PROCESSING AND PROPERTIES OF YARN AND FABRICS FROM TEXTILE PRODUCTION WASTES

ABSTRACT

Textile production wastes are undesirable but inevitable by-products in any manufacturing process (spinning, weaving or knitting) and are frequently undervalued. However, if one can convert such wastes into useful product economically, there will be great contribution to the market. In the present investigation, therefore, torn-out garments were firstly cut, then opened and carded. The carded slivers were afterwards fed into the Dref 2 Machine, and yarns were spun at different card cylinder and perforated spinning drum speeds. Testing on the yarns and fabrics were then carried out to evaluate their performance.

1. Introduction

Textile production wastes cover all those raw materials which are either accruing or being used in the textile industry such as production remnants, wastes from fibre and filament manufacture, cotton linters, wastes from spinning, weaving, knitting and making-up as well as reprocessed materials.

Textile production wastes fall into three categories : (1) trashy waste - waste which requires cleaning before reprocessing, examples are blowroom wastes, carding waste, card flat strips and filter waste; (2) clean waste - waste which requires no further cleaning, examples are comber waste, card, drawframe and combed sliver waste, filter waste from drawframes, speed frames, ring spinning frames and rotor spinning machines; (3) hard waste - waste which requires opening on special machines, examples are twisted rovings, yarns, and textile fabrics (woven rags and knitted rags).

In the past, waste produced during the manufacturing processes (spinning, weaving and knitting) was normally collected and sold to the waste spinner for relatively low prices. Certain blending of wastes with good materials was necessary in order to upgrade the quality of waste yarns produced and prevent excessive end breakage rate during spinning.

The production of waste yarns by the waste spinners was traditionally carried out by condenser spinning in which the material was processed through a card incorporating workers and strippers and condenser bobbins to produce slubbings. The slubbings were then ring-spun onto large tubes using a low draft and the yarns produced were rewound onto bobbin. It was usual to add 3 to 8% oil or soap to ensure sufficient inter-fibre cohesion for drafting and to produce yarns in the range of 60-20 tex at a production speed of 13 to I Sm/min1.

However, most fibres recovered from waste materials have a very short staple length and thus, the ring drafting system cannot be set with the roller close enough to control the number of "floating fibres" in the waste materials. Therefore, the spinning of wastes by ring system would produce yarns with drafting waves. Besides, the production speed is low in order to reduce yarn breakage rate. Up to now, these problems cannot be solved satisfactorily.

Eventually, with the advent of rotor spinning, the waste spinners were quick to realise its potential and capability of handling fibres having a wide range of micronaire values and lengths at production rates 8 times higher that of condenser spinning. However, this spinning system requires good preparation of feeding material. The slivers fed into the rotor machine must have good evenness which means that the slivers must be drawn or autolevelled before spinning. Furthermore the system requires high cleanliness of material fed. The cleaning cost, incorporating with the drawing cost, makes the system uneconomical for processing such textile wastes.

However, it seems that the introduction of Friction Spinning (Dref system) can solve the problem. The system is versatile and insensible to fibre length and type, so it can reprocess the textile wastes without any difficulties. Besides, one of its advantages over the rotor system is that it eliminates the preparation process. Only carded sliver is required for feeding into the machine. Moreover, due to the self-cleaning effect of the system, it permits certain impurities in the raw material.

In view of the above, the present work was carried out to investigate the reprocessing of textile production wastes through the Dref 2 system. With the results of this work, it is hoped that more waste spinners would reprocess their wastes through the Dref system. 2. Experimentation

(1) Introduction

The experimental work comprised opening of torn-out garments, followed by carding, spinning on Dref 2 machine, steaming of Dref 2 spun yarns, evaluation of Dref 2 spun yarns, and weaving of Dref 2 spun yarns (as weft-insertion yarns) to produce woven fabrics of weaves 2/2 and 3/1 twills. Im -

(2) Opening of raw materials (torn-out garments)

