

TENSILE PROPERTIES OF COPPER CORE YARNS

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ABSTRACT

Having excellent permanent conductivity among all of its conductive fibers, metal wire exhibits electrostatic charging or discharging in various industrial processes because of friction, separation or conductivity between objects. In the electronics industry in particular, electronic product are becoming smaller, and are sensitive to sudden electrostatic discharging in the absence of a protecting device. The electrostatic discharge generates signal interference, resulting in malfunction or breakdown of the process, hence making electrostatic protection and electromagnetic shielding important. In this investigation, 84 tex copper core spun yarns with cotton and polyester sheaths of 179 tex, 118 tex, 98 tex and 84 tex were produced by Dref II friction spinning machines. In addition, 74 tex and 59 tex copper core yarns with cotton and polyester sheaths were produced by ring spinning frames with a core attachment device for electromagnetic shielding. The paper reports the effects of the process variables on tensile properties of the copper core yarns as well as the effects on core and sheath components. Such process parameters as speed of the spinning drum, the materials used for forming slivers for the sheaths, core materials and the yarn counts were changed to in order to investigate how the changes affect the tenacity of the sheath/core spun yarns with copper cores.

Keywords: copper core yarns, conductivity, electromagnetic shielding, electromagnetic waves, spinning drum.

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INTRODUCTION

People use electrical equipment more frequently as science and technology continue to develop, exposing them to different frequencies of electromagnetic waves. Many devices contribute to such exposure as cell phones in the frequencies of 900 and 1800MHz, microwave ovens of 2450 MHz, radar signal communication systems extending from 1 to 10,000 MHz, FM/AM radio broadcasts of 30-300 MHz and 300-3000 KHz, respectively. Cell phone use has been particularly widespread in recent years.

When electromagnetic waves get into an organism, they vibrate molecules to and generate heat. In the same way, when an electromagnetic wave enters human body, it vibrates body molecules, generates heat, and obstructs cell's DNA and RNA regeneration function. Furthermore, it induces abnormal chemical activities contributing to increases in leukemia and other forms of cancer. Injuries by the electromagnetic waves to the human body are of utmost concern to everyone.

With excellent conductivity, metal wires exhibit electrostatic charging and discharging in various industrial processes owing to friction, separation or conduction among various objects. In electronics industry, in particular, the products are becoming smaller, and are sensitive to sudden electrostatic discharging in the absence of a protection device. During the triboelectric charging of objects, induction and electrostatic charge on human body can generate electrostatic charge. For example, if an operator in the clean room is insulated, grounded and walks on the floor, then the electrostatic potential of voltage will be 1.5 _35kV. Such charging to a high electrostatic potential breaks down the electrical elements, components and facilities that are sensitive to electrostatic charge. The electrostatic discharge generates signal interference, resulting in malfunction function and breakdown of electric facilities. Therefore, electromagnetic shielding and electrostatic protection are important [1 – 3].

The commercial introduction of friction-spinning technology by Ernst Fehrer in the seventies renewed the interest of research workers in core yarns. In common with other systems of core-yarn production, DREF-II is able to produce filament core-spun yarns. In the DREF-III friction spinning system, in addition to the continuous filament, staple fibers can also be introduced into the core by feeding a sliver to the apron drafting system provided on the machine [4-6]. The DREF-III friction spinning machine has two drafting units: the first unit provides core fibers along the yarn axis and the second unit supplies sheath fibers at right angles to the spinning drum. Ray et al. [7] explained that fibers fed from the second unit are wrapped around the core in the nip of the two perforated spinning drums. There is also much confusion about the yarn formation process on the DREF-III system [8-10].

Apart from the quality of raw material, the arrangement of fibers within the yarn structure has a great bearing on the

mechanical properties of the yarn [11-15]. DREF-III yarns have two distinct components-cores and sheath. These two components have different fiber configurations and thus affect yarn properties differently. The strength of such a structure largely depends on the magnitude of the radial pressure exerted by the sheath on the core and on the frictional characteristics of both core and sheath fibers [12]. There are many hypotheses concerning the tensile behavior of DREF-III yarns produced from staple fibers and the contributions of the core and sheath fibers. But almost no work has considered the contributions of staple core as an individual, separate component and its surrounding sheath as another component in terms of their tensile properties. Merati and Okamura [16-17] reported on the tensile properties and structural parameters of hollow yarns produced from an experimental friction spinning machine with only one active perforated roller.

In core spinning, the core material is fed into the center of the drafted zone and the roving is spread around in order to generate a cover and for spinning. The guide device is installed on the roller-weighting arm to feed core material stably to the center of the roving. The guide device incorporates a guide pulley, and will move with the wire in order to prevent creation of an additional friction between the metal wire and the feeding device [18]. Tyagi et al. [19, 20] reported that as the yarn delivery speed decreases, at a constant spinning drum speed, the tenacity of the parent DREF in yarn initially increases and then drops. A similar trend was also reported by earlier researchers.

The speed of the spinning drums is one of the process variables that directly influence the yarn twist. At higher speeds, the twists are expected to be higher. However, Theirron [21] has shown for 55/45 polyester/wool DRFF-3 yarns that the sheath twist, calculated from the diameter and twist angle, increases only up 3000 rpm and

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remains constant beyond that speed. Beyond the limit, he claims that the frictional forces between the spinning drums and the fiber assembly are not sufficient to overcome the torsion present in the yarn due to a greater slippage between the two. The yarn diameter was shown to decrease whereas the flexural rigidity increased change with an increase in speed within 1500-3000 rpm, but the change was more pronounced at higher speeds.

Padmanabhan and Ramakrishnan [22] reported that an increase in tenacities of cotton DREF3 yarns as the speed of the spinning drums increased from 3000 to 5000 rpm. However, they found no significant effects of the speed in CV% of single-end strength, breaking elongation, appearance, hairiness, and imperfection counts.

Ishtiaque and Swaroopa [23] found that for 44 tex filament-core DREF-3 yarns, the yarn tenacity increased as the speed of spinning drums increased from 3000 to 5000 rpm, but the yarn diameter decreased as the yarn became more compact. The breaking elongations were shown to be greater for flat and textured filament-core yarns as the speed of the drum increased whereas that for the twisted filament-core yarn were shown to be lower.

Cheng and Wong [24] conducted spinning trials using fibers obtained from torn-up garments on DREF-2 spinning machine by varying the speed of the spinning drum within 1500 to 3000 rpm range. For the 150 tex yarns produced, they have shown that the yarn strength increased with an increase in the speed of drum and it reached a maximum before it began to decrease.

Friction spinning has a large potential for increasing the delivery rate. However, it has been reported that varying delivery speeds are detrimental to strength of OE friction spun yarns [25, 26, 27]. Brockmanns and Lunnenschloss [50] have postulated that the yarn tenacity essentially depends on the delivery rate and the friction ratio. They have reported poor mass irregularities for

finer yarns spun at higher speeds. Further, they have shown similar effects of spinning speed on imperfection counts, yarn fineness, and friction ratio.

Alagha *et al.* [26] have investigated the structural parameters of yarns spun from 38 mm and 1.7 dtex viscose fibers on a Master spinner within a range of normal production speeds. They found that the tenacity and breaking elongation decreased with an increase in production speed from 150 to 250 m/min. They also found a reasonable correlation between production speed and other yarn properties and the migration characteristics.

For DREF-3 yarns, Theirron [21] has observed a reduction in the tenacity of 55/45 polyester/wool yarns spun at high delivery rates under a fixed friction ratio. In another paper [28], he reported no significant effect of delivery rate on yarn strength of 60 tex yarns spun with 70% polyester core and 30% cotton sheath. He has also shown that elongation-at-break of 55/45 polyester/wool yarns dropped with an increase in spinning speed but the yarn unevenness and imperfection counts were shown to remain unaffected. In another paper, Padmanabhan and Ramakrishnan [22] showed decreasing trends not only in yarn tenacity but also for both unevenness and breaking elongation with increases in delivery rate up to 200 m/min, but an increase beyond the speed. They have also pointed out that the yarn twists become lower at higher delivery speeds due to increased slippage.

Ishtiaque *et al.* [23] observed for 44 tex filament-core DREF-3 yarns that the tenacity decreased with an increase in the delivery rate from 100-300 m/min. They also found breaking elongation followed the same trend in case of textured filament-core yarn, but an opposite trend for flat and twisted filament-core yarns. They attributed this to a shorter elongation time while the fibers are on the spinning drums.

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Apart from other factors, the yarn twist in a friction spun yarn is generally known to depend on the friction ratio (the ratio of spinning drum surface speed to the yarn delivery rate). In one study [29] it has been found that the twist increased with an increase in friction ratio but in another study [30] this increase was found to be small for coarser yarns due to better friction transfer. Moreover, depending on the value of the friction ratio, the twists are adjusted by themselves to produce optimal yarn strength. Although it may be desirable to produce friction yarns at a low twist level, the friction ratio often cannot be reduced easily as reported by Stalder and Soliman [29].

The importance of friction ratio has also been emphasized as it relates to tracking force of the yarn [31]. In another paper [32], considerable slippage is reported between the fiber assembly and the friction drum surface. For core yarns produced on DREF-3 spinning system, it has been reported [33] that the sheath fibers are laid around the filament core at an increasingly steeper angle when the friction ratio increases.

