Dimensional Stability of CO_2 Laser-treated Denim Fabric

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Abstract: CO_2 laser process allows quick surface pattern designing of desired size and intensity on a wide range of textile surfaces with precision and without much affecting the structure of the materials. As a result, CO_2 laser application in textile material is possible to make textile fabric to have faded look, worn out and special effects without using chemical as compared with conventional process. In the past, colour fading effect of CO_2 laser-treated denim fabric was studied but the dimensional stability of the CO_2 laser-treated denim fabric is seldom reported. Therefore, this study will investigate the effect of CO_2 laser on the denim fabric in order to evaluate the effect on fabric dimensional stability. Experimental results revealed that the laser power should be carefully controlled because the laser power could affect the fabric shrinkage due to severe fabric damage.

1 INTRODUCTION

CO_2 laser process allows short-time surface designing of the patterns on a wide range of textile surfaces, including knitted or woven fabrics, with precision and without much damaging the texture of the materials at selected laser power (Ferrero and Testore, 2002); (Ondogen et al., 2005); (Wijayathunga et al., 2007); (Yip et al., 2006). As a result, CO_2 laser application in textile material has been applied possibly to make fabric looked faded and worn out, instead of using stone, sanding or chemical processes in textile industry which may cause pollution problem in the effluent (Dascalu et al., 2000); (Ozguney, 2007); (Tarhan and Sariisik, 2009). Thus, applying certain designs to the surface of textiles by changing the dye molecules in the fabric and creating alternations in its colour quality values as well as the fabric characteristics values by the removal of surface fibres from directing the laser to the material at the selected laser power were reported (Esteves and Alonso, 2007); (Kamata and Suzuki, 2004); (Naruse and Suzuki, 2004). As CO_2 laser plays an important role to modify the sense of vision, its effect on the fabric dimensional stability is seldom reported. In this study, CO_2 laser will be applied on the denim fabric in order to evaluate the effect on fabric dimensional stability.

2 EXPERIMENTAL

2.1 Material

Blue indigo-dyed denim fabric was used. The fabric weight was 384g/m^2 with warp density 20 ends/cm (80tex) and weft density 20 picks/cm (60tex). The denim fabric was conditioned under standard atmosphere of 65±2% relative humidity and 20±2°C before further treatment.

2.2 Co_2 Laser Processing

The laser process was conducted with a CO_2 source laser (wavelength: 10.6μm) engraving machine (GFK, Spain) which is computer-controlled. A circular pattern of size 200mm x 200mm as shown in Figure 1 was input into the computer system. During the laser processing, the circular pattern was transferred to denim fabric by laser engraving

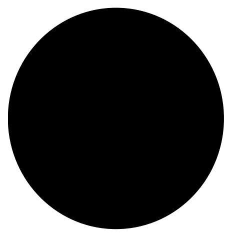

Figure 1: Circular pattern with size 200mm x 200mm.

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The resolution of the computer-controlled laser beam was set to 30, 60, 80 and 100 dot per inch (dpi) with pixel time of 110, 160, 220 and 300µs. Totally, 16 combinations were made.

2.3 Laser Power Measurement

In order to investigate the relationship between resolution (dpi) and pixel time (µs) to give the laser power density, a 842-PE hand-held Optical Power/Energy Meter was used for measuring the laser power energy of the 16 parameter combinations.

2.4. Dimensional Stability

Circular pattern was engraved on the denim fabrics and the dimension of the circular pattern was measured first as original reading before simulated domestic washing. Then the denim fabrics were washed according to AATCC Test Method 135: 2004 using a Whirlpool US washer WTW5905 with 66.0 ± 1.0g of detergent at 27±3ºC for 12 minutes. After washing, the denim fabrics were hydroextracted for 6 minutes followed by tumble drying at 66±5ºC for 10 minutes. After drying, the denim fabrics were conditioned under standard atmosphere of 65±2% relative humidity and 20±2°C before measurement. In order to study the dimensional stability, the denim fabrics were washed and dried one, three and five times. After each washing and drying, the dimension of the circular pattern was measured and the dimensional stability of the denim fabric can be calculated according to Equation (1). The measurement was made within 5% error.

