Beltran, Rafael, Wang, Lijing and Wang, Xungai 2007, Controlled experiment on yarn hairiness and fabric pilling, *Textile research journal*, vol. 77, no. 3, pp. 179-183.

# A CONTROLLED EXPERIMENT ON YARN HAIRINESS AND FABRIC PILLING

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## ABSTRACT

This study is focused on the hairiness of worsted wool yarns and how it affects the pilling propensity of knitted wool fabrics. Conventional worsted ring spun yarns are compared with comparable Solospun$^{TM}$ yarns and yarns modified with a hairiness reducing air nozzle in the winding process (JetWind). Measurements of yarn hairiness (S3) on the Zweigle G565 hairiness meter shows a reduction in the S3 value of approximately 46% was achieved using Solospun$^{TM}$ ring spinning attachment and a 33% reduction using the JetWind process. Interestingly, subsequent evaluation of the pilling performance of fabrics made from the Solospun$^{TM}$ spun yarn and JetWind modified yarn showed a half grade and full grade improvement respectively, over a similar fabric made from conventional ring spun yarns. This result suggests that a relatively large reduction in yarn hairiness is needed to achieve a moderate improvement in fabric pilling, and that the nature of yarn hairiness is also a key factor in influencing fabric pilling propensity. It is postulated that the wrapping of surface hairs by the air vortex in the JetWind process may limit the ability of those surface fibers to form fuzz and reach the critical height required for pill formation.

**Key words:** Yarn hairiness, pilling, ring spun, Solospun, JetWind, air nozzle.

# INTRODUCTION

Ring spinning remains the dominant method of yarn production. This system, unlike any other system, lends itself to the processing of different fibers over a wide range of yarn counts and end use applications. However the conventional ring spinning system is disadvantaged by several limitations, one of which is the poor integration of many fibers that protrude from the yarn surface causing yarn hairiness [15, 8]. Yarn hairiness has been shown to negatively affect the properties of the resultant fabric, particularly in terms of pilling propensity [2, 3, 12].

Analysis into yarn hairiness modification by [3] suggests that hair fiber length is of most significance, with fibers protruding from the yarn core more than 3mm affected most. Similarly in an investigation of the pilling of nylon and nylon blended fabrics, Baird *et al* [2] illustrate that the magnitude of pilling is likely dependent on the number as well as the length of protruding hair fiber.

The origin of yarn hairiness has been attributed to the escape of fibers from the twisting action from within the spinning triangle [9, 15]. The geometry of this spinning triangle has been proven to be decisive in influencing several yarn properties including yarn hairiness. These findings have instigated development of new systems to overcome this inherent problem of conventional ring spinning.

The Solospun™ system uses a spinning frame attachment consisting of a pair of slotted rollers. According to Prins et *al* [10], the slotted roller used for Solospun confers greater fiber security within the yarn formation zone, resulting in fewer protruding fiber ends per unit length. A comparison of the hairiness of Solospun™ and ring spun yarns by Chang and Wang [5] shows that Solospun™ yarns have fewer hairs in various hair length groups and a lower coefficient of variation of hairiness. Similarly, Cheng *et al* [7] reports reduced yarn hairiness of Solospun™ yarns over ring spun, especially in the instance of long hairs.

Compact or condensed spinning systems such as the Suessen EliTe®, Congnetex, and Rieter COM4, modify the drafting process of the conventional spinning frame to condense the staple fibers to achieve a much smaller spinning triangle [11]. One of the advantages of the compact spinning system over traditional ring spun yarns is a substantial reduction in yarn hairiness [4, 11].

Another modification of the ring spinning system is the JetRing spinning system first introduced by Wang *et al* [13]. Using a single air jet nozzle below the spinning triangle an upward swirling flow of air is introduced against the yarn movement, wrapping the surface hair fibers and reducing yarn hairiness. Wang *et al* [13] reported approximately 40% reduction in yarn hairiness with this setup. Further development of the JetRing principle by Wang and Miao [14], used the concept of "winding assisted by an air jet" or 'JetWind' to simultaneously false-untwist a yarn and wrap protruding fiber ends around the yarn during the process of winding. Using a modified version of this setup, Khan [8] reported that this form of post spinning yarn engineering reduced the S3 hairiness value of a 12.5 tex worsted spun yarn by almost 40% over the equivalent conventional ring spun yarn. A subsequent evaluation of the process on the pilling propensity of fabric knitted constructed from rotor yarns reported of a full grade improvement using the ICI pilling box method. Khan [8] attributed this improvement in pilling to the reduction in yarn hairiness over the original rotor spun yarn.

