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Study on the Change in Characteristics of Ring Yarn during Post Spinning and Yarn Dyeing Operations

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Abstract
The origin of yarn hairiness has been attributed to the escape of fibres from the twisting action from within the spinning triangle. The protruding fibres entangle themselves due to the rubbing of yarn with parts of the machinery during post spinning operations and form thin places, thick places and neps. In this study, cotton combed yarns were produced by removing 14, 16 and 18% of the noil at the comber. These samples were dyed before and after singeing. The hairiness, imperfections and tenacity of the yarns were measured. The results revealed that an increase in comber noil causes a decrease in imperfections at the ring bobbin stage. The imperfections changed at different stages of post spinning operations and dyeing, and finally the difference was not appreciable, especially when the noil % was extracted beyond a certain level. The tenacity of yarn decreased when the ring bobbin was converted into a cone form, singed and dyed. Removal of a higher level of comber noil or singeing did not make a significant difference at the dyed yarn stage, although there was difference at the ring bobbin and cone stages.

Key words: *yarn abrasion, cone winding, hairiness, ring spinning, ring yarn, singeing, yarn imperfections, yarn tenacity, yarn dyeing.*

Introduction

The ring spinning system remains the principal method of yarn production as it spins different fibres over a wide range of yarn counts and end use applications. However, the conventional ring spinning system has several limitations, one of which is the poor integration of fibres that protrude from the yarn surface, causing yarn hairiness [1]. Hairiness is an undesirable property of yarn, and it has always been a matter of concern to improve yarn quality [2]. Hairiness with a shorter length of fibre is preferred in knitted fabrics for softer feel of the fabric. However, hairy fibres which have a length of 3 mm and above increase yarn imperfections in post spinning operations. Although short hairs enhance certain aspects of comfort in fabric, the presence of long hairs affects the appearance of yarn and increases the surface friction of the yarn and fabric, forming pilling [3].

Yarn hairiness has been shown to negatively affect the properties of the resultant fabric, particularly in terms of pilling propensity [4-6]. Baird et al [4] illustrated that the magnitude of pilling is dependent on the number as well as length of protruding hair fibres. The passing of yarn through a number of guiding elements is unavoidable in winding, weaving and chemical processing. The protruding fibres are subjected to entanglement, removal or agglomeration during these processes, which cause thick, thin and neps, repectively. The origin of yarn hairiness has been attributed to the escape of fibres from the twisting action from within the spinning triangle [1]. The geometry of this spinning triangle has been proven to be decisive in influencing several yarn properties, including yarn hairiness. Further development of ring spinning was designed to decrease the spinning triangle by using other new systems such as the solo spun system [7], compact or condensed spinning system [8], and the jet ring spinning system [9-13] to overcome this inherent problem of conventional ring spinning.

Although there are many processes for the preparation of yarns and fabrics, it is necessary to determine the type of preparation to obtain the desired properties of yarns and fabrics as these preparations affect the surface of the yarn and, thus, the surface of the fabric [14]. Post spinninig operations develop the hairiness of yarn which depends on the physical and technological characteristics of the raw material, the method of spinning preparation, and the type of spinning system. Moreover it can be removed by singeing [15, 16]. It is believed that the removal of hairy fibres by the singeing process after cone winding may definitely reduce the chances of the creation of yarn faults. Singeing is applied on yarn and fabric to remove hairiness on their surface [2, 16, 17]. Longer hairs might be easily affected by the flame, removing a large amount of hairiness from the yarn, which may affect its different properties, such as ap-

