IMPACT PROPERTIES OF TEXTILE YARNS
I. COTTON YARNS

BY

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1. ABSTRACT

In the present investigation the work of rupture of some ring spun and open end cotton yarns when subjected to impactload has been examined using a single pendulum apparatus. The results obtained for the yarns under consideration have shown that open end yarn is inferior to ring spun yarn of the same fibre and yarn variables with respect to energy absorption. This was not only in the dry state but also in the wet state. Also it was found for both types of yarns, that heat and humidity have a remarkable effect on energy absorption, the former has a decreasing effect while the latter has an increasing effect.

2. REVIEW OF LITERATURE

The literature of the phenomenon of impact of textile materials shows that the study of this phenomenon is not recent, but goes back to 1910.
The early investigations concentrated on building instruments for measuring the work of rupture of yarns by methods rapid than that slow conventional ones, i.e. single end and lea end methods.

In 1910 Lester[2] described a gravitational method for measuring the work of rupture of cotton sewing threads, using a falling pendulum to which one end of the specimen was attached. In his conclusions he mentioned that the ballistic test gives the amount of resistance of yarns to the schocks of weaving, and it gives the resistance of cloth to those strains which most commonly cause it to fail in use.

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However in these early investigations no attention was paid to the mechanism of yarn failure due to impact load, but attention was paid towards the finding of a substitute of the conventional single end, and lea strength methods, and to find out if there is a relationship between the results obtained by these methods and the pendulum method.

F.T.Pierce[3] puplished a series of papers in the tensile testing of fibres and yarns in which the role of the time factor (or rate of loading) was comprehensively explored. In the first paper the results of cotton fibres subjected to various rates of loading (g/sec) are given. This rate was varied over a 1000 fold range and the average velocity was of about 0.047 cm/sec. Also he found that the work of rupture is not exactly proportional to the length of the specimen. This result was ascribed to irregularity in strength along the yarn, the time required to stretch a yarn to rupture, and an energy factor. The weakest link theory was introduced to dascribe the results obtained.

From the above it is evident that little attention has been paid to the behaviour of textile materials (fibres, yarns, and fabrics) under impact load, especially for the new types of yarns produced by methods other than those conventional ones.

In many mechanical applications now a days textile materials are subjected to rates of straining that are many times greater than those encountered in ordinarly apparel or house hold uses. It has been estimated for instant that in a regular passenger car tire travelling at 80 kilometer/hour, the cords are repeatdly strained at rates that equivalent to sinsoidal frequencies in the order of hundreds of cycles per second. In terms of average extension, the rate approaches or may even exceed 100%/sec, depending on the constitution of the fabric and the conditions of use. Calculations indicates that in the brief interval before the opening of a military parachute the suspension lines are subjected to an average rate of sraining of about 250%/sec, with an attendant force of about 1000 kg.

Modern high speed stitching in the commercial manufacture of textile articles of all kinds, subjects the threads to impact velocities which may be quivalent to even greater rates of extension. Stone, Shiefer, and Fox[6] mentioned velocities ranging from 10m/sec imposed on thread as often as 5000 times per minute.

The importance of studying the impact properties oftextile materials is not only limited to the previously mentioned applications but there are other applications such as military articles, i.e. armor clothing, and climbing ropes which depend for their adequate performance on the ability of the component yarns to withstand the effect of shock loading.

The advent of air plane with the attendant high velocities (especially in the military operations) brough new and unprecedented problems in areas where textile structures were put to use. Air craft during landing are subjected to severe impact loading at the instant of touch down.

No doubt the military progress in thelast decade and the need of dropping large and huge equipments from air plane, and paratroopers, a ms, and supplies, made it necessary to develop the suspension of the parachute which will carry these loads to the ground. These has to be capable of absorbing the sudden load without failure. Also the parachute used in the deceleration of high speed air craft during landing. In addition to those mentioned, there are the industrial applications of textiles where impact behaviour is the crucial property, such as safety belts and lines used by construction workers, and the heavy ropes used in the marine and other industries.

3. Yarns Used in the Present Work

The specification of yarns used in the present investigation is given in Table (1). These yarns were from Egyptian cotton (Menufi) on a conventional ring spinning machinesand on BD-200 open end spinning machine.

