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Sustainable Approach for Mélange Yarn Manufacturers by Recycling Dyed Fibre Waste

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RESEARCH & DEVELOPMENT

Abstract

The aim of this paper is to study a sustainable approach of recycling different fibre waste for the mélange yarn industry and to suggest a sustainable strategy of mixing dyed fibre waste for use by yarn supply chain engineers. Fibre waste was added to a Blow room or draw frame and compared in terms of properties. It was found that the mechanical properties of cotton mélange yarn manufactured by adding waste are suitable to be marketed. Various qualitative parameters such as the spun length, tenacity, elongation %, short fibre index (SFI), yarn evenness analysis, nep count analysis and waste assessment were discussed and compared in both kinds of mixing strategies i.e. mixing in the form of flocks in a blow room and in the form of slivers on a draw frame; as followed by the Mélange yarn Industry. The effect of increasing the number of passages on yarn quality was also analysed.

Key words: *Mélange yarn, waste recycling, spinning industry, cotton fibre.*

Introduction

The different types of blending yield different aesthetic appearances of the final yarn and, thus, different final aesthetics of the fabric [1]. The effects and aesthetic of the final product might even be changed just by changing small production parameters, i.e. the twist multiplier [2]. Due to this, there is large variety in mélange yarn not only in terms of colours but also with respect to the texture of the yarn. Correspondingly, Memon et al. [3] maintain that changing dyeing parameters causes variations in the final yarn quality. There are a wide variety of looks and colours of mélange yarns [4]. This class of yarn is produced by either mixing different coloured fibres in a Blow room or sometimes they are mixed or blended on draw frames [5].

There is a large variety of Mélange yarns, which may arise from the shades (amount of dyed fibre) present in them; and these shades may be as low as only 0.5% or as high as 100%. Among the various industries, the textile industry is considered one of the most polluting in the world. Textile wastes are growing to extraordinary levels at higher rates due to the appearance, acceptance, and obsolescence of fast fashion [6]. Often when one order is finished, there remain a large number of materials in the industry in the form of lap bits in the blow room, card webs, carded slivers, drawn slivers, slivers on the comber preparatory and comber, roving ends from the simplex department, fly in the drawing and simplex department, Pneumafil from the ring department and roller waste from ring frames. Most industries are now re-using waste generated during the production of yarns to reduce the cost; also, some technological advancements are made for waste minimisation [7]. Comparing to a dyed bale of cotton fibres, there is more damaged fibre in mélange yarn, even when manufactured from freshly dyed fibres [3]. It is obvious that after dyeing the properties will not remain the same as they were beforehand.

A very brief study detailing a comparison of the properties of rotor-spun and ring-spun mélange cotton yarns found a considerably higher loss of mechanical properties of rotor-spun than ring-spun yarn [8]. It is estimated that for every kilogram of virgin cotton displaced by second-hand clothing, approximately 65 kWh is saved, and thus there is an emphasis on the reuse/recycling of waste compared to the use of new material [9]. The current spinning industry faces a lot of problematic challenges to make a high output as well as a high-quality-manufacturing atmosphere [10]. To make profitable products, waste recycling is one of the best alternatives for the textile spinning industry. This waste can be categorised as usable. Moreover, there is a series of other types of waste such as blow room droppings (trash in cotton), waste in blow room filter waste, card waste, sweep waste, suction fan wastes of draw frames, fly frames and the humidification plant, as well as yarn waste from the ring/rotor, winding and doubling departments. This type of waste cannot be easily used in the manufacturing of fine yarn and should be mixed together carefully to minimise variation throughout the process of yarn manufacturing.

In the mélange yarn industry, mostly the mixing of different shades is done manually [11]. An exponential relationship has been found between the entropy and bulk of yarns in theoretical deviations, and higher bulk and entropy are possessed by textured yarns as compared to classical yarns [12]. In this paper, 29.5 tex cotton yarn was manufactured using 0.8 hank roving, and the textile spinning waste was recycled. Recycling was achieved in two places: in the Blow room and on drawing frames and was compared in terms of properties. It would be fruitful for the mélange yarn industry to follow the sustainable recycling strategy in this paper.

Materials and methods

Materials Xinjiang medium grade cotton, available at the Wuxi No. 1 Cotton Spinning Mill, for routine production was used for this experiment. The cotton was inspected carefully, and the average fibre staple length was determined as 28.7 mm by using an USTER Fibrograph 730. The fibre fineness was 4.38 micrograms per inch. The trash content present in the cotton bales was 7.9%. Reactive dyed fibre was used to make mélange yarn for these samples. Usable waste from the spinning department was used for this research. A 29.5 tex yarn count was used to compare the data, which is mostly produced by our industry.

