Laser Application in Apparel Industry

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Abstract: Every human being (even animals, sometimes) needs to wear clothes. Therefore the apparel/garments/textile industry is one of the most essential service providers in this world. Different types of fabrics are in demand by people depending on their age, taste, culture, season, region etc. Majority of the people want to look good in appearance by wearing designer and customized clothes. Therefore the apparel industry has to meet the requirements and aspirations of these users. There are many conventional and upcoming non-laser technologies to manufacture various types of fabrics and clothing but the quality of finished product leaves much to be desired. The advent of laser technology in textiles industry has established a new innovative solution, which successfully prevents some of the weaknesses in the conventional technologies. Many such laser-based technologies like laser marking, laser graving, laser etching, laser cutting, laser engraving, and laser fading of fabrics and clothing for better quality of the finished products, speed, volume and economy, are discussed in this paper.

Keywords: Lasers, marking, engraving, manufacturing, garments, apparel, textile, cloth, denim jeans, fading

I. INTRODUCTION

Every human being (even animals, sometimes) needs to wear clothes. Therefore the apparel/garments/textile industry is one of the most essential service providers in this world. Different types of fabrics are in demand by people depending on their age, taste, culture, season, region etc. Majority of the people want to look good in appearance by wearing designer and customized clothes. Therefore the apparel industry has to meet the requirements and aspirations of these users. There are many conventional and upcoming non-laser technologies to manufacture various types of fabrics and clothing but the quality of finished product leaves much to be desired. The advent of laser technology in textiles industry has established a new innovative solution, which successfully prevents some of the weaknesses in the conventional technologies. For example, laser systems are used on fabric, ready-made clothes, logos, labels and for many such purposes. They have been used extensively as the replacement of some conventional dry processes like sand blasting, hand sanding, destroying, and grinding etc., which are potentially harmful and disadvantageous for the environment. Laser technique is being applied in the textile and fashion industry because it is an ideal surface treatment for design application without usage of chemicals and water. In recent years, the use of lasers for textile material marking and engraving is increasing because of the speed, accuracy and flexibility of this modern technique. There are several advantages of using laser over the conventional processes in cutting, engraving, embossing, denim fading and other applications in the apparel industry. The damage to product damage potential is reduced, no/less consumables are needed and no problem of toxic by-product disposal as is found in some non-laser processes [1]. For example, the application of lasers in denim engraving gives a value addition by replacing the traditional denim-distressing techniques [2]. Laser engraving and cutting technologies are now being widely applied in many garment industries, fabric production units, and other textile industries.

1.1 Advantages of laser applications in apparel industry

Following are some of the advantages of laser applications in apparel industry:

(i) Laser marking, laser engraving and laser cutting can be combined in one step;
(ii) No mechanical wear of tools in laser-based process, hence better precision in outcome;
(iii) No fixation of material is required due to force-free processing by lasers;
(iv) No fabric fraying in synthetic fiber due to formation of fused edges;
(v) Laser-based process is clean and lint-free.

II. LASER MARKING, LASER ENGRAVING, AND LASER ETCHING

Lasers can fulfill many requirements for marking of the manufactured parts including textiles. Product marking can be carried out for the purposes of identification, for product information, for imprinting distinctive logos, for identification of gemstones, and for theft prevention. Conventional marking techniques include printing, stamping, mechanical engraving, manual scribing, and etching.

2.1 Differences between Laser Marking, Laser Engraving and Laser Etching

All three of these laser services provide a permanent marking solution and add distinction to the products and parts. But what sets them apart?
Although these terms are often used interchangeably, there are differences between laser marking, laser etching and laser engraving. Each type of process has its own applications and attributes that make it ideal for different jobs.

2.1.1 Laser Marking

Laser marking is what happens when the beam interacts with the surface of a material, slightly altering its properties or appearance. It is achieved by moving a low-powered beam slowly across the material using a method called discoloration, which creates high-contrast marks without disrupting the material. Laser heats the material, causing oxidation under the surface and sometimes turning the material black. It applies low temperatures to anneal the surface. All of this is done while leaving the surface intact.

2.1.2 Laser Engraving

The high heat of the laser beam vaporizes the material thereby cutting into the part's surface and physically removing material. This process leaves a cavity in the surfaces that is not only visible with a high contrast but also noticeable by touch. There are noteworthy differences in the depth of this cavity that varies between 0.02″ in metals to 0.125″ in harder materials. Multi-layer materials offer an alternative, as they enable to engrave other colors than black. By removing the top layers the lower layers become visible.