Chattopadhyay *et al.* [34] have studied the influence of friction ratio on the quality of DREF-2 and DREF-3 friction spun yarns made from acrylic fibers of 1.5 den and 51 mm length. They varied friction ratios from 1.7 to 7.1 with different combinations of spinning drum and yarn withdrawal speeds. For DREF-2 yarns, they found that the tenacity and breaking elongation increase first with an increase in friction ratio and reach maximum values and then decrease. For DREF-3 yarns, however, the tenacity, extension, and twists were shown to increase when the friction ratio increases up to 2.8 and remain almost constant afterwards.

Tyagi *et al.* [35] have shown that increase in friction ratio from 3.2 to 5.1 significantly increases the packing density of 59 tex and 98.4 tex DREF-3 spun yarns produced from 44 mm, 1.33 dtex polyester fibers. They had attributed this to the increase of twists in sheath fibers, which compacts the yarn.

Suction pressure in the yarn formation zone influences the twist characteristics and other properties of friction spun yarns. A higher suction pressure causes a higher restraining force on the fiber assembly so that it will be pressed more firmly against the surface of friction drums. This leads to an increased friction between the two and an increased torque on the surface of the fiber assembly [36, 37, 38]. Consequently, the amount of twist, yarn tension, and twisting efficiency were found to increase with an increasing suction pressure.

Ibrahim [39] has reported that there is a maximum suction pressure in the open-end friction spinning at which the yarns are highly twisted above this pressure, the turns per meter is reduced.

An increase in suction pressure is also accompanied by the increase of air and the mean fiber speed in the fiber transport tube [36, 37], but both of them were shown to decrease along its length. An increase in mean fiber speed along the transport tube helps to maintain fiber orientation inside the tube and prevents them from buckling, thus improving the yarn appearance and straightness if the fibers in the yarn. The yarn diameter, unevenness, irregularity and percentage elongation were reported to decrease with an increase in the suction pressure while the yarn tenacity has been shown to increase.

Louis *et al.* [40] studied the properties of cotton yarns produced by different spinning systems and the relationships between air-pressure and the properties of DREF-3 spun 74 tex yarns by reducing the suction pressure from 69.9 to 11.2 cm of water. In this investigation, they observed that a decrease in suction pressure increased the variance of the strength and mass uniformity measured by an Uster evenness tester, making the yarns relatively weak and irregular.

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Lord [41] conducted a series of experiments with a fixed core size and varying amounts of sheath. With polyester core and cotton sheath, he showed that a very steep drop in yarn strength occurred when the sheath proportion was decreased below a certain level. This critical sheath size depended on the fiber length, fineness, and type.

Kimmel and Sawhney [42] found a quadratic form in yarn tenacity over a range of core ratios between 40 and 70%, attaining a maximum in the upper range. They also showed that a lighter core supplied at a faster speed produced a more uniform and stronger yarn, exhibiting a lower elongation variance compared to that produced from a heavier sliver.

For 100% cotton, Louis *et al.* [40] found a slightly higher yarn strength in DREF-3 yarns of 50% core and 50% sheath compared to that from 70/30 core-sheath ratio although it was rather difficult to produce 50/50 combination. On the other hand, Padmanabhan and Ramakrishnan [22] showed that yarn tenacity reached a maximum at a core-sheath ratio of 70/30.

For 100% acrylic fibers of 2.2 dtex and 64 mm, it was reported by Tyagi *et al.* [62] that the breaking extension, abrasion resistance, and unevenness increased with an increase in sheath fibers up to 40%. However when polyester is used as core, the best yarn characteristics were achieved with 70% core fibers and 30% sheath fibers [28, 43].

For 100% polyester fibers of 44 mm and 1.33 dtex, it was observed that an increase in core content increased the packing density of the DREF-3 yarn [35]. As the spinning tension is a system-dependent parameter, a higher spinning tension results in a compact structure. However in open-end friction spinning, the tension was reported to be relatively low [31] and could not be increased as freely as in other spinning systems. A lower tension was found to be advantageous in terms of low end-breakage rate but due to generation of insufficient

friction between the fibers, resulting in a lower yarn strength [38]. Even at a low level, the spinning tension was said to be influenced by a number of factors. Stalder and Soliman [44] pointed out that the force due to airflow on the yarn-tail, friction coefficients with spinning drums, and yarn tail diameter are the important influencing factors. Merati *et al.* [38] found the suction air-pressure in the suction slit and the yarn size to be the most effective parameters for spinning tension. They also pointed out the importance of the width of the suction slot and the yarn-to-spinning drum drag coefficient in relation to yarn tension. In both studies, mathematical expressions were derived for yarn tension and verified experimentally. It was reported that the yarn tension increased with increasing suction pressure and yarn size (tex). Saad and Sherouf [45] also made an attempt to relate the tension variations in relation to opening roller speed and air suction pressure and found that both, specific yarn tension and its variation, increased with an increase in the opening roller speed.

In spinning with filament-cores, the tension was shown to increase at an increase in filament pre-tension [46]. The pre-tension was shown to influence the configuration of the filament in the core and the structural and mechanical properties of the spun yarns. They showed that at a low level of pre-tension, the filament did not follow a straight path and formed helix angles along the yarn axis. It was also shown that a more intimate interface with the sheath fibers occurred and enhanced the sheath slipping resistance during abrasion [47].

In an earlier work [20], it was believed that the core in a DREF-3 friction spun yarn is virtually twist-less and consists of a parallel bundle of fibers. Recently, however, other researchers observed that the core fibers exhibited some twists. Merati *et al.* [48] analyzed the distributions of false twists in filament-cores of friction spun yarns. The theoretical analysis was based on the twist distributions along the conical yarn tail, and

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the results were compared against the experimental data obtained by measuring the twists. They found existence of some twists in the filament core in both S and Z directions within short yarn intervals and the twists are combined and canceled each other as the interval size increased. They also found that the remaining false twists in the filament cores in the absence of a pre-tension was greater than that under a pre-tension.

Dhamija [49] studied the twist structure of staple-core DREF-3 friction spun yarns using Acrylic fibers of 51 mm length and with two linear densities 1.67 dtex and 3.33 dtex. The yarns were spun with sizes of 39.4, 59.0, and 118.1 tex with core-sheath ratio of 70:30 at a delivery rate of 150 m/min and spinning drums speed of 4500 rpm. The twist in the core was measured using tracer fiber technique. He found that the core fibers exhibited had twists presumed to be entrapped false twists, and that a smaller core ratio led to an increased twist. He also found that the helix angle and helix diameter for core fibers were smaller compared to that for sheath fibers.

While investigating the influence of frictional characteristics of core and sheath, Gowda [50] noticed that the core fibers exhibit straight and twisted configurations. Some showed hooked leading end leaving the trailing end almost free of hook. The fiber remained straight within a portion of its length and then formed false twists in the remaining length. The twisted and straight portions in the fiber were randomly distributed along its length in such a way that the fiber would not exhibit a regular and well-defined helix envelope. The helix angle was very. The paper clearly showed that the core in the yarn had false twists.

For DREF-3 friction spun yarns, the sheath fibers are wrapped helically over the core exhibiting Z twists. Due to different feed positions, the sheath fibers are expected to show varying structural parameters. It has been found [49, 50, 51] for these yarns with

core-sheath ratio of 70:30, the helix angle and helix diameter of sheath fibers were shown to decrease progressively from the position nearest to farthest delivery points while the twists were more or less the same for all sliver positions. In one study [50] however, core-sheath ratios of 30:70, the structural parameters of sheath fibers were shown to be different at different sliver positions.

MATERIALS AND METHODS

In this investigation, copper core spun yarns have been produced using a Dref II, and ring-spinning frame. The spun yarn differed in yarn counts, copper wire diameters, core %, sheath %, twist angle α , and the cover materials. The effects of these parameters on the yarn characteristics of the copper-core spun yarns were investigated. The objective of this study is to investigate the contribution of staple core and sheath portions separately to the tensile properties of copper core yarns. More specifically, the specific objectives are to study the effects of machine variables (spinning drum speed and yarn delivery speed) on sheath components at a core-sheath ratio.

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For this study, we used cotton and polyester slivers as covering materials. The copper wires were taken as core materials with diameters 0.09 mm, 0.1 mm and 0.12 mm. The sliver (0.12 to 0.16 hank) used in this research consisted of 100% polyester (1.4 denier, 38 mm long) and 100% cotton (sankar 6, carded sliver hank of 0.12 to 0.16, 30.1 mm staple length, 20.9g/tex tenacity). In these investigations, the copper core yarns were produced by a Dref II friction spinning machine and a ring spinning machine with a core attachment device. Yarns counts of 179, 118, 98 and 84 tex with copper cores were produced by the Dref II friction spinning frame and yarn counts of 74 and 59 tex with copper cores were produced by a ring spinning frame with a core attachment device. The copper core yarns were produced under the set

process parameters as shown in Table I and II. The spinning drum speeds were 4000, 4500, and 5000 rpm with yarn delivery speeds at 150, 160 and 170 m/min. The core to sheath ratios were selected were; (18:82), (20:80), (22:78), (24:76), (26:74), (28:72), (29:71), (31:69), (34:66), (37:63) and (41:59) for producing the copper core yarns as shown in Table II. The tensile properties

of the copper core yarns, for both cotton and polyester sheaths, were measured by a Tensomaxx 7000, run under a constant of extension (CRE) principle, at a speed of 5000 mm/min. and gauge length equal to 500 mm and a pre tension of 0.50 cN/tex as recommended by ASTM D2256.

