A new technique to tint the black dyed fibres in worsted spinning

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A new method has been developed for tinting of black dyed fibres of wool and polyester in worsted spinning system. The results of tinting process are evaluated by both visual and instrumentally. The results show that the best option for tinting of black dyed fibres is the use of pigments in mixture with titanium dioxide, spinning oil and water. The tint solution is prepared by perfectly dissolving the components at the optimum values of 2.7% pigment, 2.4% titanium dioxide powder and 3.4% spinning oil in water at room temperature. It is observed that the proposed mixture can perfectly tint the black dyed fibres of wool and polyester without any permanent effect and stain on them. The black dyed fibres could also be tinted in white colour with a solution of titanium dioxide without pigments. The tinted fibres could be washed with water and detergents in finishing process easily and without any further stage.

Keywords: Dyeing, Fibre, Tinting, Worsted spinning, Wool-polyester blend

1 Introduction

In producing textile products, the quick identification and separation of fibrous materials in production line while producing sliver, roving, yarn and fabric, is very important because of various kinds of products that may be in the production line simultaneously. In many operations, it is frequently necessary or desirable to employ numerous types of fibres which differ from each other in physical characteristics, chemical nature and dyeing properties. On the other hand, it is often desirable to process two or more different types of fibrous materials in the production line in order to produce various types of products in the same place, simultaneously. In case various types of fibrous materials may not appear to be different even on fairly close visual examination when different types of fibres are inadvertently processed in the production line, the manner in which they show up as different is often quite startling. Thus, the correct identification of the fibres and yarns by twist, denier, ply, chemical nature and blend ratio is quite important. The processing materials that have approximately similar appearance and look may be undesirably mixed, leading to economical loss. When a fabric is woven with wrong yarns, it affects the specified quality of fabric. To prevent the undesired mixing of the fibres in the processing line, they should be identifiable by human eyes. One of the methods widely employed for such identification is to apply a fugitive tint to the fibres, which is easily removed by scouring in finishing process. Fugitive tints are often used to colour code textiles during production and/or finishing operations to identify certain fibrous materials. For example, the fibres may be tinted during the spinning into yarns and the utilization of yarns in knitting or weaving operations to ensure that undesirable fibres or yarns are not present. Such tints are then removed during one of the last finishing operations prior to sale. The temporary presence of the tint on the fibres and yarns serves adequately to prevent confusion. The fugitive tint should have good colour stability to minimize fading during exposure to heat and/or light, and in the conditions which may be encountered during processing of the tinted fibres into the final product. They are generally classified as water fugitive or solvent fugitive. The particular choice of tints depends largely upon the finishing operations of the fibre and the fugitive properties of the tint. The tint solution may contain a lubricant that may, for example, be emulsified in the tint solution.

Various ways of applying the tint solutions such as spraying and saturating-squeezing may be employed. Wool and polyester fibres may be sprayed with an aqueous solution of the tint colorant to yield the desired tint shade and thereafter dried. The amount of colorant employed in the tint compositions can vary.
widely, but will generally be the major constituent of the concentrated tint composition. It will largely be dependent upon the particular shade of tint desired, the colour of the colorant, and the amount of the water-soluble polymeric resin employed.

In worsted spinning, the fugitive tints are conventionally applied during opening and drafting process on gill-box machine. The sliver is run in the gill-box machine with suitable devices to apply the desired amount of tint thereto. To be acceptable, a fugitive tint should be capable of being easily removed, even after exposure to extreme conditions which might be encountered during the production and finishing of the textile. Although the light shades are not easily distinguishable, but one should note that the adding colorants to the fibrous materials for increasing the dye shade may provide difficulties in colorants depositing process.

A process for temporarily colouring a polyamide substrate is provided whereby a poly (oxyalkylene) substituted methine colorant is applied to the substrate followed by heating the substrate with superheated steam at 120 °C, which effectively decolorizes the methine colorant.

Hinojosa has invented a fugitive ink for marking cotton modules or other like fibres, wherein the ink dries in less than about two hours in the field and does not fade or wash away when the module or fibre is stored in all-weather conditions open to the elements. However the ink is removed upon mechanical agitation of the fibre and during the scouring/bleaching process used by textile mills. The fugitive ink composition comprises a water-soluble dyestuff (sulfone containing dyestuff), a polymeric resin emulsion, a wetting agent and water.