Laser engraving has often been used to mark wood products for applications like fabrication of artistic scenes or commemorative plaques. Of late, it has found advantageous applications in the apparel industry as well. This application often employs a CO_2 laser operating in the range of 40-80 W of power. The pattern may be stored in a computer memory, which controls the scanning and the modulation of the beam. Alternatively, the laser may be controlled by the output from a photodetector that scans an original drawing synchronously with the laser scan. This method allows rapid transformation of a drawing into an engraved pattern.

Difference between laser engraving and laser marking:

Although engraving is a subsection of laser marking, it still differs in many ways:

(i) There are three types of laser engraving: etching, deep laser engraving and laser ablation (the difference between the three is what the surface is and how much material one removes).

(ii) Laser engraving is the most common option for people who want something personalized or customized.

(iii) This is the fastest way to mark with a laser.

(iv) It is suitable for materials expected to experience high wear.

(v) It is typically used to engrave serial numbers and logos, among other things.

(vi) One can engrave on almost any kind of metal, plastic, wood, leather, cloth, garments, denim jeans and glass surface.

Comparison between laser engraving with traditional engraving:

(i) Laser engraving can be done on a number of materials.

(ii) It is more legible than traditional engraving for small objects such as jewelry.

(iii) It provides one with more font options.

(iv) There is a smaller chance of product damage or deformation.

(v) Laser engraving machines are faster than traditional methods.

2.1.3 Laser Etching

Laser etching, which is a subset of laser engraving, occurs when the heat from the beam causes the surface of the material to melt. The melted material expands and causes a raised mark. Unlike with engraving, the depth in etching is typically no more than 0.001 inch. It removes 0.001″ or less of the material. It can be done on bare, anodized or plated metal surfaces, as well as polymers, textiles and ceramics.

2.2 Three Methods of Laser Marking and Engraving:

Laser marking and engraving are implemented through three main ways: (i) raster, (ii) vector and (iii) projection [3]. (i) When image is obtained by raster marking, laser beam moves sequentially in rows, similar to the dot matrix printers, but instead of an ink there is a laser beam. This method was used mainly for marking alpha-numeric information, and less frequently for graphic images. (ii) In vector marking the mark is written by a focused laser beam, which follows the contour, which in turn is guided by an optical system and operated by a computer program. Vector marking applies to all kinds of information: numeric-codes, bar-codes, 2D codes, logos, and almost any other type of image. This is the most common and versatile method of laser marking. (iii) Projection marking is implemented with mask (stencil). Laser beam passes through it and is projected onto the working area.

Each of the three systems for laser marking has its advantages and disadvantages. According to the specific case of marking the most appropriate technique is selected depending on the requirements for speed, size of the treated area, flexibility and investment costs.

2.3 Advantages of Laser Marking and Engraving on Textile Materials

Laser marking and engraving of textile materials are fundamentally different and greatly superior to conventional methods. Particular benefits when working with the laser on textiles are its speed, flexibility and precision. Moreover, the nesting feature included in the laser software ensures economical use of the fabrics.

The following advantages can be indicated [3]:

(i) Automated process of production reporting and control - reading with electronic tracking devices on the marked product during manufacturing process and throughout the retail chain;

(ii) Ability to process almost all textile materials;

(iii) Ensure the authenticity of the product and protect it against counterfeiting;

(iv) Allows storage of large amounts of data (The density of marked information is very high);

(v) The ability to read at different angles and even after a partial demolition, which is very typical for textile products during exploitation life;

(vi) Flexibility - integration in production and automated lines allows marking on the fly;

(vii) Extremely accurate and qualitative, with clear contours, very fast and precise method;

(viii) Minimal heat affected zone;

(ix) Contactless - missing mechanical impact on the treated material, and the result is getting the permanent, contrasting image;

(x) Very good quality, due to the stability and manageability of the laser source;

(xi) Environmentally friendly process;
(xii) High performance of the process;
(xiv) Profitable method as applicable for large pieces and products;
(xv) Economical - low production and operating costs without the use of consumables, there are no chemicals, nor ink ribbons or other materials;
(xvi) Laser technologies work with better precision and higher productivity.