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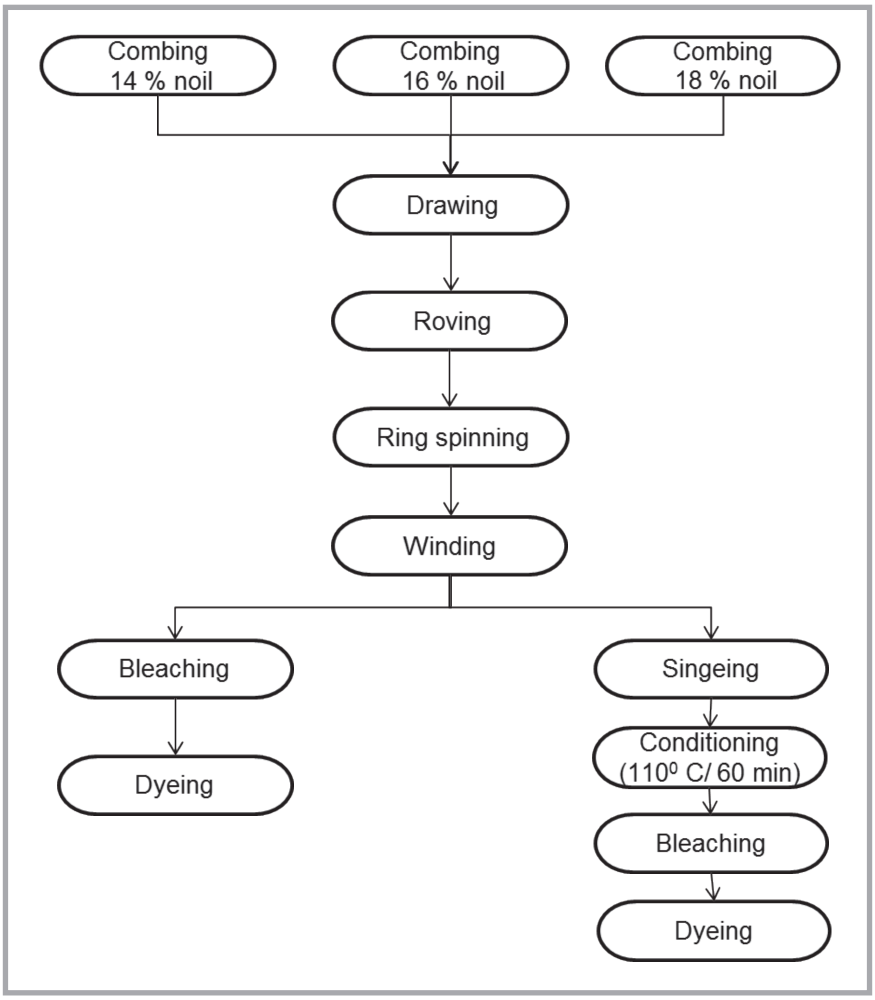


__Figure 1.__ Experimental arrangement of yarn preparation.

pearance, fineness, evenness and tensile properties [2].

Stanisław Lewandowski et al [18, 19] analysed the parameters of the spinning process in relation to the quality of yarn and the efficiency of production, and it was confirmed that the percentage of noils and the metric coefficient of the twist were important factors. A comparative analysis of selected physical proprieties of both classic and compact cotton yarns of nominal linear mass of about 20 tex was conducted by means of statistical models based on multiple regression. The analysis of results obtained showed that the statistical models proposed were very useful in making a qualitative and productive comparison of the yarns considered. Decreasing the metric coefficient of the twist – α_m and percentage noils – p_w during the production of compact yarn makes possible the obtainment of significant productive effects and lowering of the costs of producing yarn without an excessive worsening of quality.

__Table 1.__ Process parameters used for the preparation of yarn.

Comber	
Speed Linear density of lap Linear density of comber sliver	425 nips/minute 68 ktex 4.92 ktex
Post comber draw frame	
Speed Linear density of delivery sliver	350 metre/min 4.92 ktex
Roving frame	
Spindle speed Linear density of roving Twist	850 rpm 0.59 ktex 48 twist/metre
Ring frame	
Spindle speed Linear density of yarn Twist	17000 rpm 14.75 tex 905 twist/metre

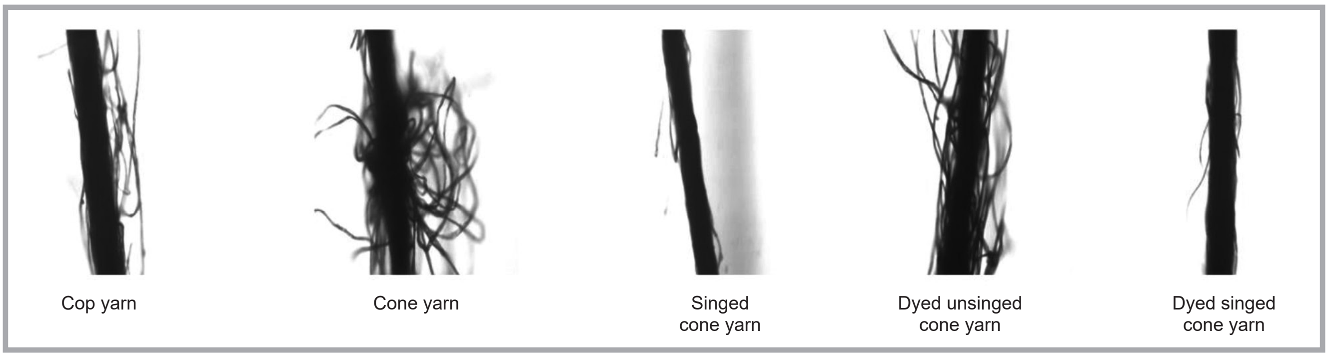
It is the normal practice in the industry to increase the noil to be removed at the comber, up to a certain level, to reduce the imperfections and increase the tenacity and uniformity of yarn. However, hairy fibres present in the yarn increase the imperfections when they are rubbed against a number of guiding elements in subsequent processes. It is now suspected whether lower imperfections achieved at the ring bobbin stage by removal of a higher noil % at the comber is maintained at a lower level during the post spinning and wet processing operations or not. There is the option that yarn may be singed to address the problem due to the increase in imperfections during post spinning and dyeing processes.