(a) Machine specification :

Machine used	:	Rag puller
Speed	:	1070 rev/min. (spiked beater)
Diameter	:	20 inches (spiked beater)
Feed area	:	36 x 9 inches^2
Wire density	:	4 wires per inch
Wire length	:	1.5 cm long

(b) Practical description :
The raw materials used were torn-out garments supplied by the International Wool Secretariat (Hong Kong Office). They were first cut into strip-form of dimensions 1.5 x 2 inches. Then, the strips were distributed evenly on the feed lattice. As the strips were delivered by means of feed roller, the torn-out garment strips were torn-off by the high speed spiked beater. The fibres produced were collected at the container while the unfilled-opened strips were collected at the separator for re-processing.

L(F3) Carding of fibres .
Machine specification :
Machine used : BEFAMA Woollen Carder - Poland

Machine setting :

Working parts	Diameter	Rev/min.
Main cylinder	80 cm	100
Doffer	45 cm	5.8
Workers	12.8 cm	6.5
Strippers	5.8 cm	334
Fancy roller	28 cm	585

(4} Spinning on the Dref 2 machine

(a) Machine specification:

Machine used	:	DREF 2
Inlet speed	:	0 - 6 m/min.
Outlet speed	:	0 - 300 m/min.
Spinning drum speed	:	0 - 4500 rev/min.
Carding drum speed	:	2850, 3400, 3800 rev/min.

(b) Practical description:
Three carded slivers each weighted 5 g/m (5 Ktex) were fed into the inlet aggregated of the Dref machine. In order to produce yarns of linear density 150 tex, a draft of 100 was required. This was done by setting the inlet speed and outlet speed at 1 m/min. and 100 m/min. respectively. Besides, nylon filament of linear density 70 dtex was used as core to strengthen the yarns produced. Twelve types of yarns were produced with different carding drum speeds and spinning drum speeds, details were given in Table 1.

Yarn Name	Carding drum speed (rev/min.)	Spinning drum speed (rev/min.)
A1	2850	1500
A2	2850	2000
A3	2850	2500
A4	2850	3000
B1	3400	1500
B2	3400	2000
B3	3400	2500
B4	3400	3000
C1	3800	1500
C2	3800	2000
C3	3800	2500
C4	3800	3000

Table 1. Specification of yarns

Steaming of the yarns at 130℃ for one hour was the n followed in order to stabilize the yarns. IV
Testing on yarnDref 2 yarns spun with different carding drum and spinning drum speeds were tested to evaluate their yarn strength, elongation at break, hairiness and evenness.Testing of yarn strength carried out on the twelve types of Dref yarns revealed that the yarn with spinning drum speed 2000 rev/min. and carding drum speed 2850 rev/min. had the highest yarn strength. So, the just-mentioned yarn was chosen as weft-insertion yarn to feed on the weaving loom.
(6} Weaving on Rapier loom

(a) Machine specification:

Machine used	:	Picanol PGW Rapier Loom
Shedding motion	:	Staubli Positive Dobby
Speed	:	240 p.p.m.
Number of ends	:	4350
Warp length	:	180 m
Reed count	:	40

(b) Practical description:
The Dref yarn with highest tensile strength was used as the weft-insertion yarn to produce fabrics of weaves 2/2 and 3/1 twills. The warp yarns used were supplied by the weaving workshop. The fabric specification was given in Table 2.

	Fabric A	Fabric B
Weave :	2/2 twill	3/1 twill
Warp yarn :	Cotton (30 tex)	Cotton (30 tex)
Weft density :	80 ends/inch	80 ends/inch
Weft yarn :	Dref (150 tex)	Dref (150 tex)
Weft density :	25 picks/inch	25 picks/inch
Fabric weight :	242 g/m	242 g/m

Table 2 Fabric specification

Testing on woven fabricsTests were carried out the 2/2 and 3/1 twill woven fabrics to evaluate their abrasion resistance and tensile strength.