III. LASER ENGRAVING IN DENIM FABRIC AND JEANS

Denim is a sturdy cotton warp-faced textile in which the weft passes under two or more warp threads crossing lines of threads in a loom). This twill weaving produces a diagonal ribbing that distinguishes it from cotton duck. The most common denim is indigo denim, in which the warp thread is dyed, while the weft thread is left white. As a result of the warp-faced twill weaving, one side of the textile is dominated by the blue warp threads and the other side is dominated by the white weft threads. This causes blue jeans to be white on the inside.
The most popular variants of denim are: (i) Stone-washed and double stone-washed denims; (ii) Chambrays; (iii) Fancy multi-color denims; (iv) Denim with metal-effects yarns; (v) Elastic denims; (vi) Printed denims; (vii) Jacquard-patterned denims; and (viii) Denims with fancy yarns. Lightweight denim fabrics are used for shirts and blouses. Heavy, classic denims are made up into trousers or coats. Besides classic indigo blue, the fabric is dyed in other fashion shades and colours, the most popular being black denim.
Laser engraving refines the surface of the material, thus increasing the quality of the fabric. Laser engraving is often embedded with the computer design process that is applied in textile industry.

Guoxianga et al [4] explored a design method that combines laser engraving technology and metallic foil laminating for a shining surface effect. Before the application of laser engraving, the aluminum foil was laminated on denim fabric with laminating adhesive. Then, the laminated denim fabric was engraved by the laser with a different DPI (dots per inch) as well as the pixel time (microsecond). The performance of the laser engraved foil laminated denim fabric was investigated, including physical and mechanical properties. The study demonstrated an embellishment application in denim fabric, which developed metallic appearance with patterns on denim fabric using laser engraving techniques. The results were found to be far better than the conventional engraving techniques. The laser engraving in this case was carried out with 280-W CO_2 laser coupled to a computer-controlled table. The size of the lens was 80cm (producing 1.5-mm beam diameter).
In a paper [5] the authors had experimented with 100% cotton fabric "Denim" with these characteristics: basic thread - linear density = 20 tex, indigoid colored in dark blue; main density 280 t/10cm; weft- linear density = 20 tex bleached; weft density 280 t/10cm; twill 2./.1 ; weighing 200 g/m2. The samples were pre de-seized, degreased and washed. The fabric was conditioned at 21±1°C and humidity of 65±5% for 24 hours before the experiments and evaluations. Nd:YAG laser beam (energy1mJ and prf 20 kHz) was then irradiated on this cloth. The parameters were adjusted for the optimum effect of laser treatment in different combined conditions. Treated samples were then subjected to enzymatic laundry. The process proceeded in the following order: rinsing, enzymatic treatment, double rinse, softening, centrifugation and drying. All output results showed that the integration of laser technology and textile (denim) materials is an effective way to create an innovative and environmentally friendly fashion design.

3.1 Effect of Laser Engraving on Seam Properties of Weaving Denim

In a study [6] three different seam types were used to sew denim fabric. Seam type-1 was superimposed seam type, seam type-2 was lapped seam type and seam type-3 was lapped seam type by using two different stitch types (Stitch type 516 and Stitch type 301). CO2 Flatbed laser machine was used to engrave shapes on denim fabric before and after sewing by using two different speeds (speed-1 180 m\s, speed-2 400 m\s). Tests were applied to determine the seam properties like thickness, breaking force, seam pucker and appearance. All tests were done according to standards and took place into conditioned atmosphere of 21ºC and 65% RH. Comparisons were made among the three different seam types and two different machine speeds. This was done with reference to durability, efficiency and appearance of textile. It was found that: (i) There is a direct relationship between Laser machine speed and breaking force. When machine speed increases, the breaking force increases, seam pucker increases and vice versa.

IV. LASER FADING OF DENIM JEANS

In the world of fashion these days, there has been a demand for denim jeans that have a worn and faded appearance. It is possible to manufacture the faded denim garments through different physical processes such as sanding, sand spraying, brushing, embroidering; and chemical processes such as pre-washing, rinsing, stone washing, sand washing, snow washing, stone washing with enzymes, bleaching etc.
Laser fading is a popular dry process for denim these days. It has been used extensively as the replacement of some conventional dry processes like sand blasting, hand sanding, destroying, and grinding etc. which are potentially harmful and disadvantageous in some manner. By using a laser it is possible to create a worn out look on denim, which could be an alternative method to conventional processes. Generally a CO_2 laser is a suitable tool for the discoloration of indigo-dye on denim fabric. In comparison with conventional techniques of processing denim fabric, a laser beam provides us with some advantages: it is environmentally friendly with respect to the consumption of chemical agents, has low water consumption, and offers flexibility of the process and replications of design [7]. He specifications of the CO_2 laser were: average output

power 150/250 watts, Peak output power 230/400 watts, Working frequency 50/60 Hz and polarization linear.