This paper aims to quantify the impact of yarn hairiness on fabric pilling through a controlled experiment, using 100% wool as the fiber material. We compare conventional worsted ring spun yarns with yarns produced by two hairiness reduction techniques, namely, Solospun™ ring spun yarns, and JetWind modified yarns. We then evaluate the hairiness of yarns produced from each process, and assess whether any reduction in hairiness has resulted in significant changes in the pilling propensity of fabrics knitted from the yarns.

# MATERIALS AND SAMPLE PREPARATION

Figure 1 outlines the experimental design.

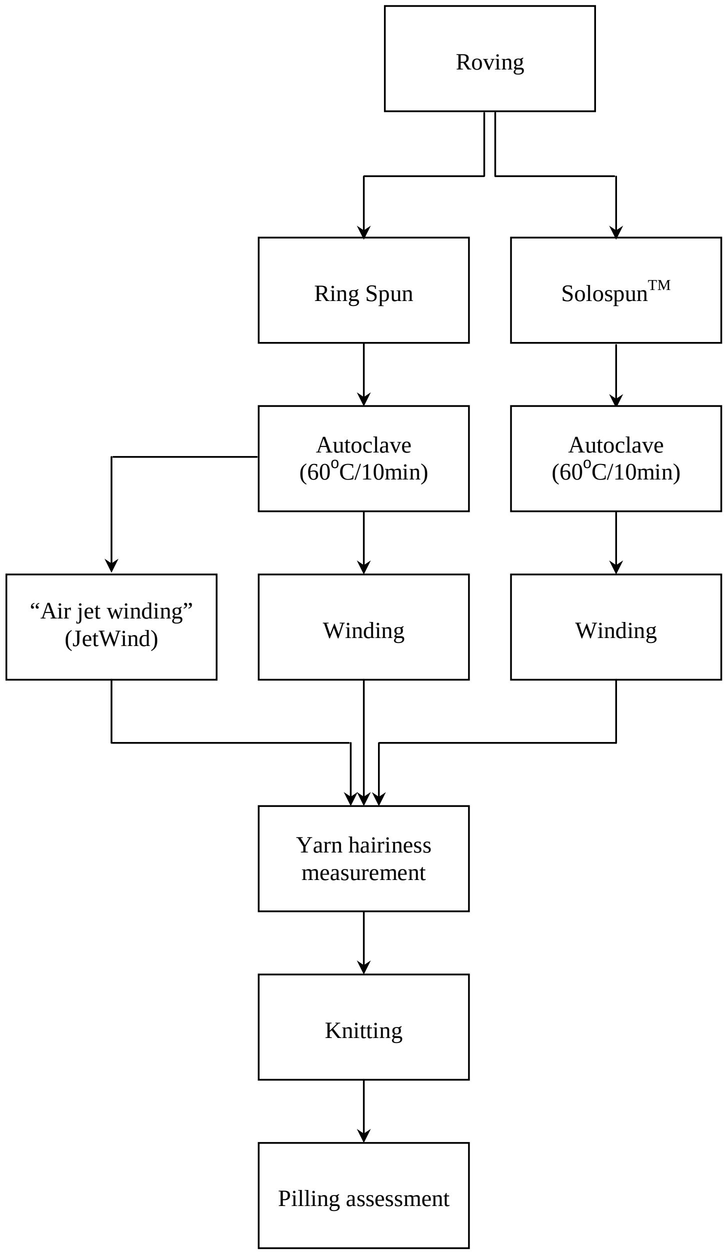


Figure 1. Flow-chart of the experimental design.

We spun the yarns from shrink-resist treated wool rub rovings. The specifications of the roving were as follows: fiber diameter 19.1μm, CV of diameter 21.08 %, mean Hauteur 71.2mm and linear density 0.49g/m (490 tex).