Table I: Actual Process Variable Setting

Process Variables		Set Values	
Copper Core- Sheath fibers %		18:82, 20:80, 22:78, 23:77, 26:74, 28:72, 29:71, 31:69, 34:66, 37:63, 41:59	
Spinning Drum RPM	4000	4500	5000
Yarn delivery speed m/min	150	160	170

Table II

Sample	Yarn	Yarn Count (tex/Ne)	Copper Diameter (mm)	Yarn Diameter (mm)	Core (%)	Sheath (%)	Copper Resistance Per meter (Ohms)
Drum speed 4000 rpm Yarn delivery speed 160m/min							
S1	Copper core (Cotton sheath)	179 / 3.3	0.09	0.51	18	82	3.72x10 ⁻⁵
S1a	Copper Filament	87/6.8	0.09	0.51			3.72x10 ⁻⁵
S2	Copper core (Cotton sheath)	179 / 3.3	0.1	0.51	20	80	3.36x10 ⁻⁵
S3	Copper core (Cotton sheath)	179 / 3.3	0.12	0.51	23	77	2.7x10 ⁻⁵
S4	Copper core (Cotton sheath)	118 / 5	0.09	0.41	22	78	3.72x10 ⁻⁵
S5	Copper core (Cotton sheath)	118 / 5	0.1	0.41	24	76	3.36x10 ⁻⁵
S5a	Copper Filament	50/11	0.1	0.41			3.36x10 ⁻⁵
S6	Copper core (Cotton sheath)	118 / 5	0.12	0.41	30	70	2.7x10 ⁻⁵
S7	Copper core (Cotton sheath)	98 / 6	0.09	0.38	24	76	3.72x10 ⁻⁵
S8	Copper core (Cotton sheath)	98 / 6	0.1	0.38	26	74	3.36x10 ⁻⁵
S9	Copper core (Cotton sheath)	98 / 6	0.12	0.38	32	68	2.7x10 ⁻⁵
S10	Copper core (Cotton sheath)	84 / 7	0.09	0.34	26	4	3.72x10 ⁻⁵
S11	Copper core (Cotton sheath)	84 / 7	0.1	0.34	29	71	3.36x10 ⁻⁵
S12	Copper core (Cotton sheath)	84 / 7	0.12	0.34	35	65	2.7x10 ⁻⁵
S13	Copper core (Cotton sheath)	74 / 8	0.09	0.32	28	72	3.72x10 ⁻⁵
S14	Copper core (Cotton sheath)	74 / 8	0.1	0.32	31	69	3.36x10 ⁻⁵
S15	Copper core (Cotton sheath)	74 / 8	0.12	0.32	37	63	2.7x10 ⁻⁵
S16	Copper core (Cotton sheath)	59/10	0.09	0.29	31	69	3.72x10 ⁻⁵
S17	Copper core (Cotton sheath)	59/10	0.1	0.29	34	66	3.36x10 ⁻⁵
S18	Copper core (Cotton sheath)	59/10	0.12	0.29	41	59	2.7x10 ⁻⁵
S19	Copper core (Polyester sheath)	179/3.3	0.09	0.51	18	82	3.72x10 ⁻⁵
S20	Copper core (Polyester sheath)	179 / 3.3	0.1	0.51	20	80	3.36x10 ⁻⁵
S21	Copper core (Polyester sheath)	179 / 3.3	0.12	0.51	23	77	2.7x10 ⁻⁵
Drum Speed at 4500 rpm Yarn Delivery Speed at 160m/min							
S1b	Copper core	179 / 3.3	0.09	0.51	18	82	3.72x10 ⁻⁵

S4b	Copper core	118 / 5	0.09	0.41	22	78	3.72×10^{-5}
S7b	Copper core	98 / 6	0.09	0.38	24	76	3.72×10^{-5}
S10b	Copper core	84 / 7	0.09	0.34	26	74	3.72×10^{-5}
S13b	Copper core	74 / 8	0.09	0.32	28	72	3.72×10^{-5}
S16b	Copper core	59/10	0.09	0.29	31	69	3.72×10^{-5}
Drum Speed at 5000 rpm		Yarn Delivery Speed at 170m/min					
S1c	Copper core	179 / 3.3	0.09	0.51	18	82	3.72×10^{-5}
S4c	Copper core	118 / 5	0.09	0.41	22	78	3.72×10^{-5}
S7c	Copper core	98 / 6	0.09	0.38	24	76	3.72×10^{-5}
S10c	Copper core	84 / 7	0.09	0.34	26	74	3.72×10^{-5}
S13c	Copper core	74 / 8	0.09	0.32	28	72	3.72×10^{-5}
S16c	Copper core	59/10	0.09	0.29	31	69	3.72×10^{-5}

RESULTS AND DISCUSSION

TENACITY

It can be observed from Tables II, III and Figures 21 and 22 that the major strength component is being borne by the sheath and the core but different structural parameters contributes not significantly to tenacity. It is also evident from Tables II, III and Figure 1, 3, 5, 7, 9 and 11 that increases in spinning drum speed increased the tenacities of the copper core yarns. This may be due to the fact that a higher drum speed provides an increase in the transverse pressure to wrap the sheath fibers around the core and that the core-sheath interaction factor increases with an increase in spinning drum speed.

It can also be observed from Tables II, III and Figures 1, 3, 5, 7, 9 and 11 that the increase in spinning speed decreased the breaking elongation of the copper core yarn. This may be because the wrapped sheath fibers are wrapped around the copper core and at a higher production speed the twist

becomes low, leading to an early ruptures of the yarn. On the other hand, the yarns containing higher proportion of wrapper fibers have considerably greater breaking elongation due to the presence of more bent and buckled fibers in sheath that tend to be aligned during the tensile loading. The core spun yarns had complex yarn structures by combining cotton staple fibers and copper wires. Their load-displacement differs from that of general spun yarns. When the staple fibers and the copper wires are put together under tension, the staple fibers are subjected to shear force whereas the copper wire is subjected to a normal force. Accordingly, the straightened fibers suffer normal force and break first making the copper wire to break. It is also evident from Figure 1.1 and Figures 21 and 22 that the yield points of samples were found at the breakage points of the copper wires. After the copper wires are broken, the cover fibers are then stretched until the fibers become straight and then suffer breakage.

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Sl Copper Core Yarn (Copper-Core & Cotton -Sheath)
Sl a Copper wire (core)
Cotton Sheath Component

Figure 1.1 Load - Elongation Curve of Copper Core Yarn and Copper Wire

In copper core yarns, breaking extensions are decided predominantly by the breakage of the size (diameter) of the copper wires as shown in Tables II and III. The breaking extensions for the regular yarns are shown to be always higher compared to the copper core yarns.

In sheath core yarns, the sheath fibers create a transverse force to hold the core fibers together. When the yarn extends, the core fibers are extended initially absorbing most of the stress, initiating breakages from the core section and then moving quickly to the wrapper fibers. The load elongation curves are different from each other for the parent copper core yarns, individual core and sheath components. The core component shows a very steep initial rise followed by a sudden drop as evident from Figure 1.1. Here, the initial rise is due to copper wire materials. The load elongation curve of the sheath component (Figure 1.1) shows no such steep rise in the stress at the initial stage and the curve is not smooth throughout. This is due to reorientation of the structure resulting from slippages and re-locking within the sheath fibers in the

absence of a core component when stress is applied to the sheath component.

When the amount of cover staples is small, there exists little cohesive force between them and the smooth copper surface. When more staples are present, the cohesion force would increase along with the breaking tenacity of the core yarns. The tenacity of the copper core yarn with cotton sheath was weak because of the small amount of cover staples and the small cohesive forces between the staple fibers and the copper wires. In Table III, it is observed that the yarns with polyester sheath and copper core are higher in tenacity than the yarns with cotton sheath and copper core yarn because of the higher tensile strength of the polyester staples than cotton. Hence, the tensile strengths of the yarns with polyester sheath were shown to be higher. It can be observed from Figures 2, 4, 6, 8, 10 and 12 that an increase in spinning drum speed increases the work-to-break of the copper core yarns. This perhaps was because of the greater amounts of work done or energy consumed by the copper cores.