Kuhn introduced some new compounds as a fugitive tint for Dacron polyester, Orlon polyacrylonitrile, cotton, cellulose acetate as well as other textile fibres. These compounds are characterized by being water soluble polymeric surfactants having at least 30 repeating ethyleneoxy units in the molecule, a molecular weight of at least 1000 and having a dyestuff molecular attached to the polymeric chain. He observed that the new compounds have outstanding fugitive for substantially all textile fibres.

While the general tints for white wool and polyester fibres have exhibited the desired fugitive properties on them, problems have been encountered when employing such tints on same black dyed fibres. The major problem encountered has been that the tints of the prior art, when used on the black dyed fibres, are not easily distinguishable in the processing line.

Since the temporary tinting treatment on dark colour fibre is not common in the textile industry, the colorant suitable for this purpose needs to be selected carefully. The present study was therefore undertaken to propose a new methodology to provide a fugitive tint composition for black dyed wool and polyester fibres.

2 Materials and Methods

2.1 Materials

To find suitable colorant, dark colour wool and polyester fibres were tinted with various types of water soluble colorants and pigments and then the results were evaluated. Because of the dark background colour of fibre, the colour and coating power of the pigment colorants are very important in tinting process. To strengthen the power of pigment colorant on the dark fibre, it is essential to use a substance having hiding power such as titanium dioxide. Titanium dioxide have high light emission and hence increases the hiding power of colorant and decreases the influences of dark colour of the background, causing better appearing of the pigment colorant imposed on the fibres. Three conventional pigments for printing textile goods and three conventional pigments for tinting the white colour fibre of wool and polyester with shades of yellow, green and red were used to tint the black dyed fibres.

In the tests and evaluations of the tinting experiment, the quick and easy identification and easy remove of the colorant from products are considered as the most important parameters.

The conventional pigments for printing textile goods are always used with binder. But, when these pigments are used as a fugitive tint, the binder may cause permanent stains on the fibres. Therefore, these colorants should be used without binder in tinting process. The application of pigments colorants without binder may cause downfall of the colorants from the surface of the fibrous materials after drying. To prevent loss of colorants from the tinted fibres, the spinning oil was used. Spinning oil causes better stickiness of the colorants on the surface of the fibres and more flexibility of the fibres. As already noted, to provide better hiding power of the colorants on the dark fibres, the titanium dioxide was used. Therefore, tint solution containing colorants, titanium dioxide, spinning oil and water with the proper
proportions was prepared, mixed together and then sprayed on the fibre.

Three conventional pigments for printing textile goods and three conventional pigments for tining the white colour fibre of wool and polyester with shades of yellow, green and red were used to tint the black dyed fibres. It is evident that although the value of colour difference between tinted samples and non-tinted dark fibres is large, the tinted samples will have a high contrast with non-tinted dark fibres that facilitate the process of identifying and investigating the fibres from each other. The percentages of components of an appropriate tint solution such as hiding substance titanium dioxide, colorant and spinning oil are the important parameters and they are calculated for sprayed tint solution in the laboratory experiments. Also, various spraying volumes of tint solution on the fibres are examined and the tinted samples are evaluated.

2.2 Industrial Experiment

The properly examined tint solutions in the laboratory scale were then applied on the fibre in the industrial scale with the spraying speed of 6.64 l/h on a gill-box machine. In the gill-box machine, the delivery speed was 35 m/min, the linear speed of the delivered sliver was 9.3 g/m, and therefore the production speed was 325.5 g/min. The volume of sprayed tint on the fibres becomes 0.34 l/kg of fibres. Using these processing parameters, the tint solutions were sprayed on the fibres and then the identifiability of the tinted fibres was evaluated by visual method.

2.3 Evaluation Methods

To evaluate the tinted samples, both visual and instrumental methods were used. In the first method, a specified number of viewers having the normal colour vision were selected as judge for all tinted samples under daylight to assess and declare that the tinted samples are assessable and identifiable from the sample of non-tinted black dyed fibres. In this study, to evaluate the identifiability of the tinted fibres by visual method, 20 peoples (10 women and 10 men) with normal colour vision were asked about the colour difference between the tinted fibres and non-tinted fibres. In order to ensure normal colour vision of the evaluators, the Ishihara colour blindness test was performed for each evaluator. Before evaluation, the evaluators were preliminary trained to ensure that they are familiar with the concept of colour difference and expressing it with the gray scale.