We used a 6-spindle SDL lab spinner in this study, and fitted a pair of Solospun™ rollers to the lab spinner in accordance to the description by Prins et *al* [10]. We produced ring spun and Solospun yarns simultaneously using identical machine settings. Twist and spindle speed were maintained at 510 t.p.m ($\alpha$-80) and 7000 rpm respectively. A total draft of 19.6 was employed to produce yarns of a linear density of 25 tex. The traveller weight used was number 26[#].

The steamed conventional ring spun yarns and Solospun™ yarns were wound on a Murata cone winder at a speed of 200m/min. In a separate step we also ran the conventional ring spun yarns through a modified Murata automatic cone winder. This process, referred to as "JetWind", consisted of an air jet nozzle located in the yarn path (Figure 2). We used an air nozzle pressure of 0.7 bar in the experiment. Winding on this modified set up was similarly conducted at a speed of 200m/min to reduce any variability derived from differences in winding speeds.

We knitted yarns from each processing methodology into single jersey fabrics on a circular weft (Mesdan Lab Knitter 294E) with a needles gauge of 36, with a constant cover factor of 1.27mmtex (5.5mm stitch length). The fabrics were subsequently finished through a process of steaming and pressing. No chemical agents that could influence the pilling outcomes were applied during sample preparation.

We conditioned the resulting fabrics in a standard atmosphere of $20^{o}C \pm 2^{o}C$ and 65% ± 2% for a minimum period of 24 hours prior to evaluating yarn hairiness and fabric pilling propensity.

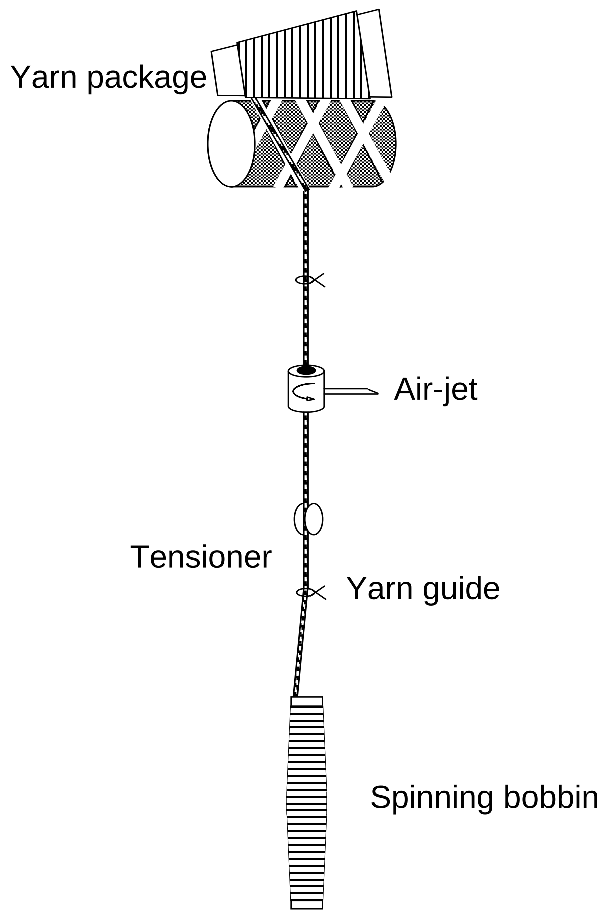


Figure 2. Schematic diagram of the JetWind process.

## TESTING METHODOLOGY

We measured the yarn hairiness on a Zweigle G565 Hairiness meter.  The S3 value (number of hairs with a length equal to or exceeding 3mm) was used as a means of comparing the hairiness level between the different yarn preparation methods. This parameter was selected on the basis of the findings by Barella *et al* [3] that indicate long hairs have much greater impact on fabric pilling tendency.  Hairiness measurements were performed on all yarns after winding.  Five measurements on each yarn type were conducted at a testing speed of 50m/min and a pretension of 5 grams over a test length of 200 meters. The average results, expressed in hairs per 100 m, were used for comparison.

