

# Characterization of Rotor Spun Knitting Yarn at High Rotor Speeds

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**Abstract**-Investigations have been made to explore the effects of rotor speeds on quality parameters of yarn such as single yarn strength, elongation, mass variation, total imperfections and hairiness. Rotor yarn samples were spun at Reiter R-40 by using Pakistani cotton at different rotor speeds i.e., 70,000, 80,000, 90,000 and 100,000 rpm with 600 tpm twist. Linear densities of these samples were kept as 40, 35 and 30 tex. Determination of yarn strength, elongation, mass variation, total imperfections and hairiness was carried out on Uster Tensorapid-4 and Uster Tester-4 according to ISO standard test methods. Based on experimental results it was found that rotor speed had marginal effect on yarn strength and coefficient of mass variation up to 90,000 rpm. However, elongation and total imperfection index brought down progressively with augmented rotor speeds. Slight improvement in hairiness was observed at increased rotor speeds.

**Keywords**-Rotor Speed, 100% Cotton Yarn, Tensile Strength, Elongation, Coefficient of Mass Variation, Total Imperfection Index.

## I. INTRODUCTION

Rotor spinning has established itself as a commercially viable technology with much higher productivity than ring spinning for coarse and medium counts. However, to get the optimum benefits from this technology, the machine parts and process parameters have to be properly chosen taking into account the raw material. [i], [ii].

Rotor speed is an imperative parameter as it influences productivity of the machine. High rotor speed upshots in increased productions, as yarn delivery increases with increasing rotor speeds which in turn facilitate the manufacturer to compete in international market [i], [iii].

In the course of development, rotor speeds have been increased from approx. 30,000 rpm originally to 160,000 rpm today. However, this has only been possible by simultaneously reducing rotor diameter. Economical running behavior can only be achieved by keeping in observation the effects of process

parameters on yarn properties and raw material [iv], [vi].

Many researchers reported the influence of rotor speed on yarn properties. Like, Roudbari found that fibre orientation deteriorated with increase in rotor speed, rotor diameter and use of grooved navel [vii], [viii]. Koc and Lawrence also reported formation of Wrapper fibres at higher rotor speeds because of augmented centrifugal force [ix], [x]. On the other hand increment in Yarn Production was observed at higher rotor speeds, which turned down with increase in yarn twist at same rotor speed [vi], [xi], [xii], [xiii]. It has also been reported that knit ability of open end yarns affected as rotor speed and fiber denier increased [xiv].

According to Arain and Barella rotor speed affects yarn tenacity, elongation and regularity in a linear manner [vi], [xv]. While Manohar, Rakshit and Balasubramanian concluded that, rotor speed had insignificant effect on yarn strength however, elongation brought down steeply with increase in rotor speed [xvi]. Vila and Trajkovic stated that rotor speed, rotor diameter and preparatory process influenced hairiness of rotor yarns [xvii], [xviii]. Whereas Ahmed and Palamutcu found that rotor speed, fiber type and twist factor are the most important parameters, that affects twisting efficiency of pure cotton and cotton/polyester blended rotor yarns [v], [xix].

In this study effects of rotor speed i.e. up to 10, 0000 rpm on 100% cotton yarn properties spun for knitting, were systematically investigated. In order to validate our research work yarns with three different linear densities (i.e. 30, 35 and 40 tex) were spun at four selected rotor speeds (i.e. 70,000, 80,000, 90,000, and 10, 0000) rpm.

## II. MATERIALS AND METHOD

### 2.1 Preparation of yarn samples

100% cotton with principal characteristics mentioned in Table 1. was processed through Rieter blow room line (consisted on mixing bale opener MBO, Uniclean B11, Mixing opener MO, Uniflex B60) followed by card (C-51) to produce card slivers of 4

Ktex. In order to get even and homogeneous drawn slivers, carded slivers were processed twice; through drawing machine (RSB D-35). These drawn slivers were used to spun yarns of selected linear densities (i.e. 40, 35 and 30 tex) and rotor speeds (i.e. 70000, 80000, 90000, and 100,000 rpm) on up to date Rieter (R-40) rotor spinning machine. Twist level for all yarn samples was kept at 600 tpm. Twenty samples for each type of yarn were prepared. Different settings of rotor machine for all yarn samples are mention in Table II.