In instrumental method, the values of reflection of non-tinted black dyed fibres of wool and polyester and that of tinted fibres with various concentrations of colorant and titanium dioxide are measured using Colour Eye 7000A spectrophotometer and then the colour difference value $\Delta E_{ab}$ of each tinted sample and non-tinted sample was calculated based on the following relationship in the CIELAB system:

$$\Delta E_{ab} = [(\Delta L^*)^2 + (\Delta a^* )^2 + (\Delta b^*)^2]^{1/2}$$

Equation (1) represents the Euclidean distance between colour coordinates of tinted samples and standard of non-tinted samples in the CIELAB colour space. In this relation, the components $L^*, a^*$ and $b^*$ are calculated using the following equations:

$$L^* = 116 \left( \frac{Y}{Y_n} \right)^{1/3} - 16$$

$$a^* = 500 \left[ \left( \frac{X}{X_n} \right)^{1/3} - \left( \frac{Y}{Y_n} \right)^{1/3} \right]$$

$$b^* = 200 \left[ \left( \frac{Y}{Y_n} \right)^{1/3} - \left( \frac{Z}{Z_n} \right)^{1/3} \right]$$

In these relations, the three colour values of CIE XYZ determine the colour of object in a visual system and $X_n$, $Y_n$ and $Z_n$ determine the values of the colour of a white and neutral object under a D65 light source.

3 Results and Discussion

For using pigments as a fugitive tint on wool and polyester fibres, it is essential to avoid the use of binder to prevent the chemical reaction or graft between the colorants and the fibres. The pigment colorants without the binder make only physical connection with the fibres. Also, the dark background of goods, the colour shade and hiding power of the pigment colorant are very important.

The results of the experiments performed using three types of conventional pigments for fugitive tints on the white wool-polyester blend fibres in the absence of titanium dioxide show that these pigments are not able to tint black dyed wool and polyester fibres. Also, pigment colorants for conventional textile printing of green, red and yellow in the absence of titanium dioxide do not have sufficient hiding power to provide enough colour change of
fibre bundle. In these experiments, the colour of tint on the fibre is not easily detectable by human eye and there are no visible stains on the goods after drying and infiltration of the colorant into the fibre. Therefore, the fibre surface remains still dark and their identification is not possible. Hence, these tinted samples are not measured instrumentally.

To magnify the potency of tints of pigment colorants on dark fibres, it is necessary to use a substance having hiding power like titanium dioxide. The results of experiments performed using a tint composition of titanium dioxide and three types of conventional pigments for fugitive tints on the white wool-polyester blend fibres shows that these pigments are not able to tint black dyed wool and polyester fibres. Due to very low power of the conventional pigment colorant for white fibres, it is not possible to tint black dyed fibres even with a mixture of high percentage pigment with titanium dioxide.

High power of general pigment colorants for conventional textile printing will cause these types of colorants to attain bright shades to be able to tint better the dark fibres. Values of colour difference obtained from the relation shown in Eq. (1) for both wool and polyester fibres tinted with green and red pigments are shown in Figs 1 and 2. It is evident that the value of colour difference between tinted samples and non-tinted dark fibres is large, the tinted samples show a high contrast with non-tinted dark fibres. This facilitates the process of identifying and investigating the fibres from each other.

It is important to consider a few points when analyzing these results. One of these points is the manner of colorant spraying on the fibres bundle and the other point is the process of mixing the tinted

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**Fig. 1**—Colour difference between non-tinted black dyed (a) wool and (b) polyester fibres and those of tinted with green pigment colorant

**Fig. 2**—Colour difference between non-tinted black dyed (a) wool and (b) polyester fibres and those of tinted with red pigment colorant
fibres with non-tinted layer of fibres bundle. In the laboratory experiment, the tint solution was sprayed using a manual spray and the fibres in a bundle were also mixed manually. Obviously, this manner of testing can affect the results of from the accuracy point of view. Therefore, it can be expected that some difference between the results of laboratory and industrial production exist. In addition, lack of coordination and coherence between some results reported in Figs 1 and 2 can also be observed due to irregularly spraying of the colorant on the surface of fibre tops and inappropriate manner of mixing them.