We used the ICI pilling box to evaluate fabric pilling propensity. The pilling test was conducted over a period of 4 hours (14400 revolutions). Pilling assessment was performed at a commercial laboratory with reference to the ISO standard 12945-1:2000. Ratings were performed by a panel of four expert observers and the average rating was used for each fabric.

## COMPARISON OF HAIR-LENGTH DISTRIBUTION

Figure 3 gives a visual representation of the average hair length distribution of the conventional ring spun, Solospun™ and JetWind yarns after winding. Evident from this distribution is a reduction in number of hairs in each length group for the two alternative processing methodologies. The Solospun™ system can be seen to create the least number of hairs followed by JetWind which in turn shows improvement over the conventional ring spun yarn.

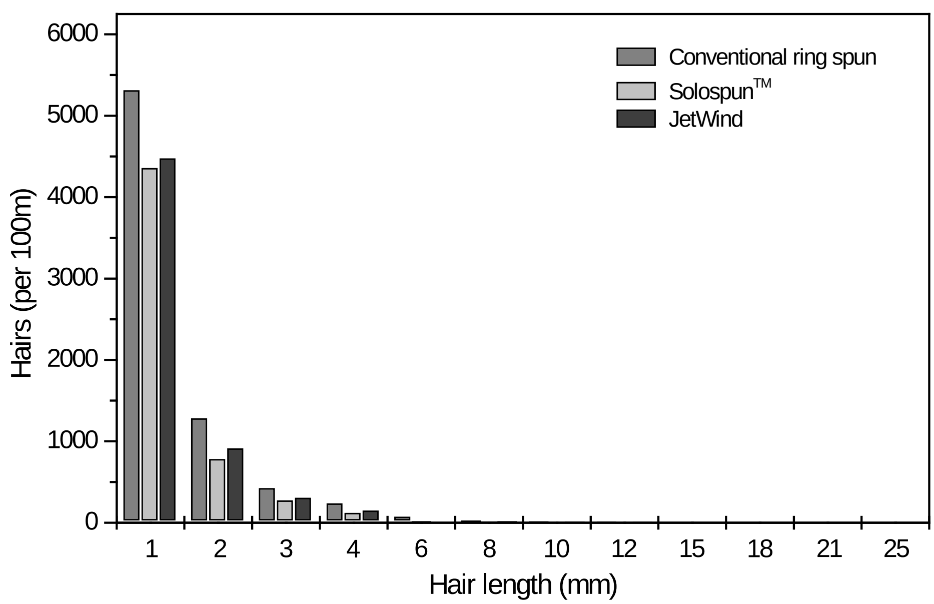


Figure 3. Comparison of the number of hairs normalised to 100 meters for the conventional ring spun, Solospun™ and JetWind yarns.

Statistical analysis in the form of an ANOVA *F* test indicates a statistically significant reduction (Table 1) in the number of hairs equal or greater than 3mm (S3) at the 95% confidence interval for the Solospun$^{TM}$ and JetWind yarns over the conventional ring spun yarn.

Table 1. Mean S3 values and corresponding hairiness reductions after winding.

| **Process methodology** | **S3/100m** | **Hairiness reduction (%)** | **Significance** |
|---|---|---|---|
| Conventional ring spun | 789 | – | – |
| Solospun$^{TM}$ | 428 | 45.8 | 0.000 |
| JetWind | 528 | 33.0 | 0.000 |

A comparison of the hairiness profiles for each yarn type can be seen in Figure 4. The hairiness characteristic of the Solospun$^{TM}$ spun yarn (Figure 4b) resembles that of a conventional ringspun yarn albeit with less hairs and a cleaner appearance. The wrapper hair fibers exhibited on the ring spun yarns wound using the JetWind method (Figure 4c) follow that detailed in Cheng and Li [6], and Khan [8] on conventional worsted spun yarns modified using the JetRing and JetWind processes.