Numerous research works have been carried out to reduce yarn imperfections by various means. Compact or condensed spinning systems, such as Suessen EliTe®, Congnetex, and Rieter COM4 modify the drafting process of the conventional spinning frame to condense the staple fibres to achieve a much smaller spinning triangle [20]. One of the advantages of compact spun yarn over traditional ring spun yarn is the substantial reduction in yarn hairiness [20, 21]. However, a huge amount of money has to be invested for the installation of compact spinning machines or modification of existing ring spinning machines into compact spinning machines. The disadvantage of compact ring spinning is that the price of yarns produced is still too high [18]. It can be understood from the above discussion that yarn faults increases during post spinning operations due to the presence of hairs in the yarn, which can be reduced by the extraction of more noils at the comber or by singeing the yarn. Hence a study is required to understand the impact of these processes on the change in imperfections during post spinning operations. In this work, the change in imperfection of yarn due to post spinning processes and dyeing are studied. The effect of singeing on these changes in imperfections is also investigated.

Materials and methods

Preparation of yarn samples

The experimental design for preparing yarn samples is shown in ***Figure 1***.


Cop yarn

Cone yarn

Singed cone yarn

Dyed unsinged cone yarn

Dyed singed cone yarn

Figure 2. *Surface hair profile of different forms of yarn at 10X magnification.*

The specifications of cotton fibre used in this study are as follows: variety, MCU5; 2.5% span length, 30.14 mm; fineness, 3.73 micronaire; fibre tenacity, 20.4 cN/tex; uniformity ratio, 0.47. The material was processed through a blow room line, card, draw frame and super lap former. Combed cotton slivers were produced by removing 14%, 16% and 18% of the noil at the comber. The process parameters used for the preparation are given in ***Table 1***.

A spacer of 3.5 mm thickness and an 8/o traveler were used in the ring frame to produce yarn. The ring spun yarn was converted into a cone using an autoconer at a drum speed of 1350 mpm (metres per minute). A set of these cone yarns were singed to burn protruding hairs on the surface of the yarn, and another set was kept for dyeing without singeing. The singeing process parameters are given as follows: winding speed: 600 mpm, and LPG gas & air mixing ratio 1:30. The singed yarn was steam set at the following conditions to avoid snarling: steaming temperature: 110 °C, pressure: 2-3 bar, and time: 1 hour. These singed and unsinged cone yarns were bleached and dyed in a package dyeing machine. Bleaching was carried out at 95 °C for 45 min using the following recipe: soda ash: 3%, wetting oil: 0.75%, sequestering agent: 0.5%, hydrogen peroxide: 2%, and peroxide stabilizer: 0.5 %. The bleached yarn samples were then dyed with reactive dye at 5% conc. for 90 min at 60 °C. In total, 15 yarn samples were produced, as per the plan given in ***Figure 1.***

Testing of samples

The yarn samples were tested for CVm % and imperfections using an Uster Tester 3 at a test speed of 400 m/min for 1 min. Tensile properties of the yarns were measured using an Uster Tenso Rapid 3 at a test speed of 5000 mm/min and gauge length of 500 mm. The hairiness count was measured using a Zweigle hairiness tester. The test was carried out with the following test parameters: pretension 5 cN and sample length 100 m. The sample size was 10 for the imperfection and hairiness tests and 100 for the tensile testing.

