Comparison of Color Properties of CO$_2$ Laser Treated Cotton Fabric Before and After Dyeing

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Abstract

Cotton fabric was treated by CO$_2$ laser under different parameters, before and after dyeing with reactive dye. Color properties, including reflectance, K/S sum and CIE $L^*$,$a^*$,$b^*$ of treated fabrics were evaluated through spectrophotometer. The dyed and then laser treated fabric (D/L) revealed lighter, more greenish and less bluish color. The laser treated and then dyed fabric (L/D) showed different results. This indicates that different treatment approaches have different influences on color properties of cotton fabric.

Key Words: Color, CO$_2$ laser, Dyeing, Cotton, fabric

1. Introduction

CO$_2$ laser is a dry treatment with advantages such as environment-friendly, short treatment time, ease of control and high precision [1, 2] and has drawn the attention of many researchers. Since most of the studies on color properties are focused on dyed fabric, e.g. indigo denim fabrics [3-6], only a small proportion of literature has addressed the effect of laser treatment on dyeing of plain fabric and comparison of effect of laser treatment after and before dyeing. Therefore, in this study, different combinations of laser parameters were applied on 100% cotton twill fabric using two approaches, before dyeing (L/D) and after dyeing (D/L) with blue reactive dye, using 1% concentration. Color properties include reflectance, color yield (in terms of K/S value) and CIE $L^*$,$a^*$ and $b^*$ values of samples treated with different approaches were compared and evaluated.

2. Experimental

2.1 Materials

100% cotton twill fabric (density: 144 ends/inch and 58 picks/inch; yarn count: 34 x 30 tex; weight: 240g/m$^2$) was used.

2.2 Laser treatment

The laser treatment was conducted by a CO$_2$ source laser with wavelength of 10.6 $\mu$m engraving machine (GFK, Spain) under atmospheric conditions. Resolution (dpi) and pixel time ($\mu$s) of computer controlled laser beam during treatment were set to 52, 60, 68 dot per inch (dpi) and 110, 120, 130 and 140$\mu$s, respectively.

2.3 Dyeing

CI Reactive Blue 19 dye was used at liquor-to-goods ratio of 50:1 in the dyeing process (Fig.1). The fabrics were rinsed in cold water to remove excess dyes on fabric surface. After washing, fabrics were undergone soaping at 90$^\circ$C with fixation time of 10 minutes.

Fig.1 Dyeing process of using CI Reactive 19 dye.

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2.4 Evaluation

Color measurements of fabric samples were evaluated using a spectrophotometer (GretagMacbeth Color-Eye 7000A) under light source of illuminant D65 daylight and with a 10° standard observer. Color properties include reflectance, color yield (in terms of K/S value) and CIE L*, a* and b* values were obtained.

3. Results and Discussion

3.1 Color measurement

Fabrics treated with two approaches revealed similar reflectance curves (Fig. 2 and Fig. 3); curves of both samples had the peak at wavelength range of 450-490nm, which is the blue region. Since the fabrics were dyed with blue dye, they had blue color. This indicates that laser treatment has no influence on shade of the samples.

Reflectance values of samples treated with the two approaches increased compared with samples dyed without laser treatment. As reflectance value measures the light reflected from a surface, the higher the reflectance value which is expressed in percentage, the lighter the surface it will be. Fig. 2 and Fig. 3 show that samples treated with the two approaches had a lighter blue surface appearance than the control sample. Therefore, laser treatment fades color performance of cotton fabric.

Color yield is indicated by K/S sum value. The higher the value, the better the color yield will be [4]. The K/S sum value of samples treated with different approaches decreased when compared with control sample.

K/S sum curves (Fig. 4) corresponding to different laser processing parameters are at a higher position for first laser treated and then dyed sample (L/D) than samples first dyed and then laser treated (D/L); e.g., according to Fig. 3, 52 dpi L/D is at a higher position than 52 dpi D/L. Thus, first laser treated and then dyed sample (L/D) has a higher K/S sum value which means a better color yield. This is because during laser treatment, in the case of first dyed and then laser treated sample (D/L), laser beam interacts with the fabric. The fabric continuously absorbs energy and dyes in the fabric are vaporized, resulting in decomposition, leaving the surface of fabric a lighter color [7, 8].

3.2 CIE L*a*b* measurement

L* stands for lightness value; the higher the L* value is, the lighter is the sample color, while a lower L* value indicates a darker color. Lightness values of samples treated with the mentioned approaches (Table 1 and Table 2) are found to be higher than the control sample, which means control has a darker color and thus, samples without laser treatment have a darker color.

CIE a* value stands for the greenish or reddish color of the sample. Positive a* value means the sample has a reddish color while negative a* value means the sample has a greenish color. Both of samples treated with the two different approaches have negative a* values, i.e. more greenish color than control. When the two approaches are compared, samples first dyed and then laser treated (D/L) show a more negative a* value than samples first laser treated and then dyed (L/D). D/L samples are more greenish as cotton fibres get burned during laser treatment, leaving a yellowish color on the fabric surface. The yellowish burnt cotton with blue
dye results in a greenish appearance. However, for L/D samples, since the fabrics were dyed after laser treatment, the yellowish burnt fibres may be washed away during dyeing, leaving less yellowish burnt cotton and thus less greenish than D/L samples.

CIE b* value stands for the yellowish or bluish color of the sample. Positive b* value means the sample has a yellowish color, while negative b* value means the sample has a bluish color. Samples treated with the two different approaches show negative b* values as the cotton fabrics were all dyed with blue dye, so the fabrics show blue color. L/D samples show a more negative b* value than D/L, the reason being that during the treatment, irradiation from laser beam on the fabric surface causes decomposition of dye of the coloring agent by thermal effect [7, 8]. Vaporization occurs when the fabric surface continuously absorbs energy from laser irradiation during treatment; dye on the fabric surface gets vaporized and is diffused away into the surrounding atmosphere [3, 6]. Also, with the yellowish burnt cotton on the fabric surface, more yellowish with blue dye results in less bluish samples, compared with L/D sample.

### 4. Conclusions

In this paper, color properties of cotton samples treated with two different approaches were studied. It was found that laser treatment has no influence on shade of cotton fabrics. Also, first dyed and then laser treated samples (D/L) show lighter shades with more greenish and less bluish color after treatment. On the other hand, first laser treated and then dyed samples (L/D) had a better color yield, less greenish and more bluish color. In order to have different color properties of cotton fabrics whether laser treatment should be done before or after dyeing needs to be considered carefully in order to obtain the desired effect.

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### References