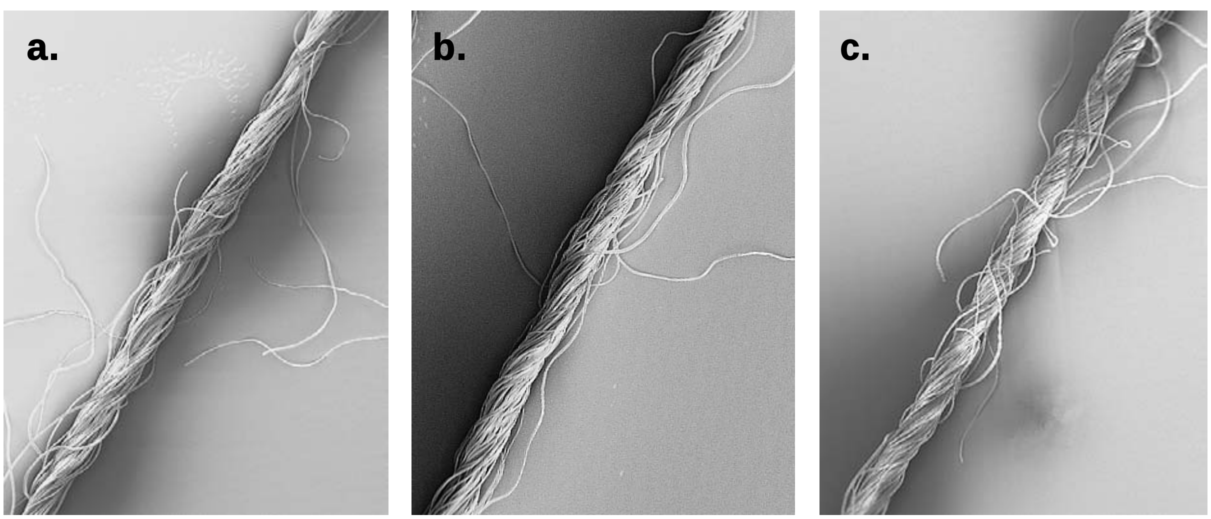


Figure 4. Representative illustrations of the hairiness characteristics of a). conventional worsted spun yarn, b). Solospun$^{TM}$ spun yarn, and c). ring spun yarn processed via JetWind set-up

The implication of hair density and length distribution on pilling propensity is subsequently addressed.

## IMPLICATIONS ON FABRIC PILLING

The effect of the resultant hair and length distribution on the fabric pilling performance is summarised in Table 2. According to the pilling test results, a reduction in pilling occurred using the Solospun$^{TM}$ yarn and JetWind yarn. To give some visual indication of the resultant pilling performance, Figure 5 depicts some representative pilled fabric samples.

Table 2. Pilling performance according to the ISO standard 12945-1:2000: ICI Pilling box method (14,400 revolutions).

| **Process methodology** | **Mean pill rating** |
|---|---|
| Conventional ring spun | 2-3 |
| Solospun$^{TM}$ | 3 |
| JetWind | 3-4 |

(a) (b) (c)

Figure 5. Examples of the presence of pills on fabric knits constituted of a). conventional ring spun yarn, b). Solospun$^{TM}$ spun yarn, and c). ring spun yarn modified via the JetWind system

The pilling results imply that relatively large reductions in hairiness are necessitated to make significant gains or the contribution of yarn hairiness to the pilling propensity of fabrics is only moderate. The half grade improvement of the Solospun$^{TM}$ yarn over the conventional ring spun yarn occurred after a 46% (Table 1) reduction in yarn hairiness (S3). Whilst the JetWind process reduced the yarn hairiness S3 value by a lesser extent (33%), a full grade improvement was noted in this instance. In each case a reduction in pilling was accompanied with the formation of little or no fuzz/pill within the pill box, indicating a slowing rate of fuzz formation and consequently pill formation.

The improved pilling performance observed with the JetWind method over Solospun$^{TM}$ suggests that the number of hairs is not the only important hairiness aspect that impacts on fabric pilling. Conceivably, what is also important is the hairiness configuration and associated fiber security within the yarn/fabric structure. The reported mechanism of hairiness reduction by means of the air jet occurs through the simultaneous loosening of yarn structure, wrapping of hair fibers followed by tightening of the structure as the yarn emerges from the air jet [13]. This process has been suggested to result in the incorporation and locking in of fiber ends within the yarn structure [14]. The work of Alston [1] may also aid in explaining the reduced tendency to pill formation. A key aspect of low pill formation exhibited by air jet yarns is derived from the tight wrapping of the surface structure and the associated reduction in surface fiber fuzz formation. Bearing in mind that the JetWind modified yarns still portray the general surface characteristics of a conventional ring spun yarn, the wrapping of surface hairs may limit the ability of those surfaces fibers to form fuzz and reach critical height required for pill formation.