Because the tinted fibres by the yellow pigments do not have sufficient colour change and the tint colours are not easily detectable by human eye, only three samples of high percentages of colorant and titanium dioxide were prepared and measured instrumentally. The colour difference values for 10% colorant and 6% TiO₂ are found to be 4.7 (wool) and 3 (polyester) respectively. However, for 12% colorant and 6% TiO₂, the values are 5 (wool) and 3.1 (polyester) respectively. In case of 12% colorant and 5% TiO₂, the colour difference values are 8.4 (wool) and 4.1 (polyester) respectively.

Figures 1 and 2 show that as the percentage of colorant increases, the colour difference between tinted and non-tinted dark fibres increases. However, in case of green pigment colorant (Figs 1 a and b), the colour difference increases as the concentration of pigment colorant increases till 8% and then decreases, while in case of red pigment colorant (Figs 2 a and b), the colour difference increases as the concentration of pigment colorant increases in whole range of colorant variation. This is because of darker shade of green pigment colorant that has little difference with dark shade of non-tinted fibres. It is necessary to note that the value of colour difference \( \Delta E_{ab} = 1 \) shows as much tolerance for colour difference that can be viewed by human vision. Therefore, it can be concluded that colour difference of all tinted samples in these experiments with non-tinted dark fibres can be understood by people with normal colour vision. However, due to the presence of dark fibres, the value of colour difference is lower in comparison with conventional tinted fibres of white colour and hence the identification of tinted fibres of dark colour becomes more difficult. The results of visual evaluation confirm that the tinted samples with pigments of green and red colorants are better detectable and identifiable in comparison with tinted samples with yellow pigment colorant.

It is also found that the efficiency of tinting the wool fibres by pigment colorants is better than that of polyester fibres. The results of visual method also confirm higher colour difference for wool fibres. In fact, it can be said that the wool fibres have better ability to keep the colorants on their surface in comparison with polyester fibres due to the physical structure of wool fibre. Therefore, it can be expected that in wool-polyester blends with higher percentage of wool fibres, the presented method will show higher efficiency to simply detect the tint colour of the tinted tops.

The effect of titanium dioxide on colour difference is not found to be significant, except in polyester fibres tinted with red pigment colorant in which the colour difference increases as the titanium dioxide percentage increases. As can be seen from Fig. 2b, on with applying higher titanium dioxide concentration, the same colour difference is achieved at lower colorant concentration. For example, the colour difference of the samples tinted by a solution of 6% colorant and 6% of titanium dioxide \( (\Delta E_{ab} = 3) \) have approximately the same colour difference shown by the samples tinted by solutions of 8% pigment and 3% titanium dioxide. This will eliminate the need to use high concentration of pigment colours. However, the use of titanium dioxide is strongly recommended to provide the necessary hiding while using pigment colorant, otherwise visible colour on dark fibre is not possible. From the obtained results by both spectrophotometer and visual methods in laboratory scale, it is found that the appropriate tint composition can be achieved using the optimum concentration of components, such as 7-8% green pigment + 6-7% titanium dioxide, and 10% red pigment + 3-4% titanium dioxide. The best composition to achieve the best colour difference for tints in industrial scale may be obtained with little modifications.

Although, the results of both visual and instrumental measurements generally confirm that the pigment and titanium dioxide concentrations in the tint solution are very important to achieve the best results, the final results strongly depend on the total area of fibre surface that has been covered by tint solution. Since spraying colorant on samples in the laboratory scale is performed manually, there is not precise control on colorant percentage and distribution on the tinted fibres. In practice, the amount of pigment colorant sprayed manually on the fibres is 1.5-2% by weight of the fibres. However, our experiences show that the tinting efficiency increases by increasing the total area
of the fibres surface that is sprayed by tint solution. This means that the higher the number of directly sprayed fibres, the higher is the tinting efficiency.