Dimensional stability (%)
= [(Final dimension – Initial dimension)/Initial dimension] x 100% (1)

Positive and negative dimensional stability means fabric growth and shrinkage respectively.

3 RESULTS AND DISCUSSION

3.1 Laser Power Measurement

The laser power (expressed as intensity, W/cm^2) of the corresponding combinations of resolutions and pixel time were described in Figure 2. For pixel time, it is a unique parameter in computer graphical file to control the time for laser head positioning in each image point in µs. The long pixel time means more energy focused on the fabric causing a higher degree of engraving effect. Resolution (in term of dpi) is a parameter to control the intensity of laser spot in a particular area; the higher dpi means a higher resolution. However, too high resolution may cause the fabric burnt. A steady increased trend of the power density was observed with the prolonged pixel time and high resolution.

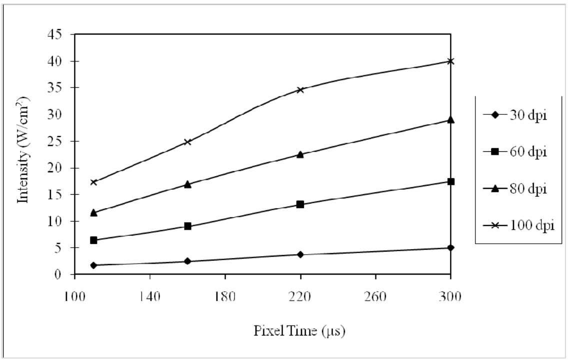

Figure 2: Laser power of different parameters.

The laser power plays an important role in the CO_2 laser treatment on the denim fabric which is closely related to the indigo removal process of textile. The physical phenomena involved in the indigo removal process will be the vapourisation process. The material removal by laser may often be a simple vapourisation process with absorption of the laser energy at a continually treated surface. As the laser energy increases, the material reaches vapourisation conditions more rapidly (Dascalu et al., 2000).

3.2 Engraved Pattern

From the observation of the fabric, 30 dpi engraving effect was not good, due to its poor resolution, with line effect on the pattern as shown in Figure 3. However, the engraving results show the resolution must be reached 60 dpi or above to ensure the pattern engraved do not shows poor line effect.

The size of circular pattern was compared with the original printing. The initial dimension and the dimension of the circular pattern engraved in the denim fabric are shown in Table 1. From Table 1, it is noted the laser process can reproduce accurately the pattern in the denim fabric. This shows that the laser process is an effective tool to transfer a pattern or image from computer to the fabric surface.

Figure 3: Line effect on 30 dpi laser engraving.

Table 1: Dimension of engraved circular pattern.

Sample	Length (mm)	Width (mm)
Circular pattern printed in paper	200	200
Circular pattern laser-engraved in denim fabric	200	200

3.3 Dimensional Stability

Dimensional stability of fabric refers to the fabric dimensional change after washing which can be divided into two types, shrinkage and growth. The causes of fabric shrinkage may be due to many reasons, there are mainly two kind of shrinkage happened on textile fabrics, relaxation shrinkage and progressive shrinkage. Relaxation shrinkage is happened on first time of washing, during production of fabric, like weaving, fabric is under tension by stretching by machines. This potential energy is retained on the fabric due to friction between yarns. During first washing of fabric, because water and detergent can lubricate yarns, so the tension released, and this cause the relaxation shrinkage of fabric. Progressive shrinkage is the continuous shrinkage of fabric during washing, it can be caused by more than one reasons, like the further relax of fabric tension, loss of elasticity of fibre and felting effect on fabric. This kind of shrinkage is not as much as relaxation shrinkage, however, it keeps on happen in every washing.

Growth on fabric after washing, this problem can also be caused by many factors, which mostly affected by yarn. Over pre-shrinkage treatment to fabric can cause relaxation growth of fabric. Low twist yarn would tend to grow because of the poor coherence of fibre cause easily lengthen when pulling force is applied to the fabric.

Table 2 shows the dimensional change (in %) in lengthwise and widthwise directions of laser-engraved circular pattern in the denim fabric after different washing cycles. In Table 2, the positive number and negative number refer to fabric growth and shrinkage in dimension respectively while "--" means fabric damaged during washing and no data can be measured.