TABLE I  
HVI RESULTS OF COTTON

PROPERTY	RESULT
Yellowness (degree)	8.91
Strength (g/tex)	30.51
Uniformity Index (%)	83.30
Micronaire Value (micro-gram/inch)	4.70
Upper Half Mean Length (mm)	28.04
Maturity Index (-)	0.91
Spinning Consistency Index (-)	134
Trash Count (number)	33
Reflectance (%)	74.70
Short Fiber Index (%)	8.31

2.2 Testing of samples

Determination of yarn strength and elongation at break were carried out on Uster Tensorapid-4 as per standard test method ISO 2062:1993 [xx]. Randomly selected ten packages from each yarn sample were conditioned for 48 hours, and put to test at a speed of 5000 mm/min with adjusted gauge length of 500 mm between the clamps. Twenty specimens were taken from each of the ten packages selected for testing, thus an average tensile strength was determined from 200 entries. Similarly; Uster Tester-4 was used to determine CVm%, total imperfections (thin places, thick places neps) and hairiness at a speed of 400 m/ min through respective passage and capacitor as per ISO 16549:2004 [xxi] test method. Each result is an average of 10 readings taken from 10 yarn packages.

III. RESULTS AND DISCUSSION

To scrutinize the effect of rotor speed on rotor yarn quality parameters, 100% cotton material was spun with three different linear densities at rotor speeds of 70000, 80000, 90000, and 100000 rpm. Twist level for all the yarn samples was kept at 600 tpm. Outcomes obtained are reported in Fig. 1-5.

TABLE II  
SETTINGS OF PROCESS PARAMETERS FOR 100% COTTON YARN SAMPLES

Twist levels (tpm)	600
Hank Sliver (ktex)	4
Rotor Diameter (mm)	31
Rotor Type	GB
Navel	K4K R
Torque Stop	w-3
Rotor speed (rpm)	70,000
Delivery Speed (m/min)	116.66
Rotor speed (rpm)	80,000
Delivery Speed (m/min)	133.33
Rotor speed (rpm)	90,000
Delivery Speed (m/min)	150
Rotor speed (rpm)	100,000
Delivery Speed (m/min)	166.66

3.1 Influence of rotor speed on strength and elongation

Rotor speed's influence on yarn strength and elongation are presented in Fig. 1 and 2 respectively. According to Fig. 1. values of yarn strength for all linear densities increases with increasing rotor speed from 70,000 to 90,000 rpm. However, a sudden down fall in yarn strength is experience as the rotor speed increases from 90,000 to 100,000 rpm. It is also evident from Fig. 1 that at rotor speed of 90,000 rpm maximum yarn strength obtained for all linear densities.

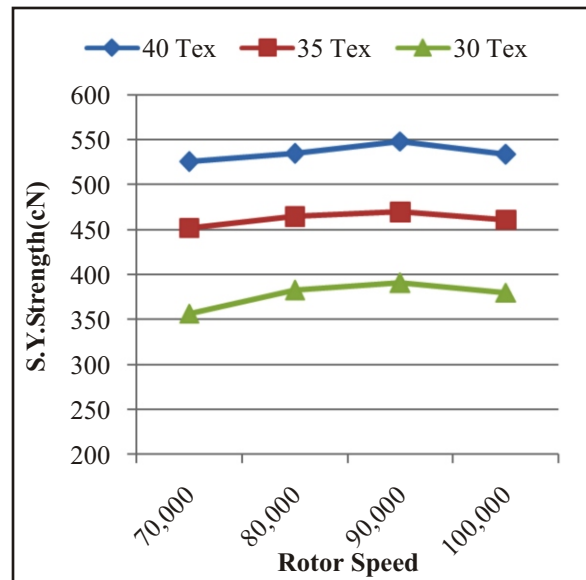


Fig. 1. Influence of rotor speed on single yarn strength

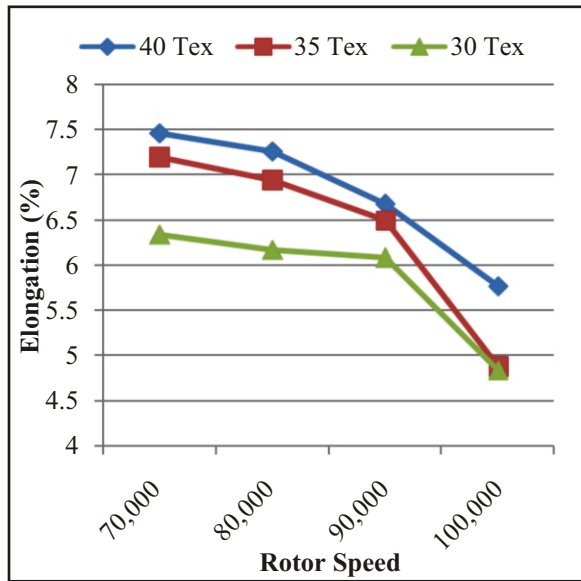


Fig. 2. Influence of rotor speed on yarn elongation

On the other hand values of elongation decreases with increasing rotor speed from 70,000 to 100,000 rpm for all linear densities. It is clear from the Fig. 2 that maximum values of yarn elongation are at a rotor speed of 70,000 rpm.