Method

In this study, waste was mixed in a blow room and on a draw frame at three different waste percentages i.e. 10%, 20%, and 30%. The waste recipe was designed by conducting some preliminary tests to assess the properties of the dyed yarn. A comparative analysis of the drawing blending and blow room blending was done. In some cases, in the mélange yarn industry, it is required to pass the mixing thrice through the draw frame, termed as breaker drawing, inter drawing and finisher drawing. Thus, the effect of the number of passages on the properties was also analysed. BRB represents blow room blending and DFB – draw frame blending. The number of passages is mainly two for all samples unless three is mentioned in brackets.

Testing

A spun length of 2.5% of the fibre samples was determined by USTER Fibrograph 730. The fibre fineness was determined by using an USTER Micronaire 775 according to ASTM D1447-89. An USTER Tensorapid 4 was used to assess the yarn tenacity and elongation at the break of all specimens according to ASTM D2256-97. An USTER Evenness tester 4 was used to assess evenness parameters, such as the irregularity index (U %), the coefficient of variation (CV %), the number of thin places (-50%), and the number of thick places (+50%) of the specimens on the basis of standard ASTM D1425-96. Moreover, the number of neps was also determined by the same machine following the same standard test method. A yarn hairiness/friction tester – Y089/6 of SDL was used to determine yarn hairiness, measured according to ASTM D3108. All the samples were tested at least five times and presented statistically.

Table 1. *Recipes for mixing.*

Waste type	% to be added
Lap bits	40%
Card web	5%
Carded sliver	10%
Drawn sliver, from preparatory to comber	10%
Combed sliver	10%
Noil	10%
Roving ends from simplex and roller waste from ring frames	5%
Fly from drawing, simplex and ring departments	5%
Pneumafil	5%

Table 2. *Spun length after each processing step in the back process.*

Sample	After blow room		After carding		After drawing	
100%	27.5	± 1.02	27.1	± 1.13	27.05	± 1.13
BRB-10	27.2	± 0.79	26.8	± 0.85	26.75	± 0.82
BRB-20	26.9	± 1.24	26.5	± 1.39	26.45	± 1.42
BRB-30	26.4	± 1.15	26.1	± 1.28	26.05	± 1.3
DFB-10	27.3	± 0.77	26.8	± 0.83	26.7	± 0.79
DFB-20	27	± 0.67	26.55	± 0.71	26.5	± 0.66
DFB-20(3)	27	± 1.24	26.55	± 1.39	26.45	± 1.42
DFB-30	26.5	± 0.91	26.15	± 1	26	± 0.98
DFB-30(3)	26.5	± 1.2	26.1	± 1.34	26.05	± 1.36

Waste recipe and mixing

It is a very technical point to decide the waste recipe for mixing the waste in mélange yarns. A little variation in the waste recipe may lead to a higher increase in the imperfection index. For this research, the mixing recipe of the waste is presented in ***Table 1***.

All the types of waste were weighed according to the given recipe and mixed properly on an old inclined bale opener in order to get uniformity. The whole mixing was passed through the same inclined bale opener twice to avoid variation among the samples.

Results and discussion

Spun length 2.5% (mm)

The waste was determined at three levels of back processing i.e. after the blow room, carding and drawing. Data showing changes in the effective spun length percentage after different back processes of the various samples are presented in ***Table 2***. Obviously, the spun length was decreased by adding the fibre waste, which is further decreased by the further processing of spinning. This may be due to fibre breakage in the spinning processes. This reduction increases in the case of blow room blending, proving that drawing blending is better for utilising the waste in mélange yarn spinning. This may be attributed to fibre entanglement in the blow room, and the higher number of beating points compared to drawn blended slivers. The spun length was decreased slightly further by increasing the number of passages.

Short Fibre Index (SFI, %)

Cotton fibre shorter than 12 mm is considered as shorter fibre, and the amount of which in textile material is measured in terms of the Short Fibre Index (SFI, %). The SFI % was measured at three levels of back processing i.e. after the blow room, carding and drawing. Data showing changes in the SFI after different back processes of various samples are presented in ***Table 3***.