Results and discussion

(]) Amount of twist and spinning drum speed

Like other unconventional spinning methods, the twist imparted on the Dref yarn could hardly be determined by the testing method as that in the ring-spun. However, approximation is possible based on the production variables. The amount of twist on the Dref yarn is approximately given by the equation1 as below:

$$\text{Tuns/unit length} = \frac{\text{Spinning drum diameter x R.P.M. of durm}}{\text{Yarn diameter x Delivery speed}}$$

During the yarn production, the yarn diameter, delivery speed and diameter of spinning drum were kept constant, so that the twist imparted on the yarn is directly proportional to the spinning drum speed.

(+►2} (+►2} Yarn countThe yarn count, in tex, is given by the equation:

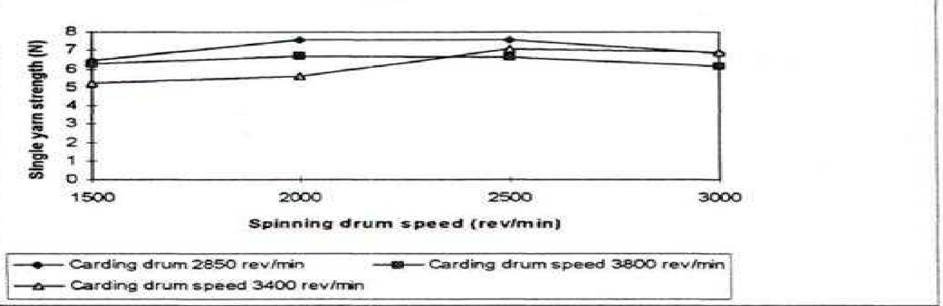
$$\text{Yarn count} = \frac{\text{Inlet speed (min/m) x Sliver weight (g/m)}}{\text{Outlet speed (m/min)}}$$

From the equation, it is seen that by varying the inlet speed and outlet speed, the yarn count can be changed easily and quickly when compared with the ring-spinning system which requires changing of gears.

Yam strength

From Figure 1, it is found that, for each carding drum speed, the yarn strength increases as the spinning drum/twist amount increases. However, when the yam reaches its highest strength, further increasing in drum speed causes decrease in yarn strength.

FIG.1. Yarn strength Vs Spinning drum speed

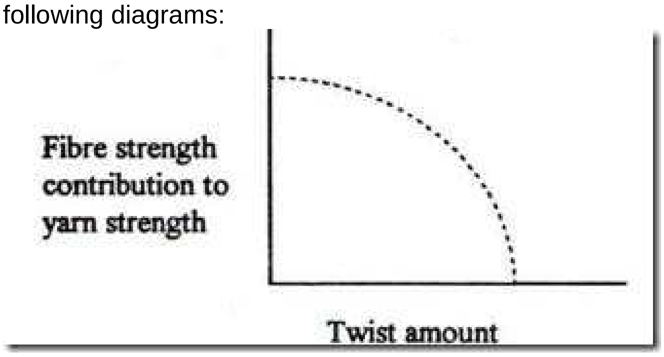


The strength of the yams depends on two principles factors - the fibre strength and the frictional resistance to slippage2.