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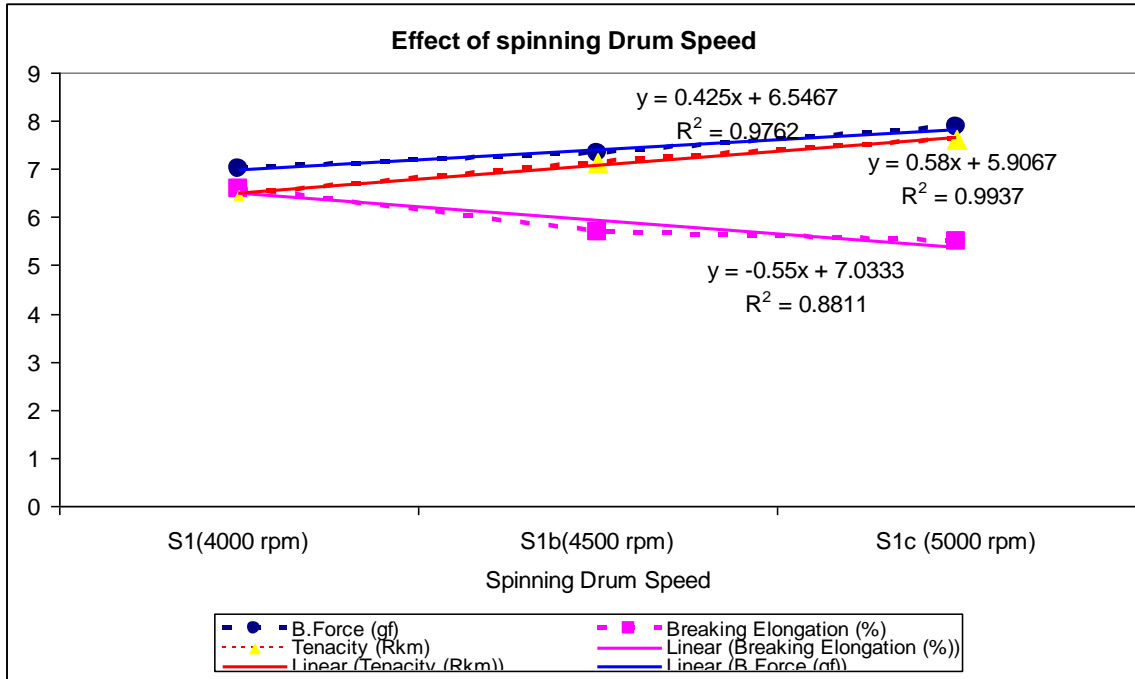