Statistical analysis

An ANOVA test was carried out at a 5% significance level to test whether there was any significant difference between the treatments of yarn samples at different noil %.

Results and discussion

Hair count (S3)

The number of protruding fibres of a length more than 3 mm (S3) per 100 m of yarn samples tested using the Zweigle hairiness tester is given in the ***Table 2.*** The results show that the number of hairs present in the yarn produced with 14% noil extraction is higher (~15%) than that with 16% and 18%. The S3 value increases more than two-fold when the yarn in the ring bobbins is converted into a cone form. This increase in hairiness is due to the rubbing of yarn over the guiding elements of the cone winding machine. However, the increase is not proportional between the ring bobbin and cone for different noil levels. The S3 value of yarns increases by about 50% when the unsinged cone yarn is dyed. This might be because of the abrading of yarn with machine elements during preparation for dyeing and flow of dye liquor through the cones. It can be seen that the S3 difference between the dyed yarns at different noil levels is not significant. There is a tenfold reduction in the S3 value when the cone yarn is singed, due to the removal of hairs during the singeing process. The S3 value increases four-fold when the singed yarn is dyed. However, the S3 values of singed and dyed yarn are four times less than that of dyed yarn produced from unsinged yarn. There is no significant difference due to comber noil in singed dyed yarns (p value = 0.4973) and unsinged dyed yarns (p value = 0.1417). Surface hair profiles of yarns at different stages are shown in ***Figure 2*** at 10X magnification.

The hairs present in unsinged cone yarn are more numerous, and the appearance of the surface is fuzzier than for ring bobbin yarn. The surface of singed cone yarn is smooth, and hairs are not present due to their removal off by the burning process. The appearance of singed dyed yarn is smoother than that of unsinged dyed yarn. It can be inferred from the results that singeing causes a significant reduction in the hairiness of yarn as well as fewer imperfections at the dyed yarn stage as compared to the higher level of noil removed at the comber.

Yarn imperfections

The imperfections of yarn at different stages viz., ring bobbin, unsinged cone, singed cone, dyed yarn from the unsinged cone, and dyed yarn from the singed cone, produced at three levels of comber noil % viz., 14%, 16%, and 18% are given in ***Table 2.*** It can be seen from the table that the total imperfections in the ring bobbin yarn decrease as the comber noil % is increased, which is obviously due to the removal of more short fibres. The imperfections, specifically neps present in the yarn, increase (~25%) during winding, and there is a significant difference in imperfections due to the different noil %. Subramanian et al [22] studied the variation in the level of imperfections due to the winding of ring bobbin yarn and observed that there is a significant increase in imperfections due to winding; the increase is more pronounced in combed yarn compared to carded yarn.

***Table 2.** Yarn imperfections, tenacity and hair count.*

Yarn samples	Noil %, p_w	Thin places/km, -50%	Thick places/km, +50%	Neps/km, +200%	Total imperfections/km	Tenacity, cN/tex	Hair count, S3
Ring bobbin	14	4	98	164	266	14.65	397
	16	4	65	96	165	15.72	342
	18	2	50	94	146	15.37	342
Unsinged cone	14	4	88	205	297	12.86	1107
	16	6	61	140	207	15.48	995
	18	4	50	127	181	14.25	1139
Dyed unsinged cone	14	4	63	190	257	14.58	1620
	16	4	68	148	220	14.86	1722
	18	3	50	132	185	13.47	1699
Singed cone	14	8	83	168	259	12.63	91
	16	3	66	104	173	14.05	127
	18	8	55	82	145	13.69	106
Dyed singed cone	14	8	83	145	236	12.58	454
	16	4	72	113	189	12.47	469
	18	13	67	93	173	13.34	482

***Table 3.** ANOVA test results.*

Parameters	F calculated	F critical	P value
Between noil levels (ring bobbin)	44.2132	3.354	3.03594E-09
Between noil levels (cone)	31.92	3.354	7.69443E-08
Between noil levels (cone singed)	33.75	3.354	4.51471E-08
Between noil levels (dyed unsinged cone)	6.623	3.354	0.00456
Between noil levels (dyed singed cone)	6.094	3.354	0.00654

The table shows that the neps present in singed cone yarns is lower (~30%) than for unsinged cone yarns, which is due to the removal of hairs and neps during the singeing process. However, improvement could not be detected in thin and thick places. The increase in neps can be attributed to the conversion of hairs into neps due to the abrasion of yarn against the guiding elements of the winding machine. The increase in thin places is due to the removal of fibres during abrasion, which causes a smaller reduction in yarn diameter. The thick places could be due to the accumulation of fibres at a place in the yarn or the accumulation of hitherto neps into thick places due to a change in dimension.