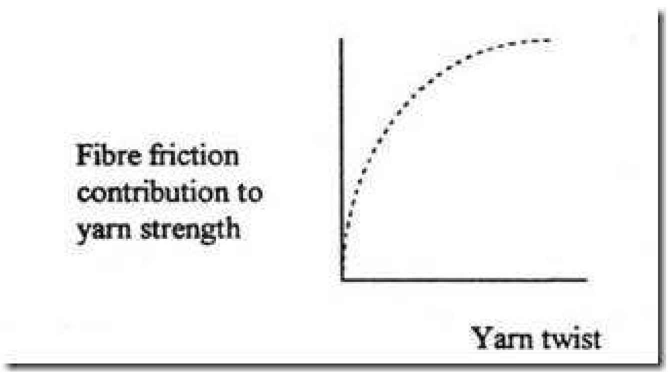
Sample	Tenacity (N)	CV%	Extension (%)	CV%
A1	6.49	6.60	19.77	12.24
A2	7.55	7.69	15.13	17.77
A3	7.54	7.43	15.59	15.09
A4	6.82	5.31	17.59	14.53
B1	5.25	9.25	22.05	15.53
B2	5.57	11.08	21.64	11.37
B3	7.09	7.11	15.57	15.32
B4	6.88	6.28	14.20	16.75
C1	6.25	8.02	20.23	10.32
C2	6.72	7.39	18.35	11.49
C3	6.63	6.41	16.25	12.47
C4	6.15	7.06	13.27	10.35

Table 3 Yarn strength and Extension at break

As the yarn twist is increased, the angle of fibre inclination (angle between fibre axis and yarn axis) increases and, therefore, the component offibre strength in the direction of the yarn axis decreases. Hence, the fibre strength contribution to yarn strength decreases as twist increases, and this relationship is illustrated in the following diagrams:



On the other hand, as yarn twist is increased, the frictional resistance between the fibres gradually increases until a point is reached at which slippage is virtually impossible. The relationship is illustrated in the diagram below:



The effect of twist/spinning drum speed on the strength of dref yarns is, therefore, determined by a combination of the two effects just described above, and the resulting relationship is as illustrated in Figure 1.

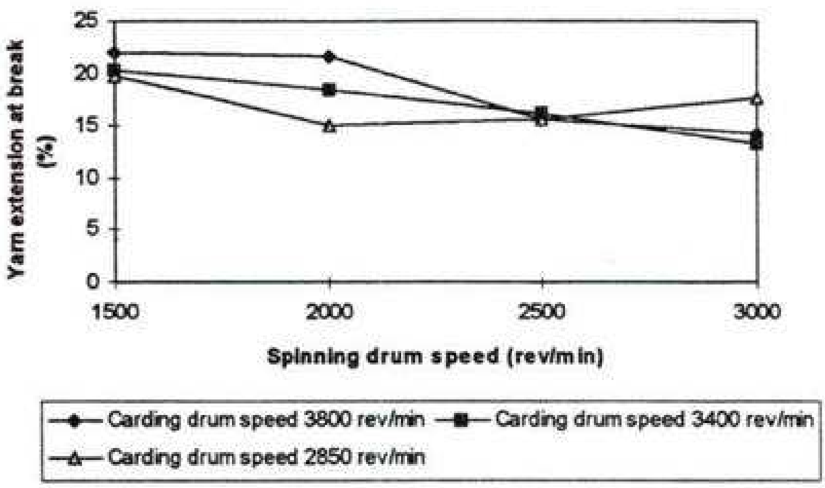
It is found that the pattern of variation of strength with twist amount in Dref yarn is similar to that in thering-spunyarn.

Besides, from Figure 1, it is found that the higher the carding drum speed, the weaker the yarn is produced. Although higher carding drum speed can result in better individualization of fibres in the fed sliver, it certainly causes much breakage of fibres due to excessive carding action, thus resulting in decreasing yarn strength.

Yarn extension at break

From Figure 2, it can be seen that as the spinning drum speed/twist increases, the extensibility of the yarn decreases. Besides, it is shown that variation of carding drum speed does not influence the extension value very much.

FIG.2. Yarn extension Vs Spinning drum speed



In order to explain the phenomenon, comparisons are now made on the strength and extension values between nylon filament core, Dref yam with core and Dref without core.

	Dref (150 tex)	
	without core	with core *
Extension value (%)	5	15.13
Tenacity (N)	3	7.29

* Nylon core (78 dtex) with extension value of 27% and tenacity of 4 N.