## CONCLUSIONS

Conventional worsted wool yarns suffer from excessive yarn hairiness. Reductions in both yarn hairiness and pill formation tendency are possible through the modification of the conventional ring spinning process. Two methodologies namely Solospun$^{TM}$ and

JetWind were investigated. Yarn hairiness (S3) was reduced by 33% using modified winding process incorporating an air jet nozzle (JetWind). A greater impact on yarn hairiness with a reduction of approximately 46% was achieved using the Solospun™ ring spinning attachment. The reduction of S3 value from the Solospun™ over the conventional worsted spun yarn was sufficient to impart a half grade improvement in pilling. A greater reduction in pilling using the JetWind method is attributed to the wrapping and incorporation of hair fibers within the yarn. These results suggest that relatively large reductions in hairiness are necessitated to achieve significant improvements in pilling performance, and the number of hairs (S3) is not the only important hairiness aspect that affects fabric pilling. Hairiness configuration, particularly increased fiber security through wrapping of hair fibers on yarn surface, may have a greater impact on pilling propensity of knitted wool fabrics.

## REFERENCES


1. Alston, P. V., 1992. Effect of Yarn Spinning System on Pill Resistance of Polyester/Cotton Knit Fabric, *Textile Research Journal*, **62**(2), 105-108.
2. Baird, M. E., Hatfield, P., and Morris, G. J., 1956. Pilling of Fabrics a Study of Nylon and Nylon Blended Fabrics, *The Journal of the Textile Institute*, **47**(4), T181-T201.
3. Barella, A., Bardi, X., and Castro, L., 1991. Hairiness Modification by Yarn/Yarn and Yarn/Metal Friction, *Melliand Textilberichte*, **72**(1), E3-E4.
4. Barrella, A., and Manich, A., 1997. Yarn Hairiness Update - A critical Appreciation of Recent Developments, *Textile Progress*, **26**(4).
5. Chang, L., and Wang, X., 2003. Comparing the Hairiness of Solospun and Ring Spun, *Textile Research Journal*, **73**(7), 640-644.
6. Cheng, K. P. S., and Li, C. H. L., 2002. JetRing Spinning and its Influence on Yarn Hairiness, *Textile Research Journal*, **72**(12), 1079-1087.

7. Cheng, L., Fu, P., and Yu, X., 2004. Relationship between Hairiness and the Twisting Principles of Solospun and Ring Spun Yarns, *Textile Research Journal*, **74**(9), 763-766.

8. Khan, Z. A., 2003. An Investigation of Post-spinning Yarn Engineering. *Ph.D Thesis*, Deakin University.

9. Najar, S. S., 1996. An Analysis of Twist Triangle in Ring Spinning, *Ph.D Thesis*, The University of New South Wales.

10. Prins, M., Lamb, P., and Finn, N., 2001. Solospun™ - The Long Staple Weavable Singles Yarn. *The 81st World Conference of the Textile Institute*, Melbourne, Australia.

11. Stalder, H., 2000. Ring Spinning Advance, *Textile Asia*, March, 43-46.

12. Timmis, J. B., 1976. How to Live with Pilling, *Knitting International*, **83**(9), 82-86.

13. Wang, X., Miao, M., and How, Y., 1997. Studies of JetRing Spinning - Part 1: Reducing Yarn Hairiness with the JetRing, *Textile Research Journal*, **67**(4), 253-258.

14. Wang, X., and Miao, M., 1997. Reducing Yarn Hairiness with an Air-Jet Attachment During Winding, *Textile Research Journal*, **67**(7), 481-485.

15. Wang, X., Huang, W., and Huang, X. B., 1999. A Study on the Formation of Yarn Hairiness, *Journal of the Textile Institute*, **90**(4), 555-569.