Figure 1

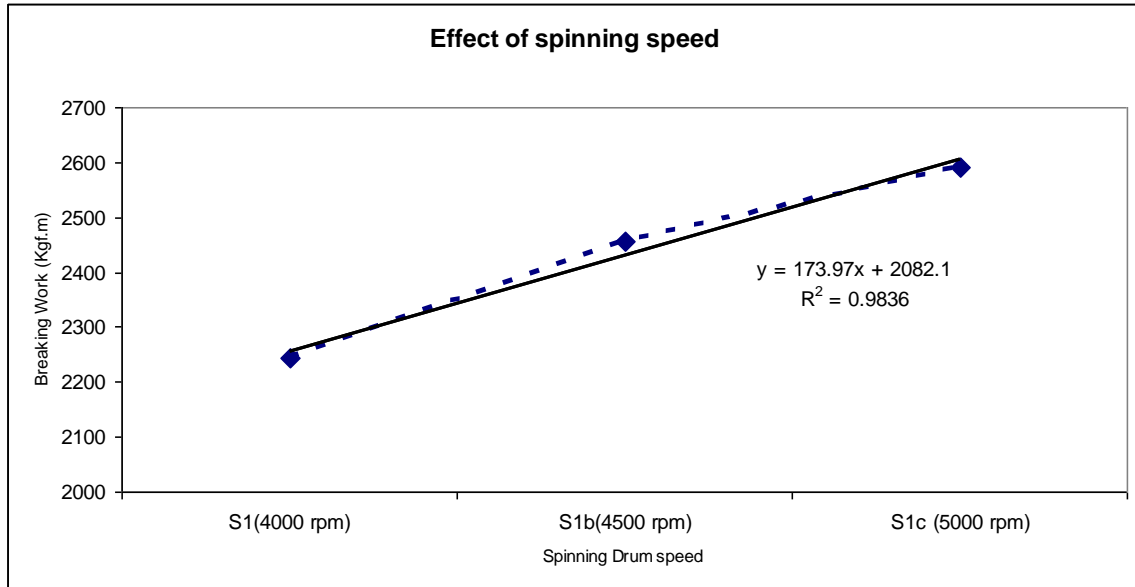


Figure 2

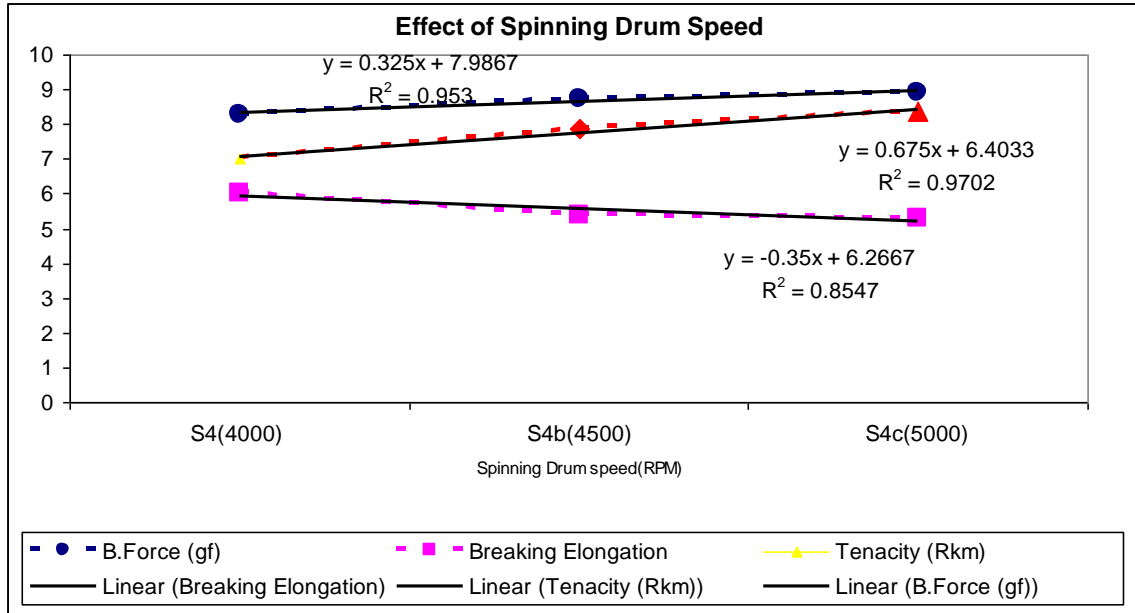


Figure 3

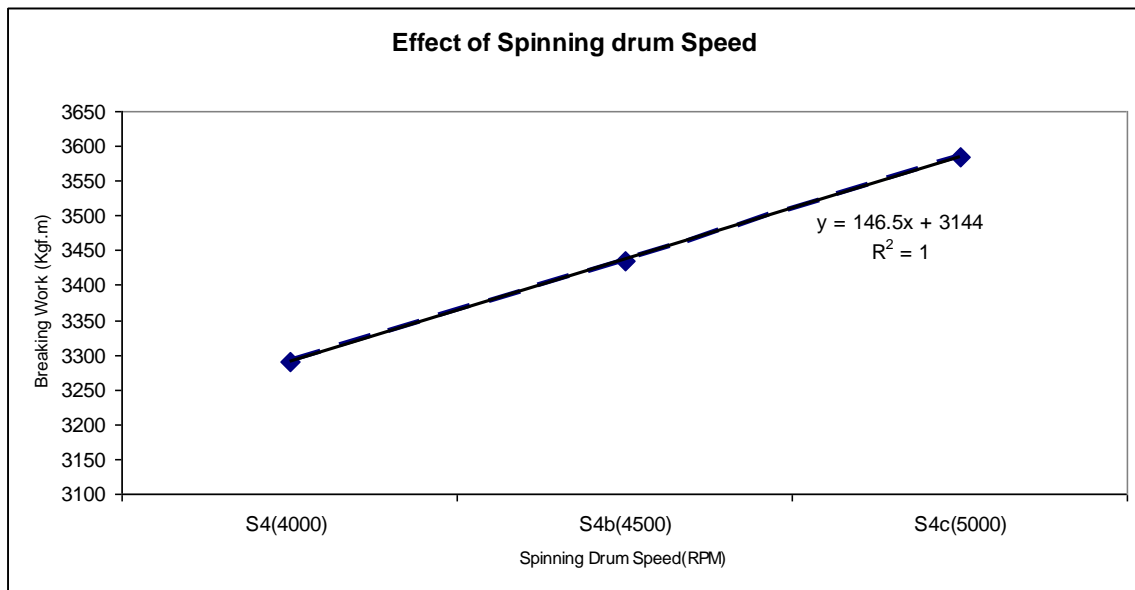


Figure 4

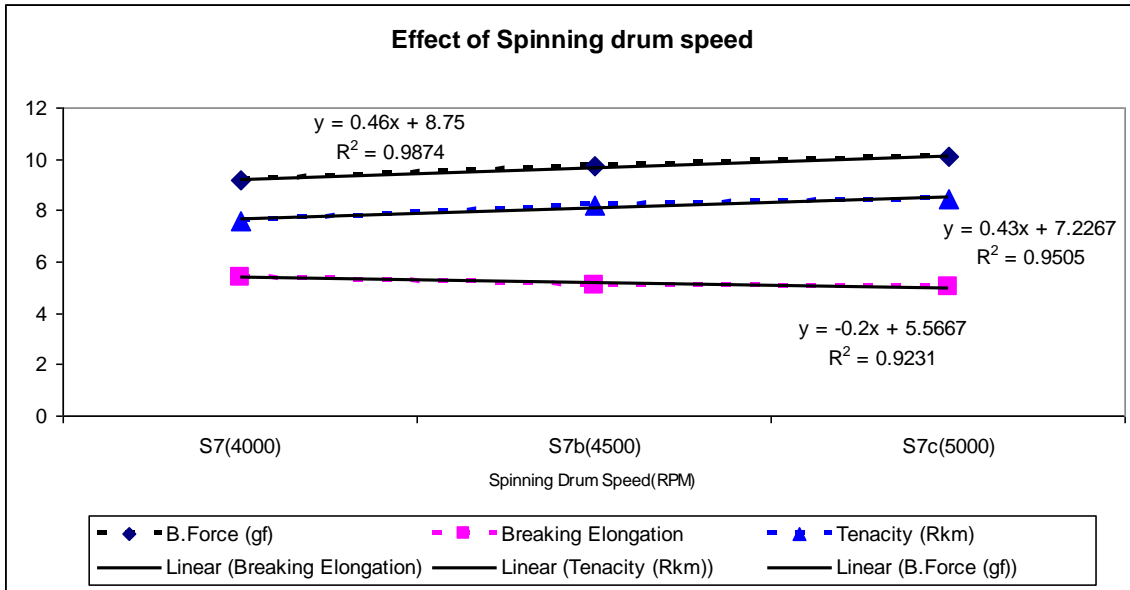


Figure 5

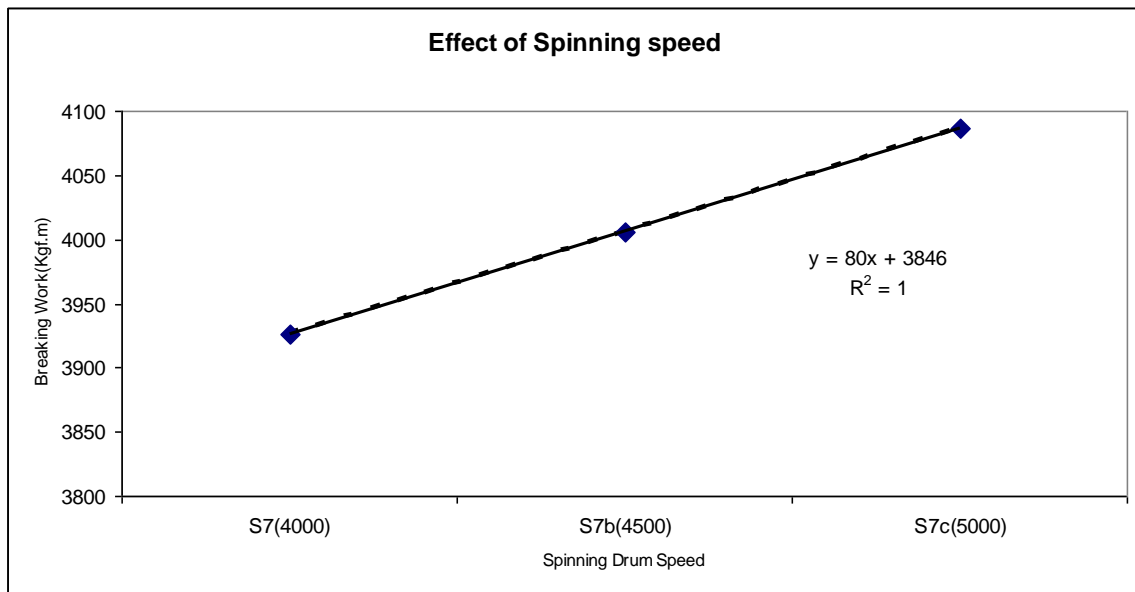


Figure 6

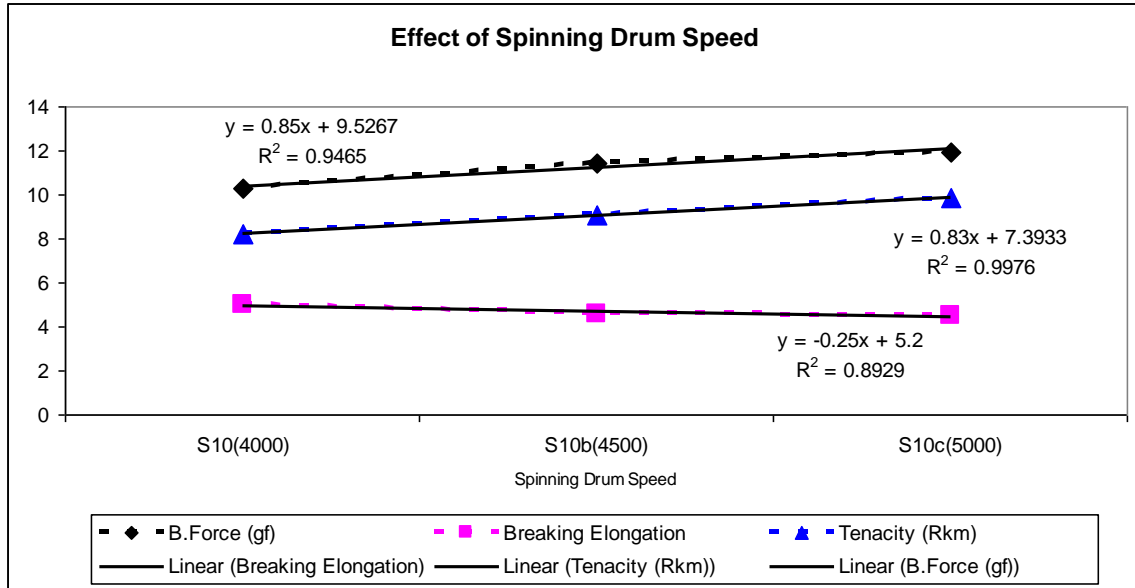


Figure 7

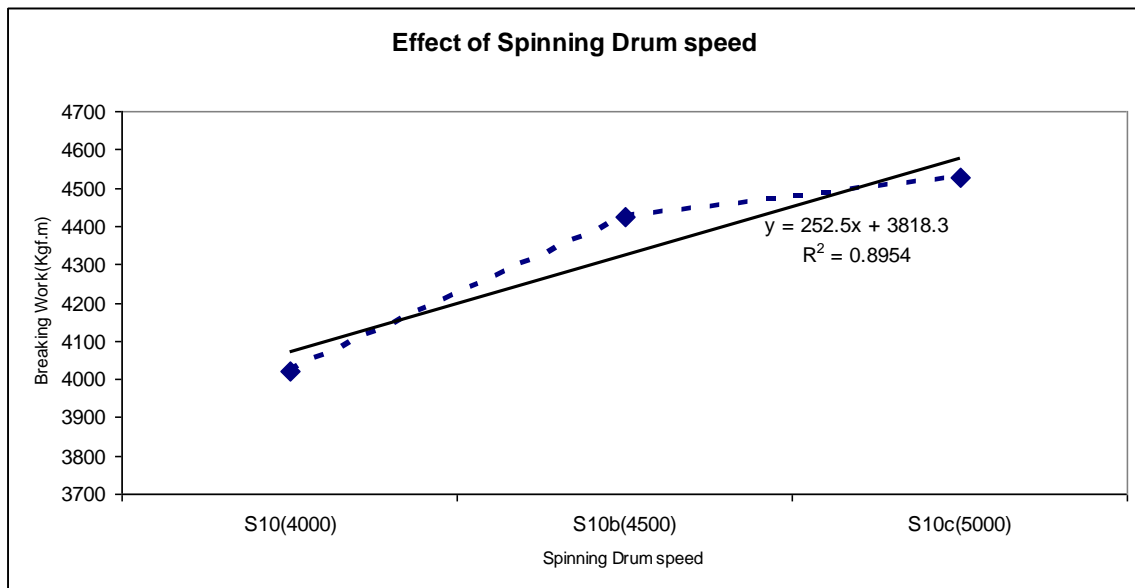


Figure 8

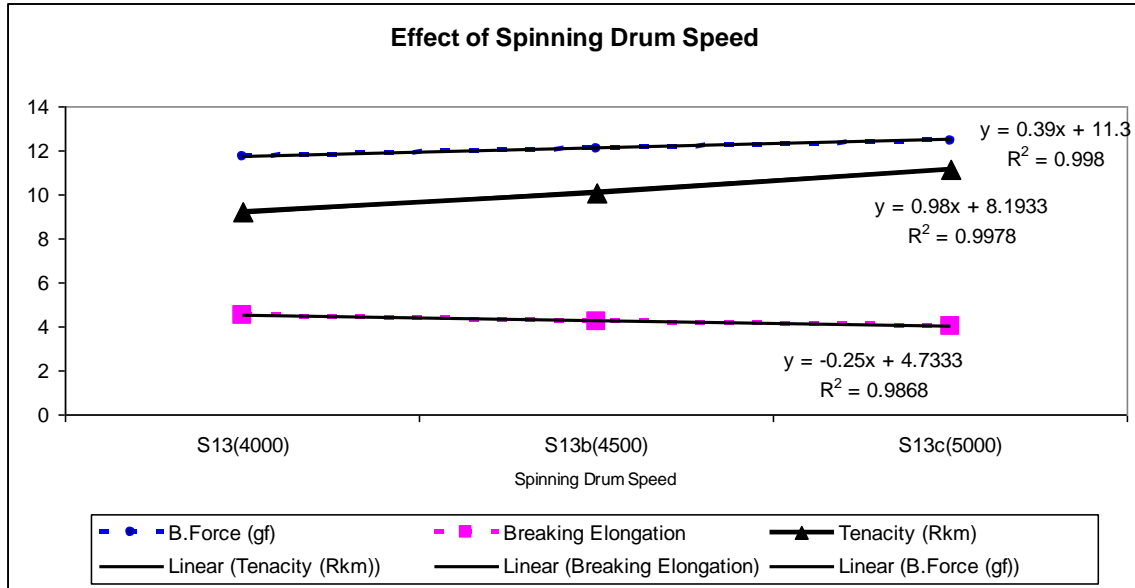


Figure 9

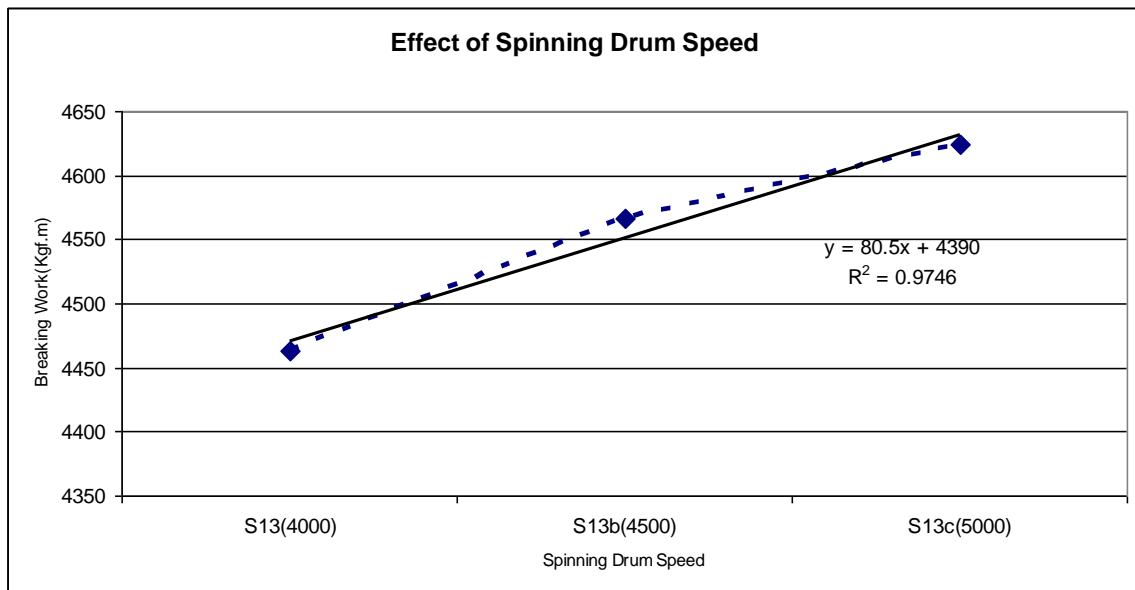


Figure 10

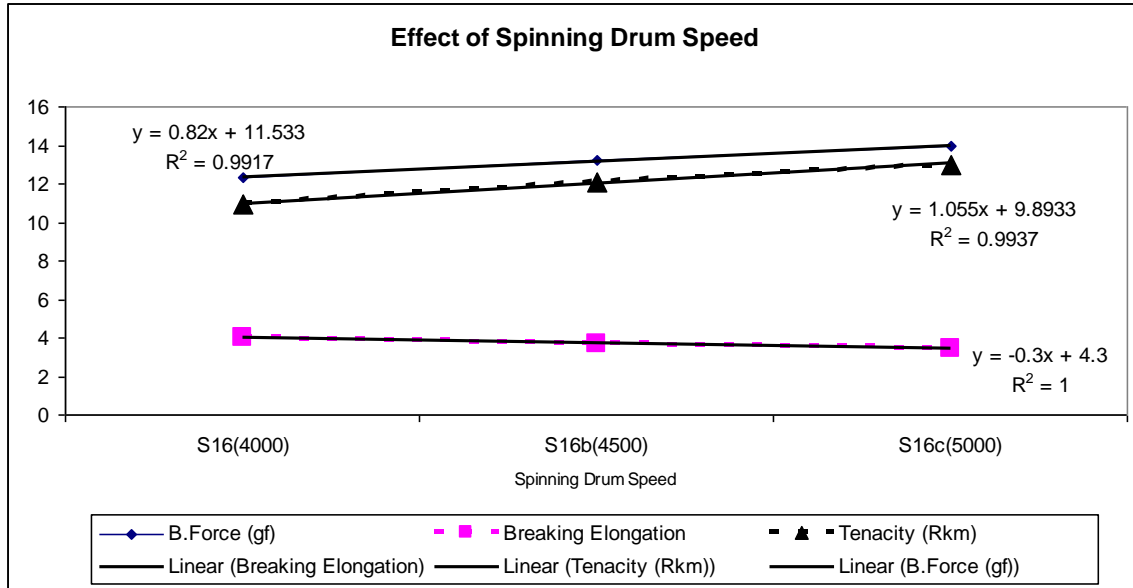


Figure 11

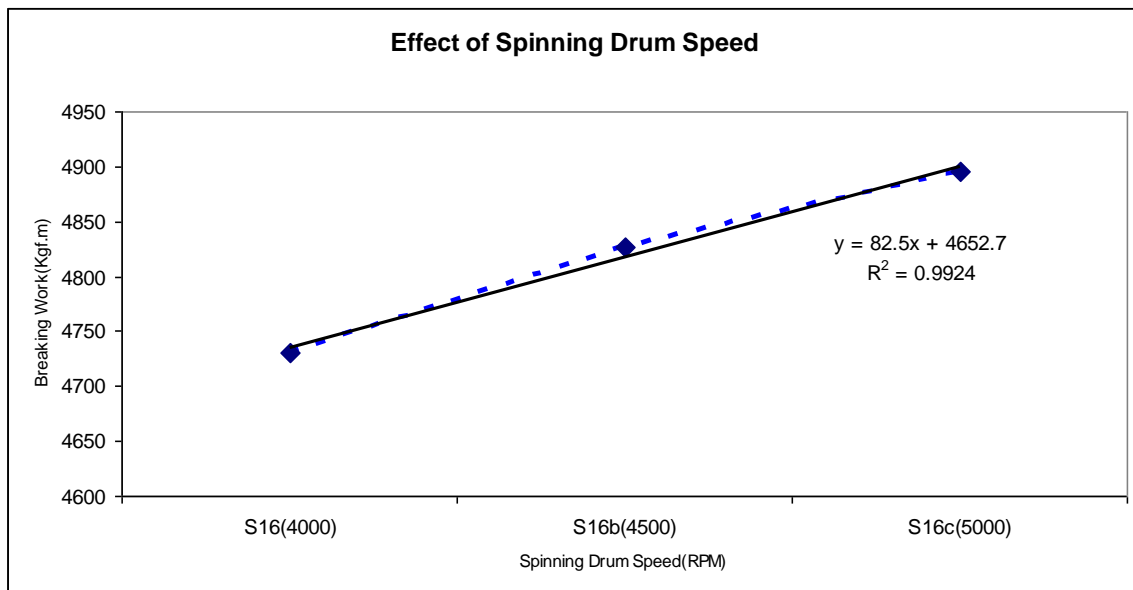


Figure 12

EFFECTS OF CORE- SHEATH RATIO

To study the effects of copper core and cotton sheath ratio on tensile properties, samples S4, S5, S11, S13, S14, S15 and S17 were considered and line charts were drawn from Table III. Figures 13 and 14 show the effects of core sheath ratios of copper core yarn on tensile properties.

In Figures 13 and 14, it can be seen that the increases in copper core contents increased the tenacity of the core yarns and the decreases in sheath contents increased the tenacities and work-to-break of the copper core yarns. The effects of the core content are linear with the lowest yarn tenacity at 24% core and the highest at 41%. It shows

that the yarn core affects yarn tenacity directly in the presence of sufficient wrap fibers to maintain yarn integrity. The yarns with thicker copper cores, in general, were significantly stronger and yielded higher

work-to-break. It can be seen from Tables III and Figure 13 that larger core contents decreased the breaking elongations. This may be due to the effects of the sheath fibers wrapped around the copper cores.