From the above Table, it is seen that the nylon filament core dominates the extension value of the dref yams. However, it is apparent that the insertion of twist restrains the extensibility of the core. As the twist amount is increased, thefibresbecome so closely packed to one another that the overall adhesion (friction resistance) of thefibresto the core increases, resulting in the decreasing extensibility of the core. The higher the twist, the higher is thefrictionalresistance to the core.

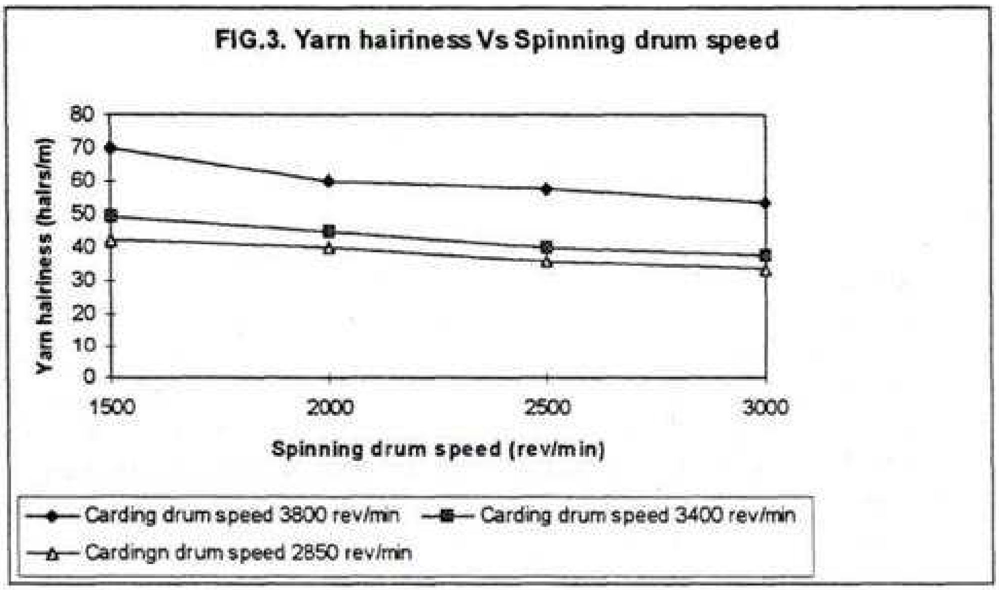
Role offilamentcore in the Dref Yam

The Dref yam produced, in fact, is a type of core-spun yams which are produced by twisting a fibrous sheath round a continuous filament or a spun thread which forms a core for the composite yam. In the present work, the core used was nylonfilament(78 tex) with strength 4 N and extension at break value 27%. The introduction of filament core in the Dref yam is very important as the former enhances the yam strength and dominates the extensibility of the yam produced.

(6} Yarn hairiness

Yarn hairiness has been observed subjectively and assessed for many years as it is one of the main properties affecting the fabric appearance and comfortability. In the spun silk and cotton trades, yarns may be singed to remove protruding fibres in order to provide a smoother yarn with added luster, and in some worsted and mohair yarns, hairiness may be a nuisance.

Based on the above reasons, it was thus decided in the present work to investigate the hairiness of the Dref yarns produced.