Table (1): Specifications of Yarns Used

Ring spun yarns				Open end yarns			
Count	Twist factor			Count	Twist factor		
18s	5.0	5.5	-	18s	2.8	3.5	4.5
22s	4.5	5.0	5.5	22s	2.8	3.5	4.5
26s	4.5	5.0	5.5	24s	2.8	3.0	3.5

4. Apparatus Used for Measuring Work of Rupture of Yarn

The apparatus used in the present investigation for measuring the work of rupture of cotton yarns is that falling pendulum tester made by Goodbrand and, Ltd. company. It is a single pendulum apparatus and is used to measure the work of rupture of textile materials, i.e. fibres, yarns, and fabrics. The principle and the theory of the apparatus is given in Ref. 1. The average velocity of the pendulum at the time of impact is 0.047 cm/sec.

5. RESULTS

5.1 Effect of Number of Threads on Work of Rupture (Dry)

The effect of number of threads on the work of rupture of cotton yarns has been examined for 22s open end, and 22s ring spun yarn of the same fibre, and yarn variables. Skeins of 50cm long were made and tested in the dry state.

The values of work of rupture for the two mentioned yarns are plotted against the number of threads in Figs. 1, and 2. From the figures one may observe that the relationship is linear, and positive, i.e. as the number of threads increases the work of rupture increases. The correlation coefficient is very high and highly significant at the 5% level. The closseness of the points to the best fit line indicates the high regularity of both yarns.

Pierce[4] examined the effect of number of threads on the work of rupture of some ring spun yarns for number of threads ranging between 10 and 80 and found a similar relationship to that obtained