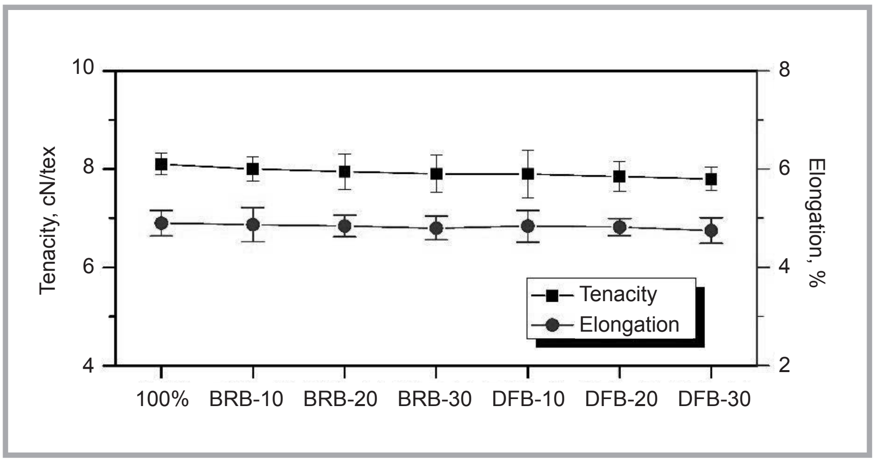

***Figure 1.** Comparison of the yarn tenacity and elongation of different yarns.*

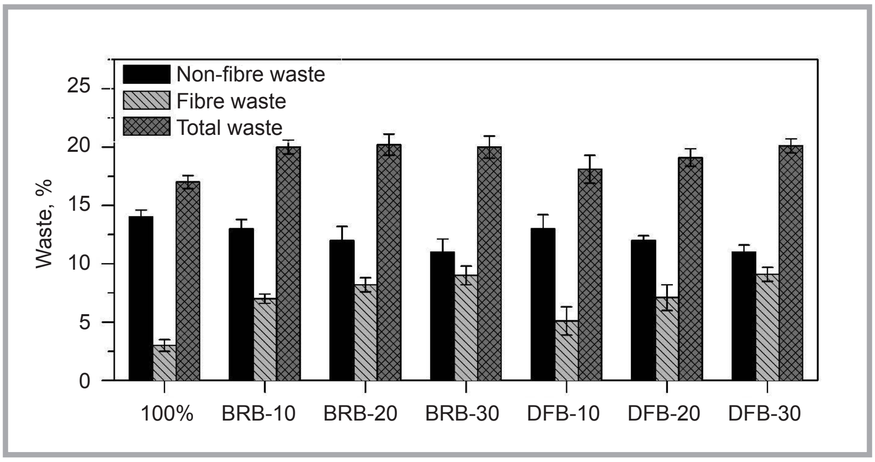

***Figure 2.** Waste assessment after adding various ratios of waste at various stages.*

***Table 3.** SFI after each processing step in the back process.*

Sample	After blow room		After carding		After drawing	
100%	30	± 0.93	34	± 1.02	31	± 1.02
BRB-10	36	± 0.74	42	± 0.79	38	± 0.76
BRB-20	45	± 1.11	50	± 1.24	48	± 1.26
BRB-30	52	± 1.04	56	± 1.15	54	± 1.16
DFB-10	34	± 0.72	40	± 0.77	36	± 0.74
DFB-20	43	± 0.64	47	± 0.67	44	± 0.63
DFB-20(3)	44	± 1.11	48	± 1.24	46	± 1.26
DFB-30	50	± 0.84	54	± 0.91	51	± 0.9
DFB-30(3)	51	± 1.08	55	± 1.2	52	± 1.21

***Table 4.** Comparison of the coefficient of variation (CV %), number of thin places (-50%), and number of thick places (+50%) of different yarns.*

Sample	Coefficient of variation, CV %		No. of thin places, -50%		No. of thick places, +50%	
100%	25	± 0.44	1100	± 54	1500	± 34
BRB-10	25.5	± 0.32	1130	± 43	1560	± 55
BRB-20	25.75	± 0.43	1160	± 34	1630	± 23
BRB-30	26	± 0.43	1200	± 67	1700	± 43
DFB-10	26.5	± 0.34	1600	± 23	1650	± 26
DFB-20	26.75	± 0.43	1700	± 32	1700	± 45
DFB-20(3)	27	± 0.44	2000	± 43	1850	± 34
DFB-30	27	± 0.23	1750	± 43	1750	± 65
DFB-30(3)	27.5	± 0.54	2100	± 34	1900	± 34

It can be seen that more short fibres were produced by blending in the blow room as compared to drawing blending. There are severe contacts of fibre to fibre and fibre to the machine in the blow room, resulting in an increase in short fibres at each beating point in the blow room. Moreover, the short fibre index was increased slightly further by increasing the number of passages. One noticeable result was found that the short fibre index increased for the carded sliver as compared to the drawn sliver and lap, which may be due to the rough entanglement between card wires and specimens.

Tenacity and elongation at break of yarns

29.5 tex ring-spun yarn were produced from 0.8 hank roving on a ring-spinning frame to assess the yarn tenacity, elongation at break and other yarn characteristics. All the roving bobbins were properly marked for their identification in order to ensure that they have not been mixed with the other bobbins. It is obvious that both the yarn tenacity and elongation at break were gradually decreased, and were proportional to the adding the fibre waste, as can be seen in ***Figure 1***. It can be deduced that drawing blending results in a lower tenacity and elongation at break of yarns compared to the blow room blending of waste and pure fibre, which might be attributed to the weaker streamline of the yarn formation method of the former.