It can be seen from the table that imperfections increase marginally in most cases during the dyeing of yarn due to the preparation of yarn for dyeing and the process of dyeing. Imperfections are higher for yarns which are dyed from unsinged cones as compared to those of singed cone yarns. The imperfections of unsinged dyed yarn with 18% noil removed are nearly the same as those of singed dyed yarn with 16% noil removed. A similar trend is found between singed and unsinged cone yarns. When hairy fibres are removed by the singeing process, the chances of entanglement will be less, which causes fewer neps in the yarn after singeing.

ANOVA was performed on the imperfections of yarn for various noil levels in different treatments. The F values and P values of ANOVA are tabulated in ***Table 3.***

The difference in imperfection due to different comber noil % is found to be higher at the ring bobbin yarn (p = 3.03594E-09) and unsinged cone stages (p = 7.69443E-08), which is normally measured for assessing the quality of yarn and for quality control. However, the difference decreases at the final stage i.e. dyed yarns (p = 0.00456, 0.00654). A higher difference is found when the yarn is dyed from an unsinged cone (p = 0.00456) as compared to a singed cone (p = 0.00654). Hence it can be inferred that an increase in the comber noil shows a decrease in imperfections at the ring bobbin stage. However, the level of imperfections changes at different stages of post spinning operations and dyeing, and finally the difference is not appreciable, especially when the noil % is extracted beyond a certain level i.e. between 16% and 18%.

Tenacity

The tenacity (cN/tex) of yarn samples is given in ***Table 2.*** Statistical analysis, ANOVA, was conducted on the change in tenacity due to that in noil %. It indicates that there is a significant difference in the tenacity of ring bobbin yarn in relation to the noil % (p = 4.639E-11). However, a relation could not be found between the change in noil % and that in the tenacity value.

The results show that the tenacity decreases when the cop is converted into a cone form, which may be attributed to increasing imperfections during this process. The tenacity further decreases when the cone yarn is singed, which may be due to the burning of surface fibres and weakening of the interlacement of fibres in yarn. Furthermore, in most cases, the tenacity decreases due to the dyeing of yarn, swelling of yarn, and hence to the decrease in cohesion between fibres in the yarn. It can be inferred from the results that the singeing and dyeing processes decrease the tenacity of yarn.

In practice, the comber noil % is optimised based on the level of imperfections, tenacity and evenness of yarn required at the ring bobbin or cone yarn stage. However, these yarns undergo different processes before reaching the finished fabric. The yarns rub against parts of machinery, and surface fibres emerge as hairy fibres. When these hairy fibres are entangled, removed or agglomerated during rubbing against machine elements, they form thick, thin and neps. As there is no appreciable difference in the quality of yarns at the dyed yarn stage, the removal of a higher level of comber noil or singeing are not required to produce high quality ring bobbin yarns meant for yarn dyeing.

Conslusions

Yarns were produced at different comber noil%. They were dyed in two stages: (i) before singeing and (ii) after singeing. The following conclusions are drawn from the results.

- The hair count (S3) of ring bobbin yarn decreases with an increase in comber noil, and it increases by more than two-fold when the yarn is converted into a cone form. There is a tenfold reduction in S3 when the cone yarn is singed. The S3 increases by about 50% when the unsinged cone yarn is dyed. The S3 value increases four-fold when the singed yarn is dyed. The S3 of dyed yarn produced from singed yarn is four times lower than that produced from unsinged yarn.

- The total imperfection in ring bobbin yarn decreases as the comber noil % is increased. The imperfections, specifically neps present in the yarn, significantly increase during winding. Neps present in singed cone yarns are lower than in unsinged cone yarns. Imperfections increase marginally in most cases during the dyeing of yarn due to the preparation of yarn for this and the process of dyeing.
- Imperfections are higher for yarns dyed from unsinged cone yarns compared to singed cone yarns.
- An increase in comber noil shows a decrease in imperfections at the ring bobbin stage. However, the level of imperfections changes at different stages of post spinning operations and dyeing, and finally the difference is not appreciable.
- The tenacity of yarn decreases when the ring bobbin is (i) converted into a cone form, (ii) singed, and (iii) dyed.

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