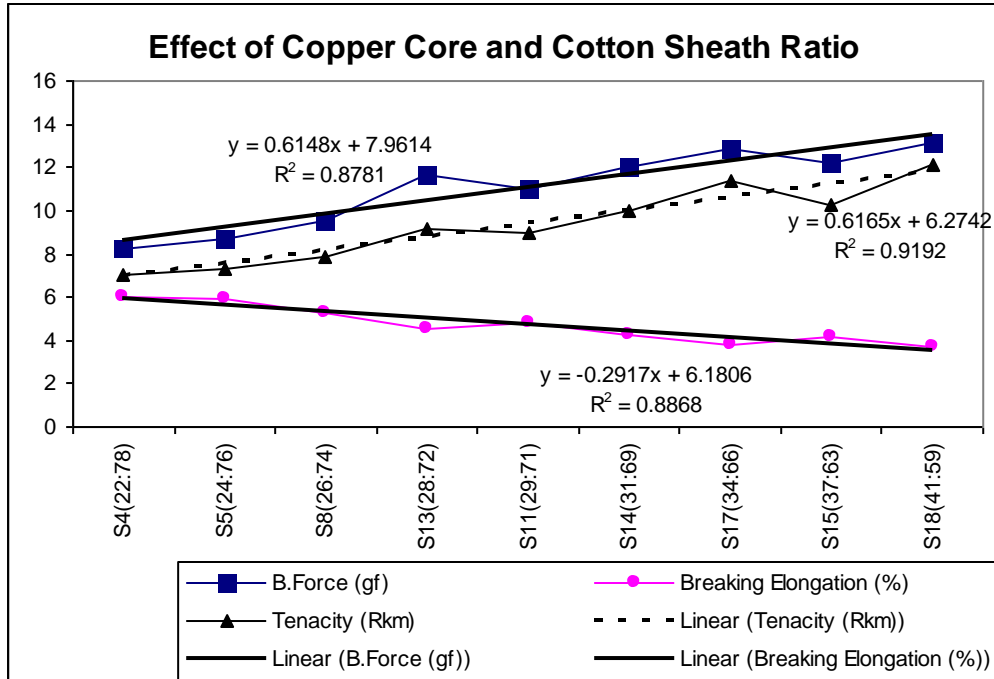


Figure 13

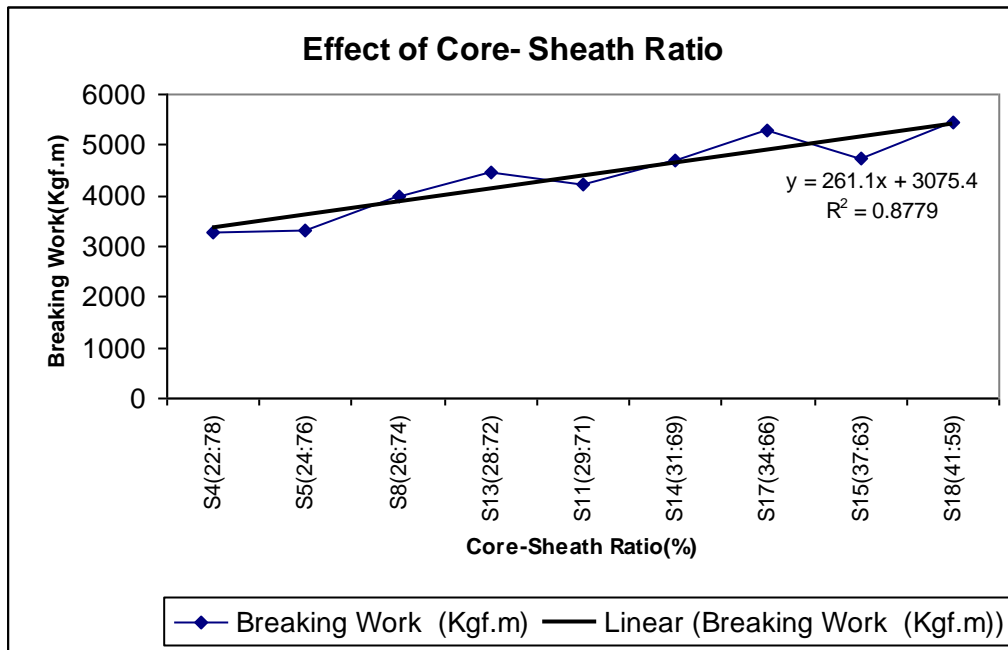


Figure 14

EFFECTS OF SHEATH MATERIALS ON TENSILE PROPERTIES

In order to study the effects of the sheath fiber types on tensile properties of the resulting yarns, Samples 1 and 19, Samples 2 and 20, and Samples 3 and 21 were compared (Table 2) to produce Figure 15, 16, 17, 18, 19 and 20 showing the effects of sheath materials on tensile properties. It is thought that yarns with copper cores and

polyester sheaths were shown to be better in tenacity than that with copper cores and cotton sheaths due to a better packing efficiency produced with polyester fibers. The polyester fibers wrap contributes to the overall yarn strength. It can be also observed that the yarns with copper cores and polyester sheaths had better breaking elongation as well as work-to-break than that with copper cores and cotton sheaths.