On increasing rotor speed Centrifugal force (g.tex) increases which in turn increases the number of wrapper fibers per unit length [vi], [xxii]. These wrappers act like constriction on the yarn whilst the flow of the strain along the length of fibers, this provides supplementary binding to the yarn. Further at higher rotor speeds higher frequency of wrapping occurs [ix], [xxiii] which contributes in better fiber consolidation and strength up to 90,000 rpm.

However, by increasing rotor speed above 90,000 rpm, centrifugal force and spinning tension get further intensify which increases the pressure of yarn on navel. Higher centrifugal force deteriorates fibre orientation and instead of getting set down in single file they get deposited in bunches at rotor groove [xxiv], [xxv]. This disturbs the binding effect of fibers and their sharing towards yarn strength, which is the reason of sharp decline in strength after 90,000 rpm. However, this is not true for coarser yarns, since due to greater yarn diameter and more number of fibers in cross-section they can withstand against high yarn tensions up to certain limits as compared to fine counts.

It is apparent from Fig. 2 that yarn elongation is brought down moderately with increasing rotor speeds at all linear densities.

Actually by increasing twist factor, angle between yarn axis and fiber spiral position gets increase, which perks up the springy behavior of fibers and responsible for higher elongation [vi], [xxvi]. Similarly, at higher linear densities fiber owes enhanced elongation and improved cohesion force in between them due to

greater number of fibers per unit cross section [vi], [xxvii], [xxviii].

However, at high rotor speeds the fibres are peeled off and twisted at higher tension which created a permanent strain in the yarn. This higher spinning tension straightened the curliness in fibres provided increased centrifugal force made the yarn more compact. Combine effect of both factors lessened the fiber slippage during tensile testing which in return reduced the elongation [xxv], [xxvii].

Almost Similar trends of rotor speeds on yarn strength and elongation are observed at all linear densities i.e. 40, 35, and 30 tex.

### 3.2 Influence of rotor speed on yarn mass variation, imperfections and hairiness

To analyze rotor speed's impact on mass variation, hairiness and total imperfections of yarn, comparison of data reported is made in Fig. 3, 4 and 5. According to results shown in Fig. 3 coefficient of mass variation slightly decreases by increasing rotor speed from 70,000 to 90,000 rpm and then sharply amplify at 100,000 rpm for all linear densities. This means that Yarn irregularity for cotton is slightly improved up to 90,000 rpm but after that it is degraded markedly. Actually By increasing rotor speed number of wrapper fibres/unit length and frequency of incidence of wrapper fibres increases. Provided less time is allowed to the fibers to align them in rotor groove which deteriorate their arrangement [vi], [ix], [xxix]. Furthermore, fast rotor speed increases the twisting torque at the yarn formation point which produces the yarn with poor fiber orientation and results in intensified irregularity and imperfections [ii], [xxx].

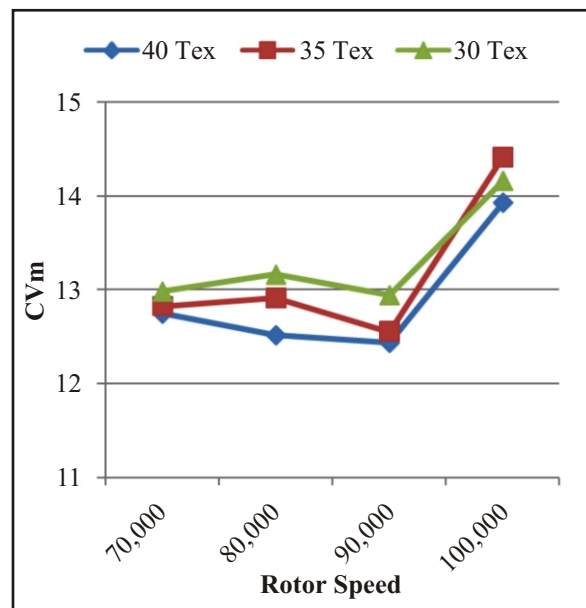


Fig. 3. Influence of rotor speed on Cvm

It is evident from Fig. 4 and Table III that total imperfection of yarns continuously increases as the rotor speed accelerating from 70,000 to 100,000 rpm. However, increase in imperfection is steady when rotor speed increasing from 70,000 to 90,000 rpm but it shows a sharp rise at speed of 100,000 rpm. Trend of change in imperfections is similar for all linear densities with increasing rotor speeds. However, a marginal decrease in TIPI was observed with increasing yarn linear density at lower rotor speed.

