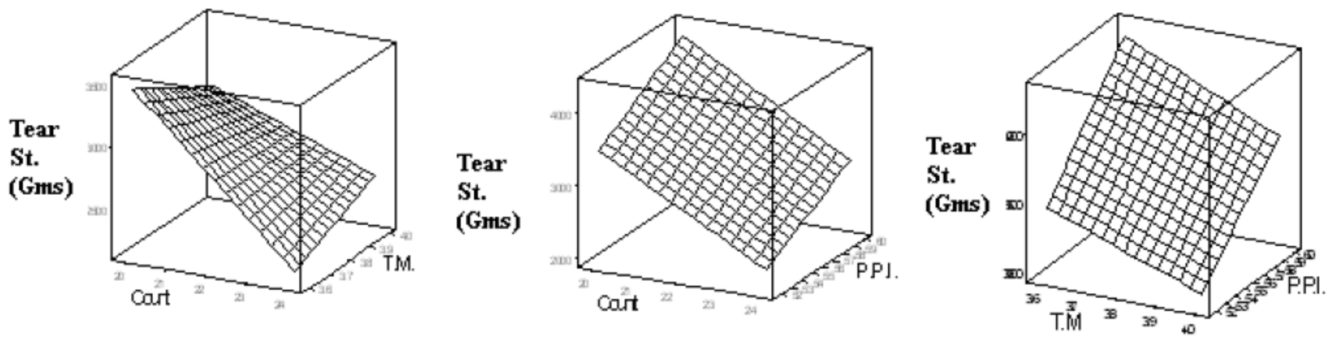

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Figure 4. Response surface plot of tearing strenght of fabric in weft direction (weft; ring yarn).

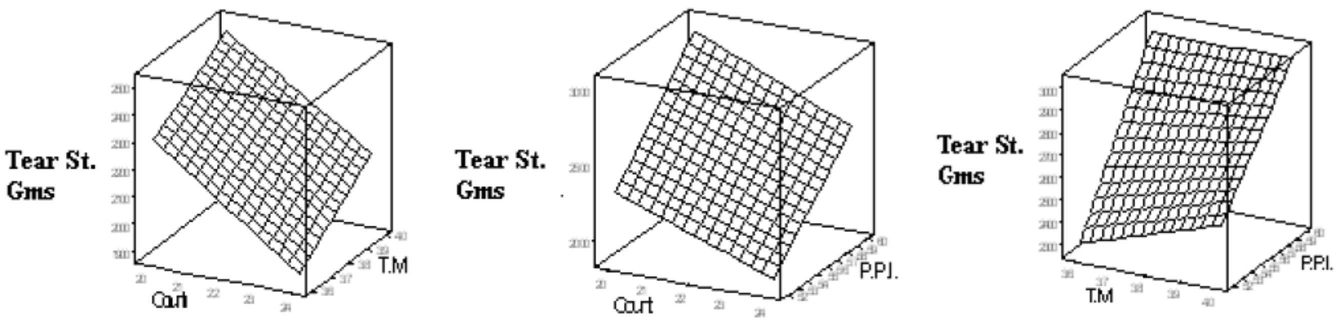

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Figure 5. Response surface plot of tearing strenght of fabric in weft direction (weft; rotor yarn).

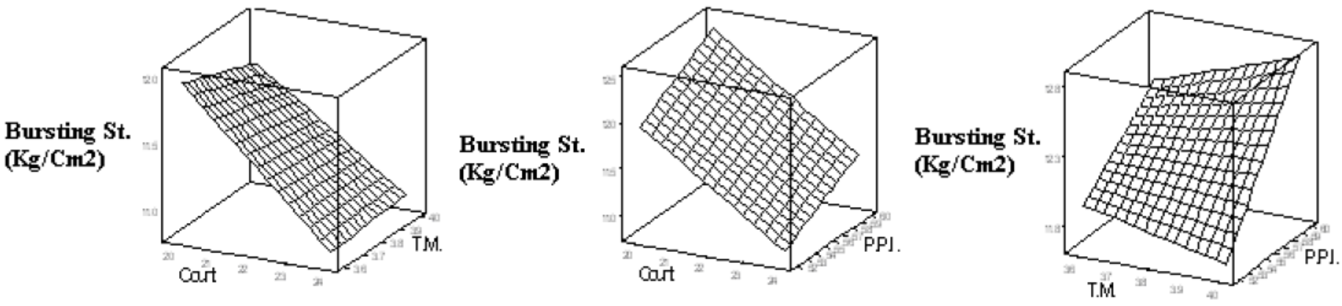

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Figure 6. Response surface plot of bursting strenght of fabric in weft direction (weft; ring yarn).

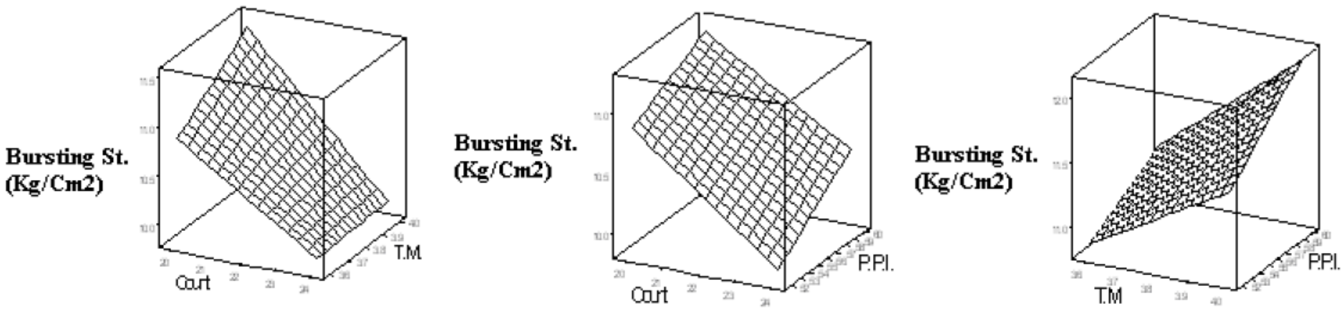

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Figure 7. Response surface plot of bursting strenght of fabric in weft direction (weft; rotor yarn).

of the two yarns, the difference was not so appreciable in the case of tensile strength and bursting strength of the fabric for the common warp yarn seemed to reduce or camouflage the effect to a greater extent. Only in the case of tear strength, the difference was significant as to truly affect the performance of the fabric.

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