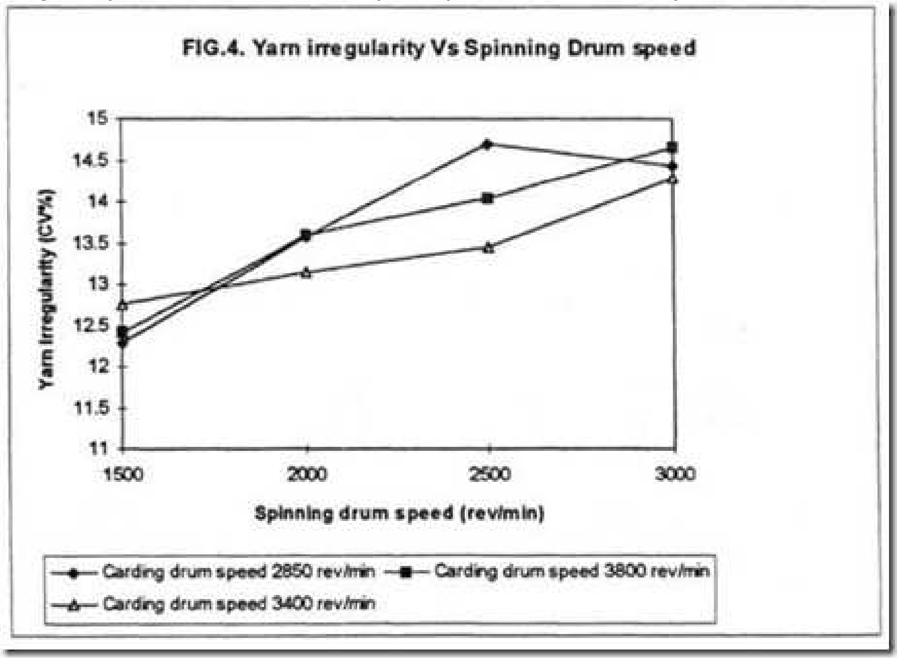
From Figure 3, it is observed that:
(a) For a constant carding drum speed, an increase in spinning drum speed/twist amount causes decrease in hairiness.
(b) For a constant spinning drum speed, an increase in carding drum speed causes increases in yarn hairiness.
As the spinning drum speed increases, the frictional resistance between fibres increases, so the tendency for the fibres protruding from the yarn surface decreases.
On the other hand, higher carding drum speed causes much breakage of fibres and therefore the percentage of the short fibres in the yarn increases. As a result, yarn hairiness increases.
Besides, the other factors which affect the hairiness of the Dref yarns include fibre length, fibre fineness, number of fibres in the yarn cross-section, yarn count, as well as fibre torsional rigidity, flexural rigidity and diameter3.

Sample	Hairiness (hairs/m)	CV%
A1	42.52	7.87
A2	39.74	11.37
A3	36.12	8.28
A4	33.62	10.55
B1	49.44	7.71
B2	44.60	9.10
B3	40.78	8.72
B4	37.52	8.27
C1	70.18	9.07
C2	60.17	12.15
C3	57.44	5.63
C4	53.58	6.26

Table 4 : Yarn Hairiness

Yarn irregularity and faults
All spun yams show a certain degree of irregularity and this is the factor which determines whether the yams are acceptable or not for a particular end-use. The appearance of many fabrics is influenced by yam irregularity

which is frequently regarded as one of the most important yam characteristics. Nevertheless, in some end-uses, such as industrial fabrics, interiinings, pile fabrics, and carpets, yam irregularity may be relatively less important, but long-term count variation may be important in order to control the total pile mass per unit area, the irregularity and faults of the Dref yams produced were analyzed as follows:



From Figure 4, it is found that when the spinning drum speed increases, the yarn irregularity (CV%) increases. Besides, the Figure shows that carding drum speed contributes little influence on the CV% value.

As the spinning drum speed/twist increases, the mean yarn volume decreases, making the yarn more sensitive to the change of volume (unevenness). Thus, a higher CV% results when compared with yarns of same count, but larger volume/lower twist level.

Furthermore, when we consider the fault frequencies of Dref yarns in Table 5, it is found that, for all yarns produced, there is a tendency that the frequencies of thick and nep places' occurrence is higher than that of the thin places. This may be due to the presence of entangled fibres, neps, wastes in the slivers which cannot be opened completely by the action of the carding drums.