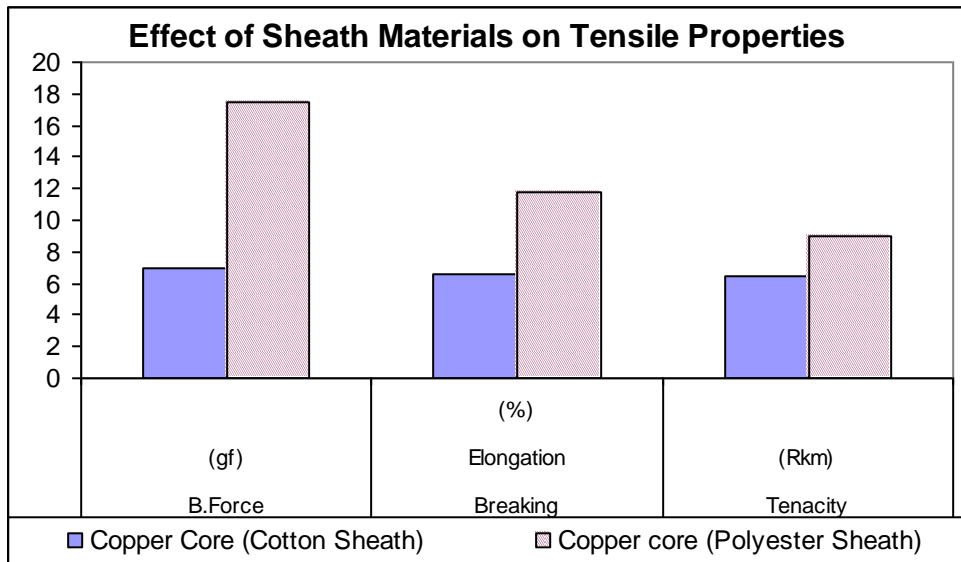


Figure 15

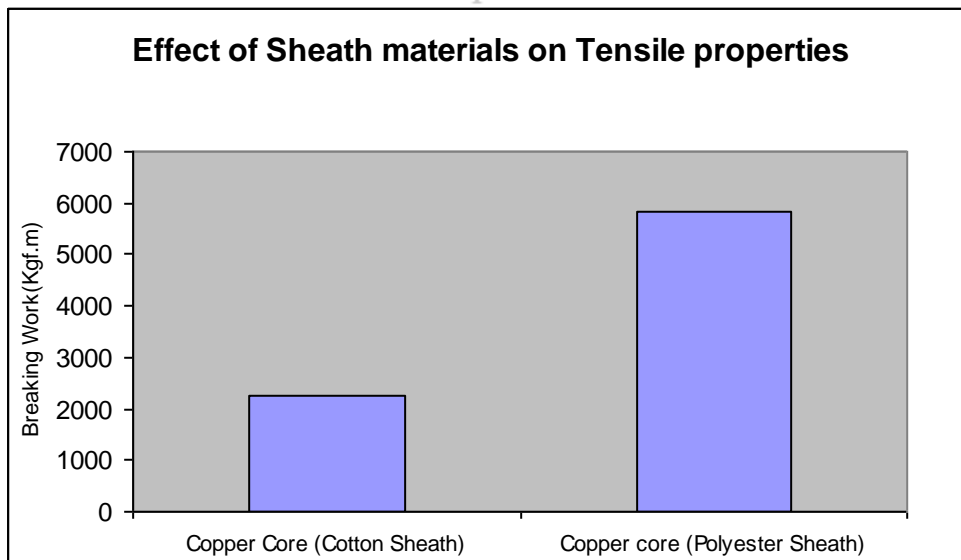


Figure 16

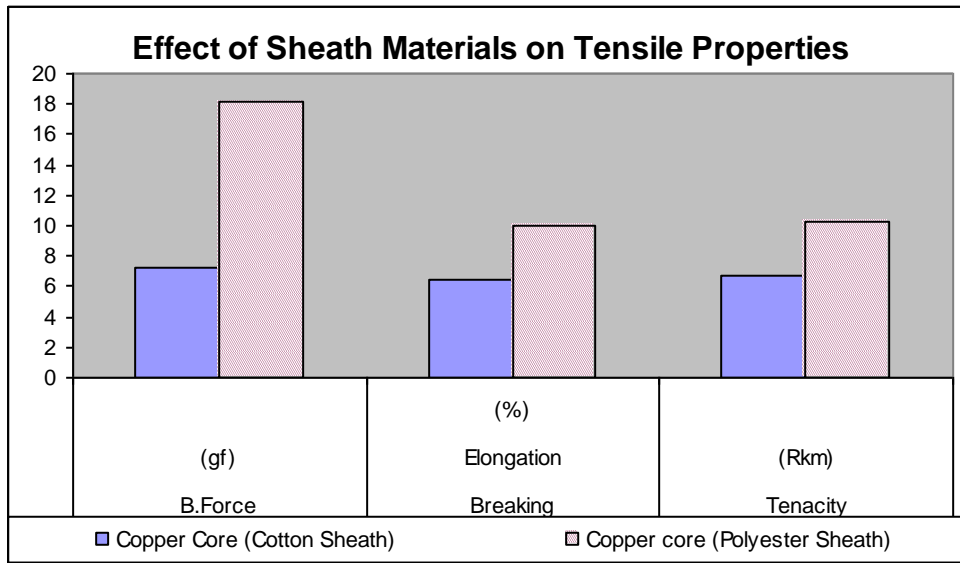


Figure 17

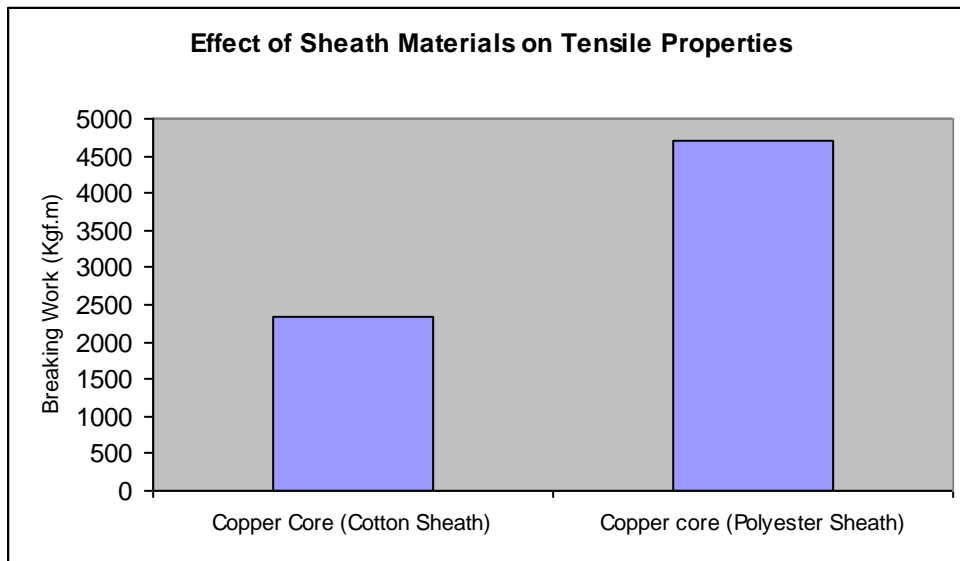


Figure 18

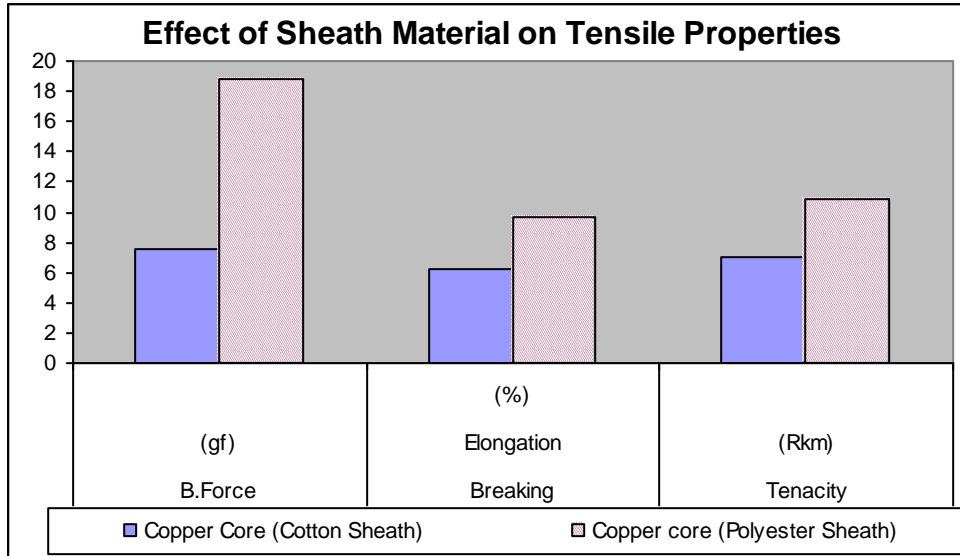


Figure 19

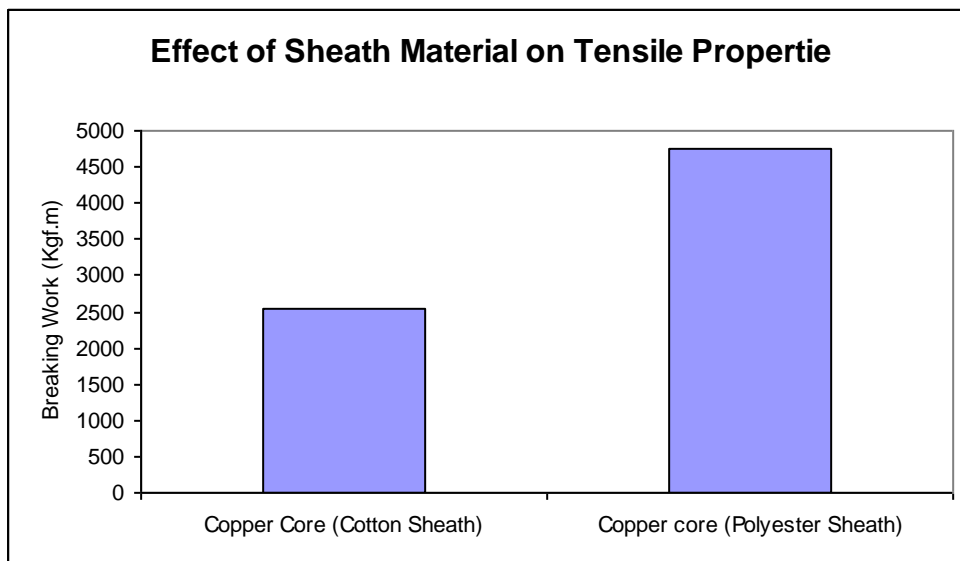


Figure 20

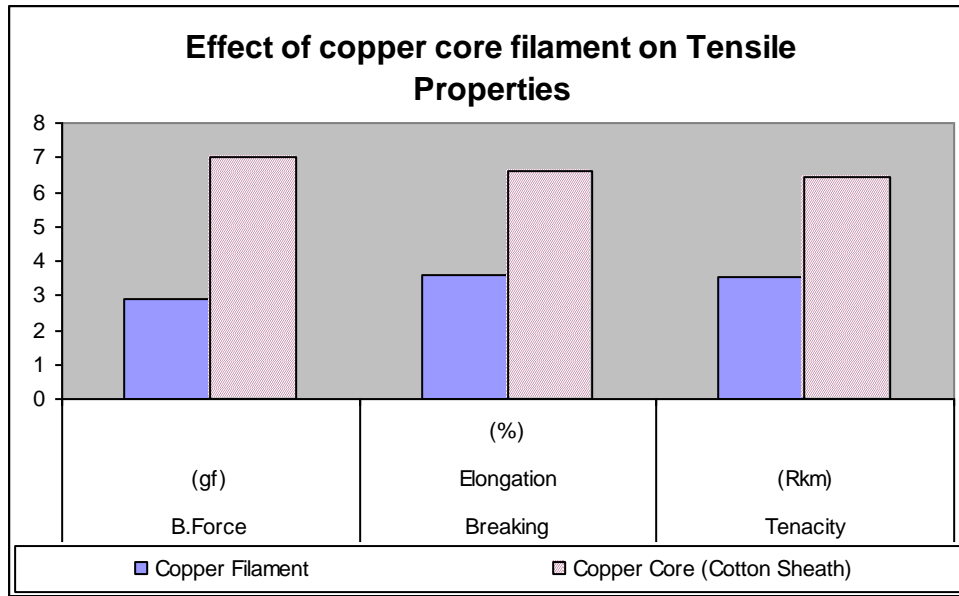


Figure 21

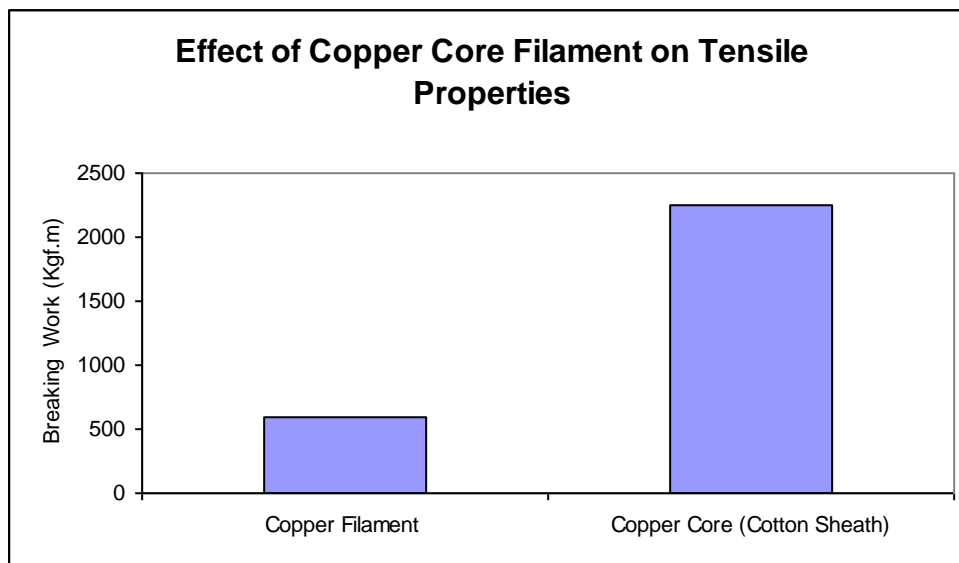


Figure 22

CONCLUSIONS

The results of our study indicate that a substantial proportion of yarn tenacity is generated by the interaction of copper core and polyester and cotton sheaths in the sheath core yarns produced from the two components. The shares of the copper cores are shown to be small in terms of the contribution to the yarn tenacity whereas

the contributions by the sheaths are the major components.

For the copper core yarns with polyester and cotton sheaths are entirely different in their load-elongation behaviors. The copper wires are broken first while the cover materials in the sheath are being stretched till the fibers become straight and then break.

With an increase in spinning drum speed, the tenacities of copper core yarns are shown to increase as the higher drum speed provides a greater transverse pressure, forcing the sheath fibers to wrap around the core fibers more tightly.

An increase in copper core content or a decrease in sheath content is shown to increase the tenacity of the sheath core yarns

due to the complex relationship between the contributions of copper wire and sheaths.

The yarns with copper cores and polyester sheaths produce better tenacity than that with copper core and with cotton sheaths. This phenomenon is due to a greater packing efficiency of polyester fibers. The better wrap with polyester fibers is shown to increase in the overall yarn strength.

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