3.3.1 Damage of Fabric during Washing

In the washing process, there are numbers of fabric damaged after washing cycle. The possible reason of the damaging of fabric was severe damage by excess laser power. Most of the 100 dpi laser treated fabrics could not withstand the washing cycle because energy treated the fabric was too high because the laser power of 100 dpi was at least 17.34 W/cm^2. The strongest power of laser which could withstand washing test was 80 dpi with pixel time 160µs which power intensity was 16.92 W/cm^2.

3.3.2 Dimensional Change

In Table 2, the dimensional change of the circular pattern was different in lengthwise and widthwise directions. However, the widthwise direction has a higher shrinkage. This may be due to the yarn in the widthwise direction subjected to a higher tension during the fabric production process. As a result, during the washing process, a severe relaxation shrinkage occurred. In general view for the samples in Table 2, most of them was facing shrinkage in their lengthwise and widthwise directions. The relaxation shrinkage contributes most of the first time shrinkage but the lengthwise direction did not have much change in first washing cycle.

Denim fabric sample treated with high laser power had less shrinkage because the fabric samples were severely damaged by laser, so the fibre in the yarn structure was damaged and no longer had high coherence with each other, so when fabric was washed, the yarn was started to relax and grow with help of agitation and lubrication of water and detergents. As there is a chance of dimensional change of the laser- treated denim fabric, it would have a risk of shape deformation in engraved pattern in the denim fabric. So it is necessary to select the laser processing parameters carefully to avoid the shape deformation but with desired result.

Table 2: Dimensional change of circular pattern after different washing cycles.

Pixel time (µs)	dpi	Washing cycle	Length change (%)	Width change (%)
110	30	One	1.06	-4.71
	60		0.53	-4.21
	80		-1.05	-4.69
	100		0.52	-4.12
	30	Three	0.00	-5.76
	60		0.00	-7.37
	80		-1.05	-6.25
	100		-0.52	-3.09
	30	Five	-0.53	-6.28
	60		-0.53	-7.33
	80		-1.58	-1.56
	100		--	--
160	30	One	0.53	-4.71
	60		0.00	-4.71
	80		1.05	-3.65
	100		--	--
	30	Three	-0.53	-6.28
	60		0.00	-6.54
	80		0.00	-3.65
	100		--	--
	30	Five	-0.53	-6.28
	60		-1.06	-7.33
	80		-2.63	-1.56
	100		--	--
220	30	One	0.53	-4.19
	60		0.53	-4.71
	80		--	--
	100		--	--
	30	Three	-0.53	-6.28
	60		-0.53	-6.28
	80		--	--
	100		--	--
	30	Five	-1.05	-6.28
	60		-1.60	-6.28
	80		--	--
	100		--	--
300	30	One	0.53	-4.19
	60		1.06	-1.05
	80		--	--
	100		--	--
	30	Three	-0.53	-5.76
	60		--	--
	80		--	--
	100		--	--
	30	Five	-1.58	-6.28
	60		--	--
	80		--	--
	100		--	--

4 CONCLUSIONS

In this paper, denim fabric was laser-treated under with different laser power using different combination of pixel and dpi. Experimental results that higher pixel time and dpi would contribute to a higher laser power for denim fabric surface engraving. However, fabric damage occurred if high laser power was used. Therefore, it is necessary to control the laser power carefully during the laser engraving process. With the use of laser processing, the engraved pattern could totally match the desired size. When the laser-treated denim fabrics were subjected to simulated domestic washing with different washing cycles, Shrinkage and growth in fabric dimension were noted but the degree of shrinkage and growth depended much on the later power used. Generally speaking, shrinkage occurred mostly in the widthwise direction because of the yarn in the widthwise direction subjected to a higher tension during the fabric production process. So during washing, the relaxation shrinkage occurred severely in the widthwise direction. It was also important to note that during the washing process, damage of denim fabric occurred when it was treated with very high laser power. As a result, when using laser for creating pattern or design in textile fabric, a careful selection of laser processing parameters was recommended so as to prevent shape deformation without affecting the final result.

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