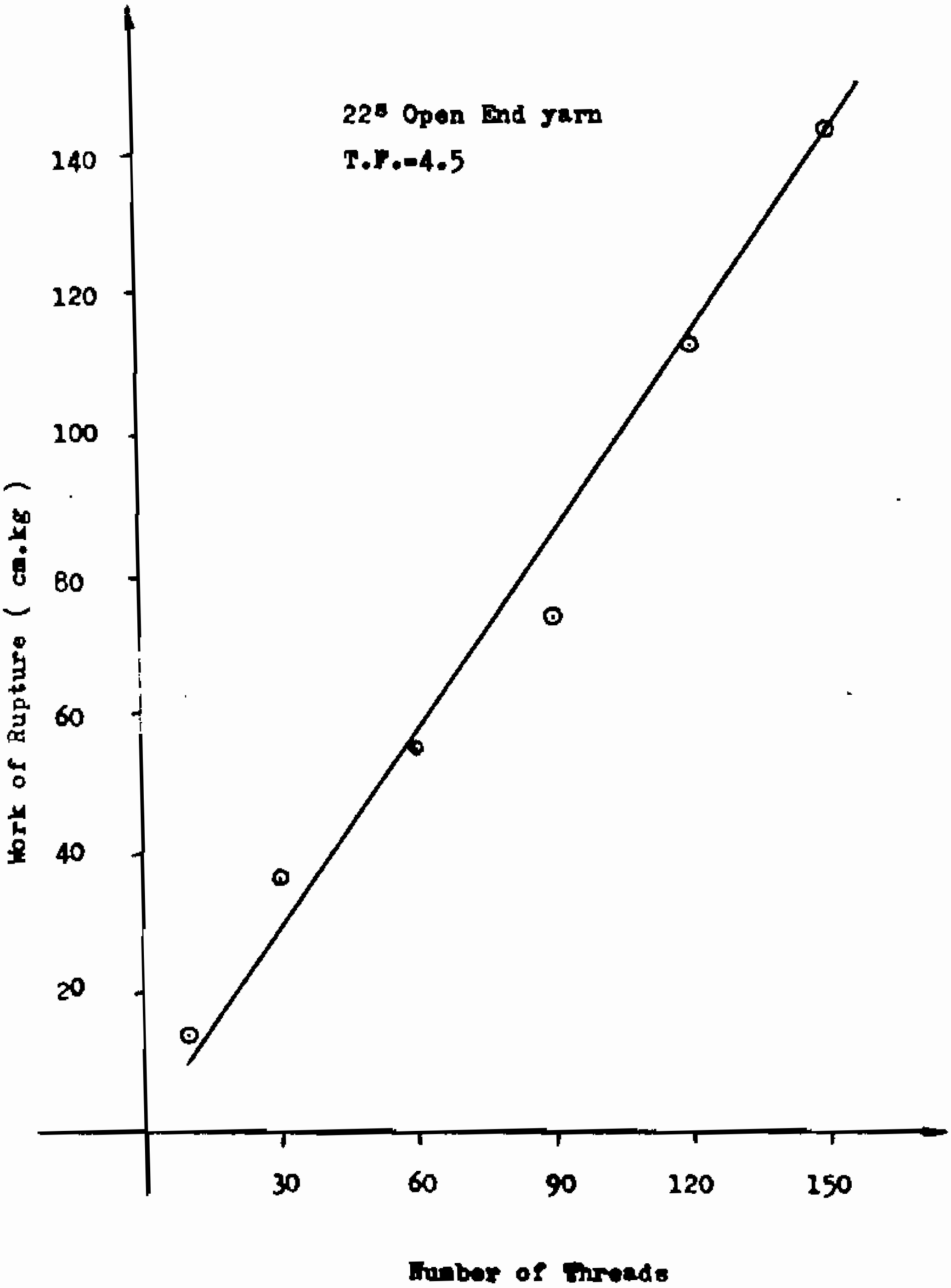

22^{s} Open End yarn
T.F.=4.5
140
120
100
80
60
40
20
Work of Rupture (cm.kg)
30
60
90
120
150
Number of Threads

Fig.1

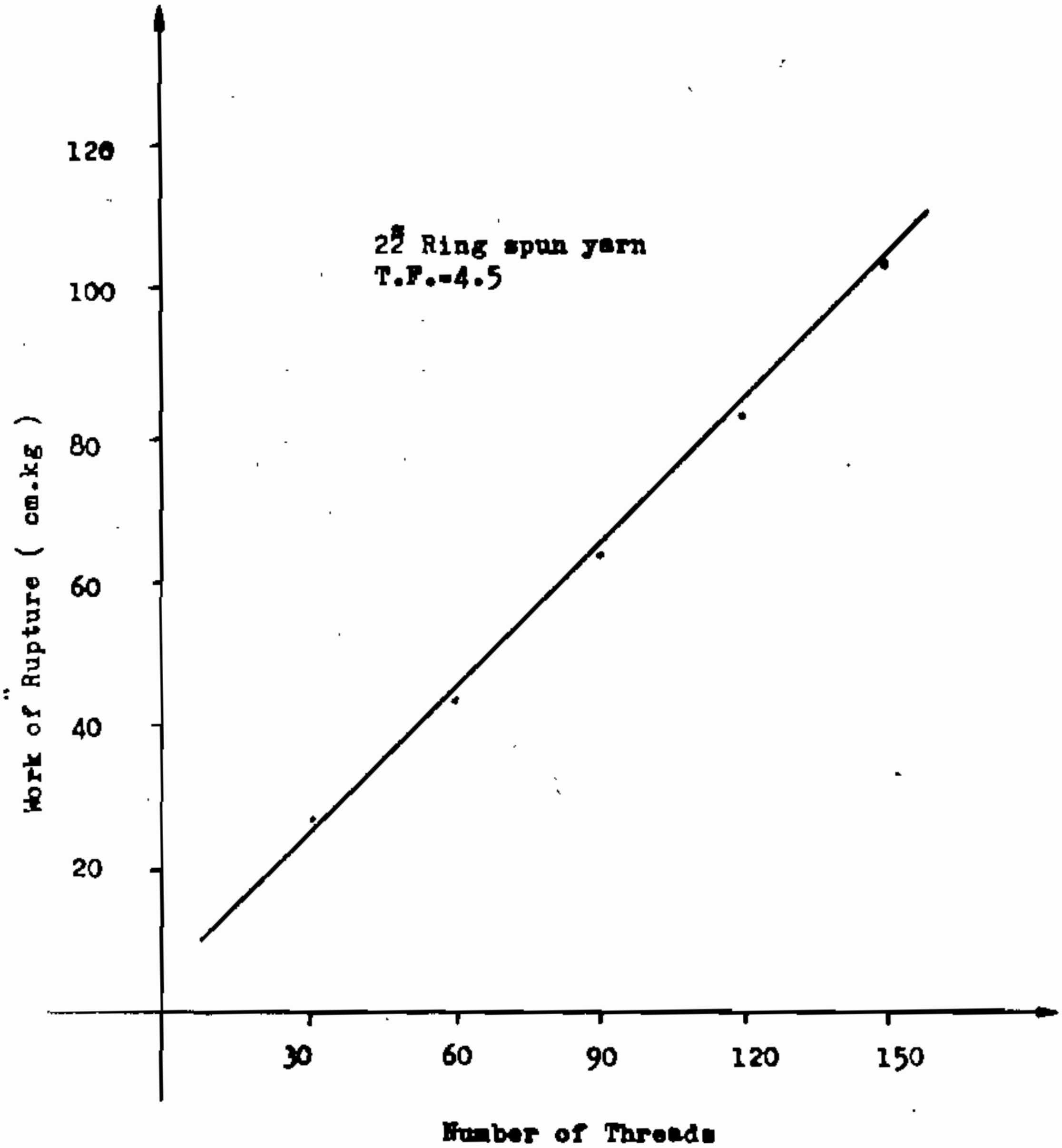

22 Ring spun yarn
T.F.=4.5
120
100
80
60
40
20
Work of Rupture (cm.kg)
30
60
90
120
150
Number of Threads

Fig.2

in the present investigation. In the present investigation the number of threads varied between 10, and 140. Beyond this number yarns did not break, and this seems to be the limit of the oapac-tyof the apparatus.