Sample	Irregularity (CV%)	Thick place (1 Km)	Think place (1Km)	Neps
A1	12.29	10	0	20
A2	13.57	15	0	30
A3	14.69	25	4	26
A4	14.43	90	20	30
B1	12.75	25	5	35
B2	13.15	40	10	7
B3	13.45	30	15	0
B4	14.28	50	11	19
C1	12.40	50	11	19
C2	13.59	3	28	5
C3	14.05	17	33	23
C4	14.65	25	70	43

Table 5 : Yarn irregularity and imperfection

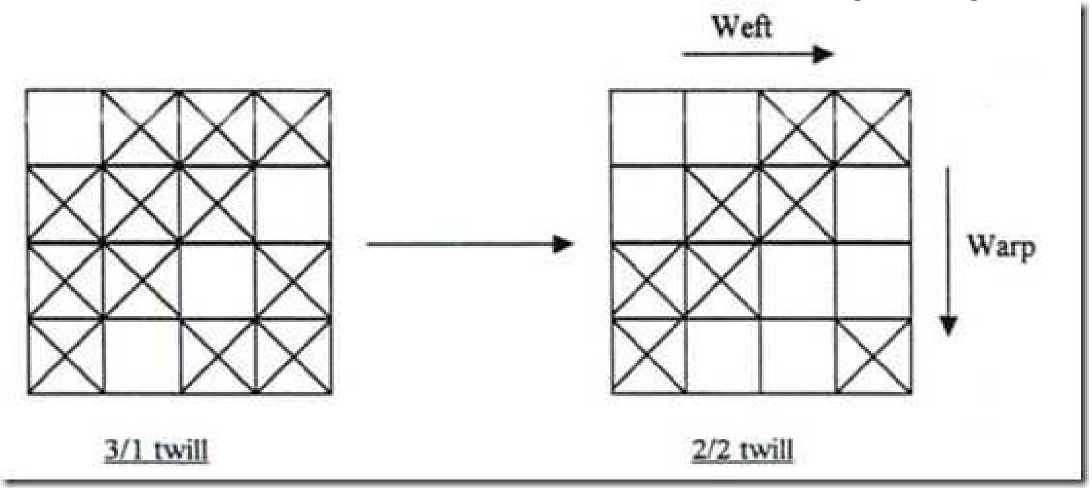
Fabric tensile strength and extensibility

From Table 6, it is found that the fabric with weave 3/1 twill has a higher tensile strength than the one with weave 2/2 twill.

Fabric	Tensile strength	CV%	Extension (%)	CV%
2/2 twill	24.65 Kg	4.49	28.25	2.25
3/1 twill	30.75 Kg	5.27	27.40	3.53

Table 6 : Fabric tensile strength and extension at break

Clearly, the strength of the fabric strip is mainly determined by the strength of the individual threads and the number of threads per unit length. However, a simple calculation based on these quantities might be in error by as much as 20%, for it is found that the pressure of the warp and weft yarns on each other may increase the fibre bonding and hence the strength of the yarns. Other effects such as the support of weak places in yarns by the neighboring threads are also important. Besides, the factors that contribute cloth strength is the weave. Thefirms,closely bound weaves such as plain, simple twill and mats are stronger than the looser weaves such as the satin.
By comparing the basic structures of 2/2 twill and 3/1 twill, one may discover that, in the case of 3/1 twill, for every weft yam, there are three warps interlacing with the same weft whereas in the 2/2 twill, there are only two warps interlacing with the same weft. Thus, the overall pressure between warps and wefts in 3/1 twill is higher than that of 2/2 twill. So, it is this weave variation which accounts for the higher strength of the 3/1 twill fabric.