Temporary tinting of the fibres using titanium dioxide without colorant is a very affordable method. For this purpose, tint solutions with different percentages of titanium dioxide and spinning oil were prepared and then sprayed on the surface of dark fibres. The results of considering the effect of titanium dioxide percentages on colour difference values between tinted samples and non-tinted fibres of wool and polyester show the best results with 5% titanium dioxide in tint solution. The colour difference values are found to be 9.85 and 3.45 for wool and polyester fibres respectively. The different values of tinting efficiency for wool and polyester fibres are due to the difference in surface structure of two types of fibres. To achieve the same tinting effect on polyester fibres in comparison with wool fibres, it is necessary to increase the titanium dioxide concentration in the tint solution as same as spraying volume. In tinting of the fibres using titanium dioxide without colorant, the only colour that can be achieved is white, and these results lead to eliminate the need of using pigment colours in the mentioned tint solution.

Tint solutions used in the industrial scales were prepared with composition as used in laboratory scale, where the tint solutions composed of 8% of green pigment colorant, 7% of titanium dioxide and 10% of spinning oil were sprayed with the speed of 6.64 l/h on the fibres in the gill-box machine. The speed of gill-box machine was 35 m/min and the linear speed of the produced sliver was 9.3 g/m. Hence, the production speed of the gill-box machine becomes 325.5 g/min and consequently the volume of sprayed tint on the fibres becomes 0.34 l/kg of fibres. The percentage of tint components per weight of fibres was calculated using the following relationship:

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\text{Tint components per weight of fibres (\%)} = \frac{\text{Vol. of sprayed tint on fibres (l/kg)} \times \% \text{ Component in tint solution}}{}
\]

Therefore, the optimum percentage of tint solution components per weight of fibres is found to be pigment colorant 2.7%, titanium dioxide 2.4%, spinning oil 3.4% and water 25.5%. The production process on industrial gill-box with these settings of tint solution, spraying rate and production speed is found to be very successful and without any problem. The tinting operations do not affect the production process. Figure 3 shows a photograph of the tinted sliver of wool-polyester blend fibres on industrial gill-box.

It is necessary to point out that the tint spraying on the fibres is performed in front of the delivery roller of gill-box. However, it is also possible to spray the tint solution on the top fibres before the draft zone of the gill-box which causes greater parts of the fibres to be tinted and consequently higher colour difference between the tinted sample and the non-tinted fibres. But, as the fibres are sprayed before the draft zone, the tinted fibres are feed to the draft zone before drying their surface and therefore they are subjected to twist around the draft rollers. Hence, it is recommended to perform the spraying operations after the draft zone.

The results of evaluation by 20 evaluators with normal colour vision show that all evaluators are able to easily distinguish and identify the tinted fibres from non-tinted fibres and they confirm that the colour difference between tinted fibres and non-tinted fibres in the form of sliver and roving are of the grade 1-2 of gray scale. This difference for the yarn is grade 3-4 of gray scale, its detection by human evaluators in this case is also possible with enough speed and accuracy.

The results of the removal of colorants from the fibres at the end of process show that the tint colorant is removed perfectly from the fibre surface after washing with water and detergents (Fig. 4). However, there is enough risk of remaining pigment colorants on white colour fibres, and hence the pigment colorant use on white colour fibres should be avoided.


4 Conclusion

It is observed that the general pigment colorant used for conventional printing of fabrics are the best selection to tint the dark colour fibres of wool and polyester in the form of sliver on gill-box machine of spinning process. The titanium dioxide powder is used in the tint solution as a substance having hiding power. The spinning oil was also used in the tint solution to prevent the downfall of the colorants from the surface of the fibrous materials after drying. The spinning oil causes better stickiness of the colorants on the surface of fibres and more flexibility of the fibres. The results of experiment in laboratory and industrial scales show that a composition of pigment colorant, titanium dioxide, spinning oil and water with proper proportions can properly tint the dark colour fibres of wool and polyester without any permanent effect or stain on the fibrous products.

To obtain the best results, a tint solution having the optimum component percentages of 2.7% pigment colorant, 2.4% titanium dioxide and 3.4% spinning oil can be used. It is also infused that the titanium dioxide in the tint solution will eliminate the need to use high concentration of pigment colours.

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