In fact the above finding concoerning the relationship between the number of threads and the work of rupture has its economical importance, from the point of view of testing skeins with low number of threads per skein, which gives the same average work of rupture as the large number of threads skeins. The observed small differences obtained in the present work between small number and large number of threads is due to sample variation.

5.2. Effect of Twist on Work of Rupture (Dry)

The average values of work of rupture of ring spun, and open end yarns used in the present study are given in Table 2. and plotted against the twist factor in Figs. 3 to 6.

Table (2): Values of Work of Rupture of Cotton Yarn (Dry)

Ring Spun			Open End		
Count	T.F.	W.R.	Count	T.F.	W.R.
18^s	2.8	36.0	18^s	5.0	44.8
	3.5	44.3		5.5	46.8
	4.5	51.4			
22^s	2.8	33.8	22^s	4.5	36.5
	3.5	34.9		5.0	36.9
	4.5	44.4		5.5	38.6
				6.0	32.3
24^s	2.8	25.0	26^s	4.5	25.8
	3.0	30.8		5.0	27.3
	3.5	32.5		5.5	25.3
				6.0	24.7

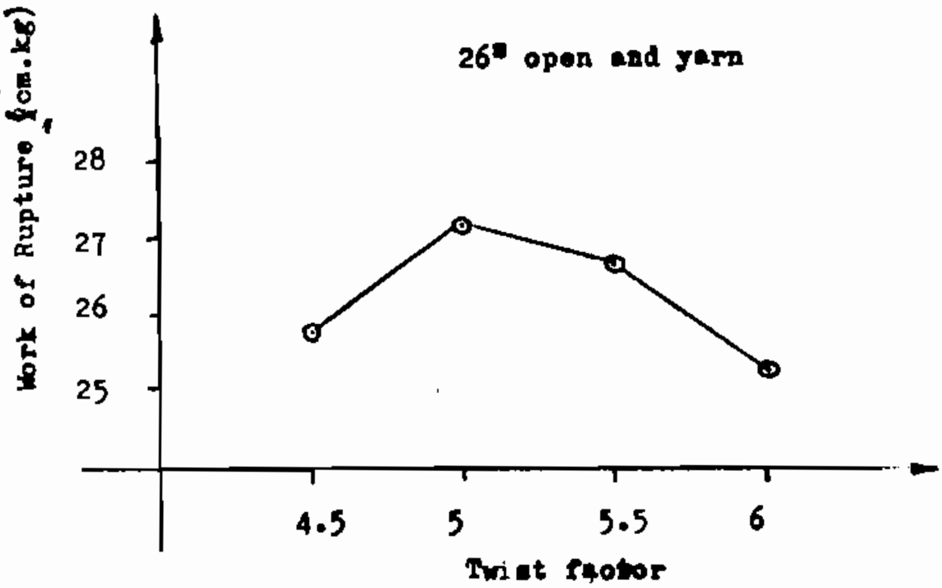

26s open and yarn
Work of Rupture (cm.kg)
28
27
26
25
4.5
5
5.5
6
Twist factor

Fig. 3

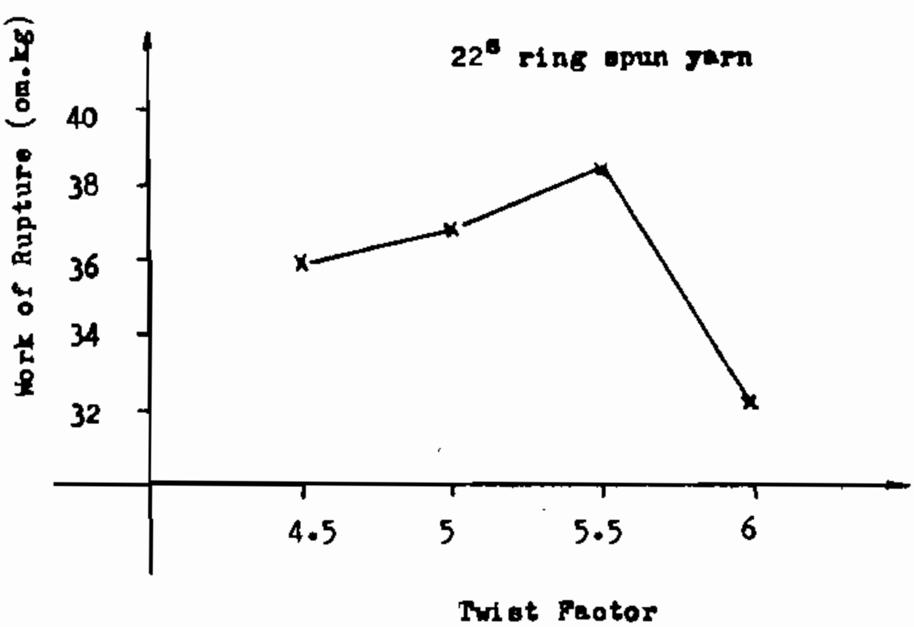

22s ring spun yarn
Work of Rupture (cm.kg)
40
38
36
34
32
4.5
5
5.5
6
Twist Factor