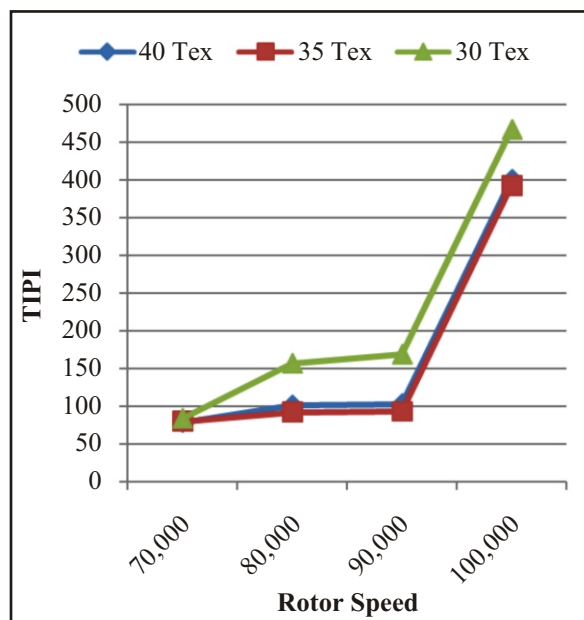


Fig. 4. Influence of rotor speed on total imperfection

Higher rotor speed results in more number of tight belts on yarn surface, which are counted by evenness tester as imperfection, in particular as neps. This steep increase in neps is partly because of close wrapping of wrapper fibres, which increases the mass and these places get counted as neps. Such neps generation rise markedly at high rotor speeds because of higher false twist and consequently higher incidence of wrapper fibres [vi], [ix]. Furthermore, higher rotor speeds reduces the short-term uniformity and fiber parallelization [xviii].

It is clear from Fig. 5 that hairiness decreasing or improving as the rotor speed increasing from 70,000 to 90,000 rpm and then increases at 100,000 rpm for all yarn samples. This significant effect of rotor speed on hairiness can be discussed as actually, negative role of speed was subsided by twist factor up to 90,000 rpm which improved the hairiness due to yarn compactness but at last step rotor speed's aspect became dominant on compactness factor and consequently hairiness increased as a result of greater disorientation in fiber arrangement. Provided on raising rotor speed hooks got less time to straighten out.

It is also apparent from the Fig. 5 that with increase

in yarn linear density, hairiness increases owing to greater number of fibers per unit cross section, which results in more protruding ends from yarn surface.

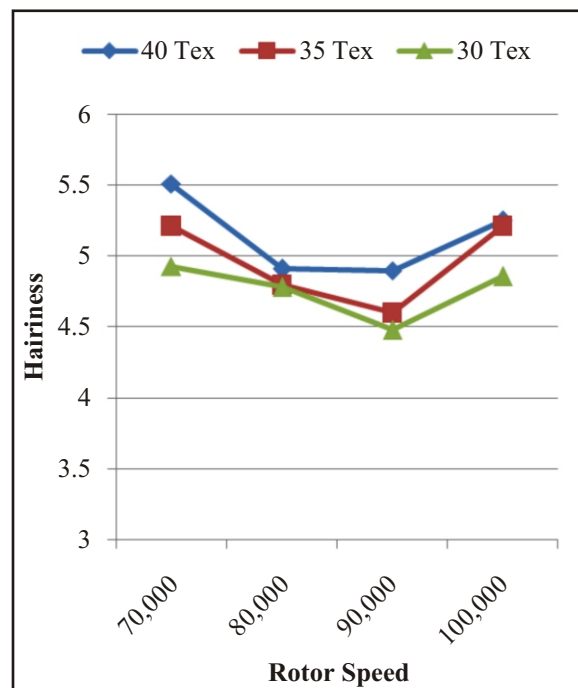


Fig. 5. Influence of rotor speed on hairiness

#### IV. CONCLUSION

Results discussed above reveal that Tensile strength of rotor yarn enhances when rotor speed increases from 70,000 to 90,000 rpm; however, a sharp downfall in strength is observed when speed is further raise to 100,000 rpm. Elongation reduces steadily by accelerating rotor speeds from 70,000 rpm to 100,000 rpm. Coefficient of mass variation slightly improves up to 90,000 rpm but after that it degrades moderately. Total imperfection index continuously increase with increasing rotor speed. Furthermore, hairiness improves slightly with increasing pace of rotor for all linear densities.

TABLE III  
INFLUENCE OF ROTOR SPEED ON THICK PLACES, THIN PLACES AND NEPS

Y.L.D (tex)	40				35				30			
Rotor rpm in thousands	70	80	90	100	70	80	90	100	70	80	90	100
Thick	2.25	10.75	11.75	50.77	6.5	10.88	9.76	39.25	12.53	15.25	14.25	45.85
Thin	14.75	28.55	28.44	120.34	18.25	25.75	24.67	85.22	28.83	42.75	43.25	99.75
Neps	33.50	62.50	62.85	230.25	46.25	66.65	70.45	276.55	50.55	95.25	95.89	259.97

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