Evenness

The variation in mass over the length is referred to as yarn evenness or the imperfection index (IPI), and affects the final appearance of the fabric [13]. This imperfection is proportional to the decrease in the effective spun length of fibres. Four different yarn evenness parameters of 29.5 tex ring-spun yarn were analysed in this study, and the coefficient of variation (CV %), number of thin places (-50%), and number of thick places (+50%) thereof are presented in ***Table 4***. Yarn evenness was analysed for a 1000 m length of yarn, and the yarn evenness of the drawn blended samples was found to be lower than that of the blow room blended samples. Moreover, yarn evenness was found to be worse on adding to the number of passages of the draw frame.

Number of neps

Fibre entanglements are termed as neps and are found scattered throughout the fabric surface if they are present in the yarn [14]. A new technique has recently been devised to determine the neps of mélange yarn using image processing [15]. In this study, 29.5 tex ring-spun yarn was assessed for the number of neps present in 1000 m of yarn length. Obviously, the number of neps were in direct relation to the amount of waste present in the yarns. It was found that drawing blending was favourable for nep formation, as compared to blow room blending, as can be seen in ***Table 5***. It can be surmised that blow room blended waste of 30% is even lower than drawing a blended waste of 10%. The number of neps was increased by increasing that of passages, even 30% added waste passed through two passages resulted in fewer neps comparing to the number of neps generated in 20% added waste passed through three passages.

Yarn hairiness

Among other different properties, hairiness is also considered as one of the main properties of ring-spun yarns, as the end-use performance is determined by it [16]. There is a relationship between the spinning triangle and yarn hairiness, as has been studied recently [17]. Yarn hairiness was proportional to increasing fibre waste, as presented in ***Table 5***. It can also be seen that drawn blended yarn showed less hairiness compared to blow room blended yarn; however, if the number of passages is increased, the hairiness also increases. The lower hairiness of drawn blended yarns may be associated with the coverage provided by white pristine fibres to recycled fibres.

Waste assessment

Whether doing non-fibre waste or fibre waste analysis, it would be ridiculous to assess its effect on the number of passages. Thus, the effect of the number of passages was eliminated during this research. The waste assessment covers non-fibre waste, fibre waste and the summation of non-fibre and fibre waste, called total waste. The waste assessment is presented in ***Figure 2***. The non-fibre waste was found to decrease by adding waste to the mixing. Moreover, it can be seen that the non-fibre waste was more in the case of drawing blending. The fibre waste gradually increases by adding waste. But it is worth knowing that the fibre waste obtained is much lower than the waste added into the mixing, due to the different nature of the two fibre wastes.

Table 5. *Number of neps and yarn hairiness in 1000 m of all samples.*

Sample	Number of neps		Hairiness	
100%	125	± 12	37	± 2
BRB-10	145	± 22	42	± 3
BRB-20	162	± 13	44	± 5
BRB-30	175	± 23	50	± 5
DFB-10	246	± 21	39	± 4
DFB-20	264	± 12	42	± 5
DFB-20(3)	278	± 32	46	± 4
DFB-30	270	± 17	45	± 6
DFB-30(3)	305	± 29	49	± 4

The waste percentage can be measured as the sum of the non-fibre waste and fibre waste. Non-fibre waste can be trash, leave particles, dirt, dust, etc. whereas fibre waste is waste fibrous material taken out from the whole spinning line by the suction devices of various machines. The relative higher value of fibrous waste is due to the higher amount of damage experienced by the machines in the spinning line, which results in a loss of strength of fibres made already weak because of dyeing. However, it must be noted that the type of cotton, moisture conditions of the spinning plant, and the settings of the spinning machines play a significant role in maintaining low fibre damage.

Conclusions

From these results, it can be summed up that a sustainable strategy of waste recycling from in the supply chain of the mélange yarn industry can be effectively utilised without affecting yarn quality significantly to produce mélange yarn of the same yarn count at the same twist. By this practice, a large number of cotton fibres can be effectively used, and the fibre yield can be maximised. It was found that the effective spun length of fibres became worse in the case of blow room blending than in drawing blending. Moreover, the spun length was found to decrease slightly further by increasing the number of passages. Overall drawing blending produced fewer even yarns than blow room blending. Increasing the number of passages on the draw frame assisted this unevenness further. Severe hairiness was found in the case of blow room blending. Moreover, a higher number of passages resulted in more hairiness in mélange yarn. The Short Fibre Index was higher in the case of blow room blended mélange yarns, and increasing the number of passages on the draw frame increased it further. As drawing blending yielded less waste, it can be recommended for maximising the utilisation of waste, but with some effect on the quality of yarn. Contrarily, better tensile properties were found in blow room blending than in drawing blending; however, they further became worse by increasing the number of passages of drawing.

Data availability

All data is available on request by writing an email to the main corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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