Fig. 4

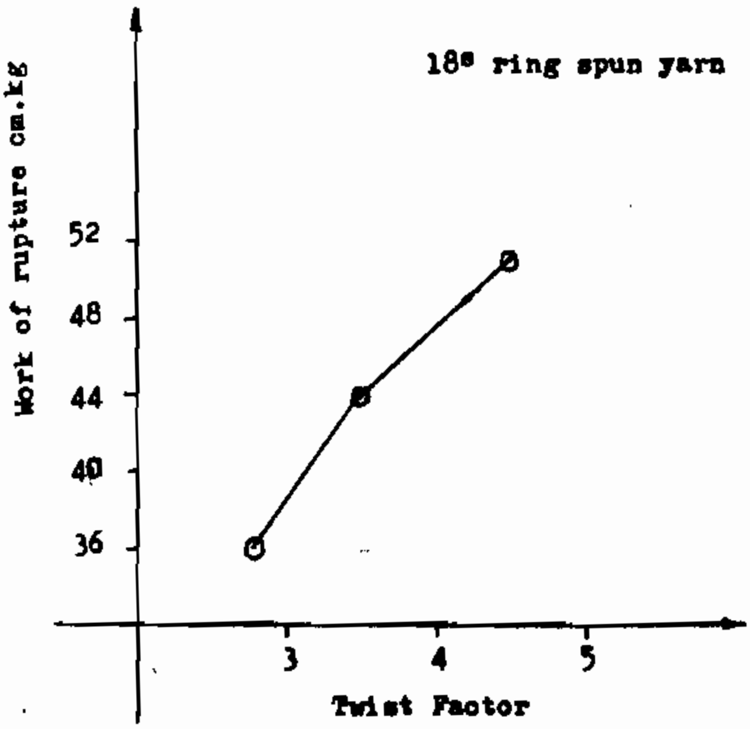

18s ring spun yarn
Work of rupture cm.kg
52
48
44
40
36
3
4
5
Twist Factor

Fig.5

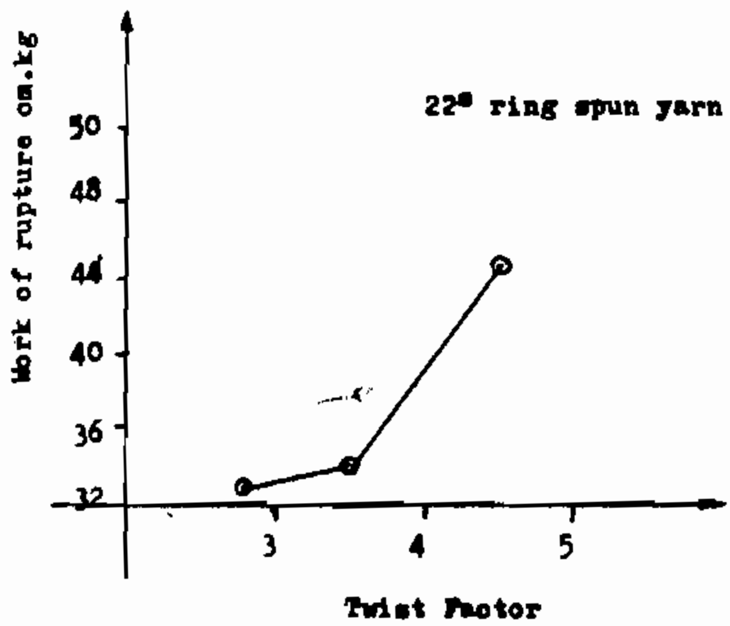

22s ring spun yarn
Work of rupture cm.kg
50
48
44
40
36
32
3
4
5
Twist Factor

Fig.6

From the values given in the table, and the plotts, one can observe that there is a general trend between the work of rupture and the twist factor for both ring spun and open end yarns. As the twist factor increases the work of rupture increases. For 22^s, and 26^s open end yarn this trend changes for twist factors ranging between 5, and 6. The work of rupture falls down, and the fall is considerable. Also from the values obtained it is evident for both yarns that, as the yarns gets finer the work of rupture decreases remarkably. For example, at a twist of 5.5 the drop in work of rupture for 22^s, and 26^s open end yarns was 19%, and 46% respectively, this is relative to the work of rupture of 18^s yarn of the same twist factor. From Table (2) there is another trend concerning the value of the work of rupture of ring spun, and open end yarns, and that is, in general, ring spun yarns have higher work of rupture than that of open end yarn. It is evident from the table also that even with high levels of twist factors the work of rupture values, for open end yarns are much less than that of ring spun yarns. The average difference is 20%.

5.3. Effect of wetting on Work of Rupture

The influence of immersing cotton skeins in water for various periods of time on work of rupture has been examined. The skeins were immersed loose in water for periods of time ranging between ½min, and 120 min, After this the skeins were removed and hydro-extracted, and fixed directly in its place in the ballistic tester. Given in Table 3, the average value of work of rupture (5 readings) for each period.

Table (3): Values of Work of Rupture of 26^s Wet Ring Spun Yarn (T.F. = 3.5).

Time of immersion (min)	Work of rupture (cm. kg)
½	47
30	49
60	51
90	52
120	53

From the table it is clear that the work of rupture of cotton yarn increases as the time of immersion increases. The increase at any of the above used periods of immersion is considerable compared with that obtained in the dry state (34 cm.kg).

Given in Table (4) the values of work of rupture of a 22^s ring spun, and open end yarn with various twist factors befors and after wetting.

Table (4): Values of Work of Rupture before and after Wetting.

Count	Type of yarn	T.F.	Work of rupture	
			Dry	Wet
22^s	ring spun	2.8	33.8	50.3
	"	3.5	34.9	51.3
	"	4.5	44.4	53.3
22^s	open end	4.5	36.5	41.5
	"	5.0	36.9	40.0
	"	5.5	38.8	39.3

From the table one may observe the remarkable increase in the work of rupture after wetting, for both ring spun and open end yarns, especially at low twist factors (Table 5), and that wet ring spun yarns (at 4.5 twist factor) have higher work of rupture, than that of open end yarns.

Table(5): Percentage Increase in Work of Rupture of 22^s cotton yarns after Wetting.

Type of Yarn	T.F.	% Increase
ring spun	2.8	48.8
	3.5	46.9
	4.5	19.9
open end	4.5	13.7
	5.0	8.4
	5.5	1.2

Also from Table (4)it is clear that the previously founded trend between work of rupture and twist factor in the dry state is also valid in the wet state, i.e. as the twist factor increases the work of rupture increases.