On the other hand, when we consider the fabric extensibility in weft direction, both weaves give satisfactory results as they give high extension at break values (28.25% for 2/2 twill, 27.4% for 3/1 twill) and low CV% (2.25% for 2/2 twill, 3.53% for 3/1 twill). The reason is due to the participation of nylon filament core which contributes most of the fabric extension value.
Its is interesting to point out that, by varying the core materials, fabrics with different extensibility but same appearance can be produced easily according to the field of application. The following table illustrates the extension values of various fibres5 which can be used as core materials: - ,

Fibre	Elongation at break %
Cotton	3-7
Flax	2.0
Silk	20
Wool	25
Acetate	25
Acrylic	20
Glass	3.1
Modacrylic	30 - 60
Nylon	16
Olefin	10 - 45
Polyester	40 - 45
Rayon	15
Rubber	500
Spandex	400 - 700

When compared with knitted fabrics, one of the drawbacks of woven fabrics is their low extensibility. It seems that the application of dref yarns in woven industry can solve the problem. By choosing elastic materials (rubber, spandex) as core materials, stretch fabrics with extra high elasticity and extensibility can be produced to compete with the knitwear market.

Fabric abrasion resistance

A durable textile product should last an adequate period of time for its end use. Durability properties can be tested in the laboratory, but laboratory results do not always accurately predict performance during actual use. One of the main durability properties of a fabric is its abrasion resistance. Abrasion can occur when the fabric is fairly flat - as when the knees of jeans scrapes along a cement side-walk. Edge abrasion can occur when the fabric is folded - as when the bottom of a drapery fabric rubs against a carpet. Flex abrasion can occur when the fabric is moving and bending - as in shoes-laces that wear out where they are laced through the shoes. From Table 7, it is found that the resistance to flexing and abrasion in 2/2 twill is greater than that of 3/1 twill. The variation is due to the weave difference between the two fabrics. In explaining the difference, it must be emphasized that, in the testing, only the back sides of the two fabrics were abraded.

4. Conclusion

Although the Dref system is capable of handling all types of materials with different fibre length and denier, it is suggested that sorting of raw materials (e.g. torn out garments) to the same kind is advantageous to produce yarns with acceptable quality. Besjdes^injthe cutting
process of torn-out garments, it should be noted that the size of strips cut plays an important role in the quality of the waste fibres produced. If the size of strips is too small there will be much breakage of fibres.

On the other hand, larger size of strips will make opening difficult and more opening cycles of the rag puller are required to producefibreswith longer staple length.

When we consider the qualities of the Dref yarns produced, it was found that the machine settings (carding drum speed and spinning drum speed) affect the qualities of the yarns produced. High carding drum speed tends to produce yarns with weaker strength and more hairs as it causes considerable breakage of fibres. However, when dealing with hard wastes such as selvedges, high carding speed is necessary to ensure sufficient opening.

The role of spinning drum speed is its control on yarn appearance and physical properties. High spinning speed will produce yarns with harsh handle and less hairs. In addition, it increases the snarling of the yarns due to more twist insertion. The high liveliness of Dref yarns makes them unsuitable for knitting purpose. To counteract this effect, it seems that low spinning speed is advisable. However, this decreases the yarn strength and abrasion resistance. The snarling of the yarn is nevertheless improved by steaming treatment.

In general, satisfactory result is obtained in the Dref yarns as the weft-insertion yarns. In the weaving process, the mounting of the yarns by the rapier-head helped to decrease the snarling effect of the yarns. Moreover, it was found that the weft strength of the fabrics is determined by the yarn strength and weave structure. The 3/1 twill exhibited a higher value than the 2/2 twill. However, the flex abrasion resistance of both weaves were poor and could be improved by using yarn of higher twist, but this would decrease the fabric strength and so

compromises should be made.
As the raw materials used are wastes, the fabrics produced, of course, belong to the class of "cheap fabrics" which are suggested to be used in the fields of cleaning cloth, wrapping cloth and covering fabric.
Due to the high end-breakage rate in producing fine yarns and poor evenness of these yarns, the Dref system is still unable to compete withring-spinningin producing yarns of fine count range for suiting and apparel purposes. The Dref system is nevertheless good enough to produce coarser yarns for industrial and upholstery uses.
It can be concluded that the Dref system has proven its capacity in recycling textile production wastes. Being at its developing stage, efforts are suggested to be concentrated on the developments of machine design, engineering and mechanism of the spinning technology to increase it acceptance by the market.