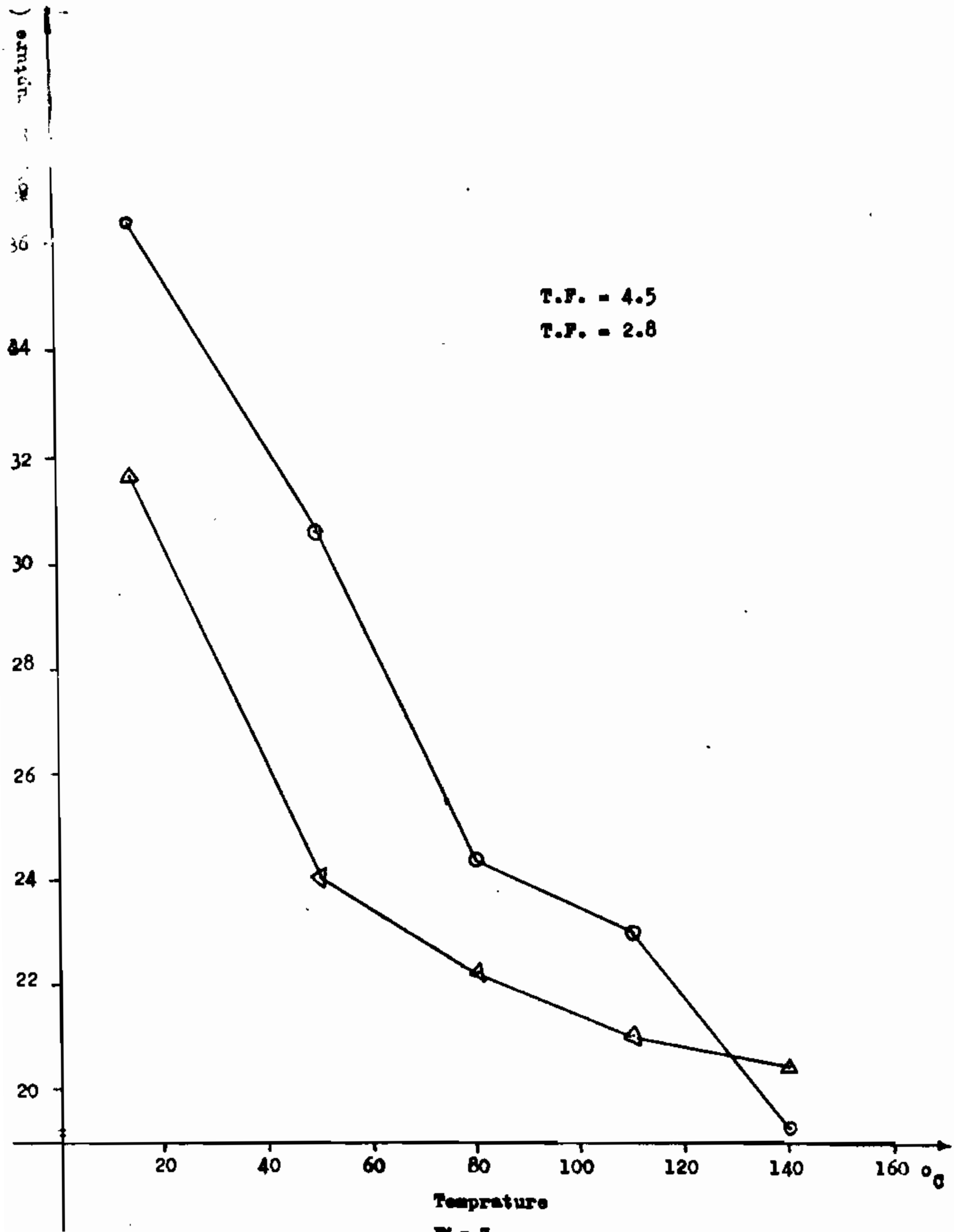
5.4. Effect of Heat on Work of Rupture

The effect of heat on the work of rupture of cotton yarns has been only examined for a 26^s ring spun yarn with two twist factors and namely 2.8, and 4.5. Skeins of 60 threads were made and exposed to tempratures ranging between 50°C, and 140°C. The skeins were left in a drying oven for ½ hr, after which the skeins were removed and tested directly by the ballistic tester. The average values (of 10 readings) of work of rupture of yarn used, at the various tempratures, are plotted in Fig.(7). Given in Table (6) the average values of work of rupture at the various tempratures, and the percentage drop in these values (relative to 18°C value) after exposing to heat.

Table (6): Values of Work of Rupture at Various Temperatures.

Count	T.F.	Temperature (°C)	W.R.	% drop
26^s	2.8	18	36.4	-
		50	30.65	15.8
		80	24.4	32.9
		110	23.05	36.7
		140	19.3	46.9
	4.5	18	31.65	-
		50	24.1	20.7
		80	22.25	29.7
		110	21.05	33.5
		140	20.5	35.2

From the table, and the figure it is evident that the work of rupture of cotton yarn is greatly affected by heat, and the



T.F. = 4.5
T.F. = 2.8
36
34
32
30
28
26
24
22
20
20
40
60
80
100
120
140
160 °C
Temprature

Fig.7

largest drop occurs between temperatures 18°C, and 80°C, for the twist factors under consideration. After 80°C and up to 140°C the drop although large but slow, compared with that occured between 18°C, and 80°C.

6. GENERAL DISCUSSION

The results obtained in the previous sections show that the work of rupture (or energy absorbed till rupture) of cotton yarns spun by the conventional, and the unconventional method, generally increases with the increase of twist factor. This trend reverses as the results of work of rupture have shown for open end yarn spun with wide range of twist factors. Also it was evident from the results obtained that, in general ring spun yarns have higher energy absorption than that of open end yarn of same fibre and yarn variables, when subjected to impact load. The difference in energy absorption reached in the average to 20%.

In fact the observed difference in the value of work of rupture of ring spun, and open end yarn, when subjected to impact load in the dry or wet state may be explained in the light of the differences found in the structure of both yarns.
Open end yarn contains many hooked fibres, and this fibre hooking does not always result in an interlocking structure that could cause the yarn coherent under external load. It is surprising to find out that the hooked fibres may reach half the number of population of fibre[7]. Accordingly the work of rupture is expected to be less than that of the highly arranged ring spun yarn. These hooked fibres will reduce the number of fibres sharing in carrying the strain generated at the impact point and that the fibres near theimpact point will carry on loads higher than their breaking load. This in turn will cause the fibres to reach to their full extension early, and this will result in low work of rupture.
It is also possible to explain the difference in energy absorption of ring spun and open end in the light of fibre packing, and fibre migration[7]. Fibre migration in open end yarn is less than that of

ring spun (1/6th). This is expected to affect work of rupture, since migration affects the degree of fibre interlocking within the yarn, which in turn would affect the property of the yarn, and among these properties is the work of rupture.
With respect to fibre packing, open end yarn is more open than ring spun yarn of the same count, and twist factor. Fibre pacing will affect internal friction between fibres inside the yarn, and this is expected to have its great influence in carrying the load between fibres, or on transmitting the strain from the point of impact to the tail of the yarn.

If one consider the strain wave generated at the time of impact as a sound wave, it would be possible to explain the observed differences found between ring spun, and open end, when subjected to impact load.
Consider the yarn a completely elastic material, and hence following Hooks law, then the strain wave generated at the time of impact may be cosidered as a sound wave. The propagation of the sound wave depends upon material modulus of elasticity (E), and material density (p). In other words the speed of propagation(c) of the strain wave depends on both (E), and (p). The speed of propagation (c) is proportional to the square root of the ratio E/p. This ratio is expected to be high for ring spun yarn than for open end yarn of same fibre, and yarn variables. Accordingly the strain wave will travel faster in the former, and hence the speed (c) will be higher. It is known that the load generated at the point of impact will be higher for higher values of (c), and vice versa. This will explain the higher values of work of rupture obtained for ring spun yarns. It was observed during the impact test that the time of rupture is less for ring spun, than for open end. This explain the previously mentioned point concerning the time of propagation of the strain wave from the point of impact to the tail of the yarn.

With respect to the effect of wetting on work of rupture, it was evident from the results, that water has a remarkable effect on the work of rupture of cotton yarns, irrespective of the method used in producing this yarn. The general increase in work of rupture after wetting for ring spun, and open end yarns is due to the increase in both breaking load, and elongation of these yarns. Also it is due to the increase of friction because of fibre swelling. The increase of friction between fibres will increase fibre cohesion along the length of yarn tested. Therefore the load generated at the point of impact will be distributed over a large number of fibres along the yarn length. As a result of this the resistance of the structure as a whole will increase, and hence will increase the work of rupture (or energy absorption).

The results obtained for the work of rupture of wet ring spun, and wet open end yarns (Table 5) show two trends concerning the tendency of the percentage increase in energy absorption after wetting. The first common trend is that the highest percentage increase in work of rupture occurred at low twist factors. Secondly that the percentage increase in work of rupture is considerably higher for ring spun yarns (at twist factor 4.5), than for open end yarns.

In fact this difference in behaviour of ring spun, and open end yarn when wet may be explained in the light of the possible effect of water on the response of the structure to water, and consequently on carrying the load generated at the time of impact. It seems that at high levels of twist, water will not penetrate much inside the yarn, and hence swelling would not cause much increase in internal friction between fibres. As a result of thie the work of rupture is expected not to increase much (compared with that obtained before wetting). At low twist factor levels it seems that water works as a lubricant, which facilitates fibre slippage, rather than fibre failure. The porous nature of the open end yarn reflected itself on the very slight increase in the work of rupture when wet.

With respect to the effect of heat on the ability of cotton yarn to energy absorption, it is evident from the results obtained, that, heat had a reverse effect to water, i.e. the work of rupture droped considerably as the temperature increased. As temperature increassd the percentage drop in work of rupture increased and reached its maximum value at 140°C. This trend could be explained in the light of the fact that, as temperature increases the moisture regain decreases. This will reduce internal friction between fibres (also yarn elongation decreases by drying). The reduction in friction between fibres will lead to more fibre slippage rather than getting use of fibre strength when subjected to impact load. Add to this the loss in elongation, hence the work of rupture will drop considerably.

7. CONCLUSIONS

1) For strands of cotton yarns (ring spun, and open end) subjected to impact load the work of rupture varies linearly with the number of threads in the strand.

2) The work of rupture increases with the increase of twist factor, and reaches a maximum then falls down.

3) Open end yarn is inferior from the point of view of energy absorption to ring spun yarn of the same fibre, and yarn variables.

4) The work of rupture of open end, and ring spun yarn increases by wetting. The largest percentage inorease for both oocurs at low twist factors.

5) Heat has a considerable effect in the work of rupture of cotton yarn. As the temperature increases the work of rupture decreases.

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