It was concluded [7] that (i) the desired colour fading effect can be obtained due to hand sand brushed fading. The yellowness index (YI) changed significantly for hand sand brushed but YI decreased for laser faded sample. (ii) The result showed that the wash fastness by Hand sand treated and PP sprayed on denim fabrics had improved but had reduced significantly for laser treated sample. (iii) Light fastness was excellent for hand sand treated sample and comparable for both laser treated and PP sprayed samples, respectively. (iv) Further it was found that, for hands sand brush tensile strength in warp ways decreased by 56.68%, for laser faded tensile strength decreased by 1.31% and for PP spraying reduced by 2.57% in comparison with the raw denim.

Madian et al [8] studied the effect of laser-denim-wash-process onto abrasion of seamed denim. They used three different weight 100% cotton fabrics: all indigo dyed. The fabrics were faded using industrial CO_2 laser beam onto the seamed areas. Seams were completed on the weft direction for each tested denim fabric. The three seamed denim fabrics, unwashed and laser-faded, were tested. Color hues were detected showing the change in colour, by comparing with the unwashed to CO_2 laser-faded fabrics. The study recommended that for industrial use, it is advisable to use laser fading onto heavy weight twill denim garments, and utilize the superimposed seam instead of top-stitched lap-felled seam for an aesthetic durable piece of laser faded garment.

4.1 Advantages of laser fading technology:

(i) Any design at any place can be created.
(ii) Fading on seams, on metal buttons is possible.
(iii) Faster process compared to the conventional dry processes.
(iv) Cent percent design accuracy.
(v) Suitable for wide range of material.
(vi) Comparatively less strength loss than other mechanical fading.
(vii) Low hairiness compared to other mechanical fading.
(viii) Environment friendly.
(ix) Zero water waste.
(x) Requires no chemicals.
(xi) Less manpower required.

4.2 Disadvantages of laser fading technology:

Despite so many advantages of laser-based apparel technologies, following are some of their limitations [9]:
(i) Initial investment is very high, which is a problem for small and medium size industries.
(ii) Skilled operator is needed, which might be a disadvantage in some particular circumstances.
(iii) Producing natural effect is difficult and often requires some manual touch after the fading to give the product natural look.
(iv) The laser beam itself and the produced fumes are health hazardous.
(v) Maintenance and servicing of the laser system may be troublesome in some circumstances.

V. LASER TREATMENT ON COTTON AND COTTON/POLYESTER BLENDED FABRIC

Fabric hand has been recognized as one of the most important performance attributes of apparel textiles. It is defined as “perceived overall fabric aesthetic quality”. The quality of the textile material is mainly perceived by touching and has a direct impact on the product’s appeal. Fabric hand not only affects the perception of consumers towards the products, but also development from the stage of design to manufacturing and merchandising through to the final consumer.

In a study on laser-based treatment on cotton and cotton/polyester blended fabric [10], five fabric hand properties, namely, stiffness, smoothness, softness, wrinkle recovery rate, and drapability, were studied. It was shown that the laser treatment could be successfully used to change the fabric hand. In the case of pure cotton woven fabrics, the fabrics were found to have better drapability and wrinkle recovery after laser treatment. In cotton/polyester blended fabrics, stiffness was found to be relatively higher after laser irradiation. Carbon dioxide (CO_2) laser was used with different intensities in terms of resolution and treatment time.

The fabric samples were soaked with 30 ml/L acetone for 10 min to remove any grease and dirt on the surface. After washing, the samples were rinsed with water and hydro-extracted in a Hydro-extractor for 5 min. Lastly, the samples were dried in a tumble dryer (Electrolux, for 15 min. All cleaned samples were conditioned under standard conditions of about 65% relative humidity and at about 21^0 C, for at least 24 h0urs prior to all experimental and evaluation tests. A pulsed CO2 source laser engraving machine was used under atmospheric conditions. The fabric samples were treated at different combinations of processing variables (resolution and pixel time.

Results obtained for the fabric hand properties demonstrated that laser treatment can be successfully used to change different aspects of the fabrics including stiffness, smoothness, softness, drapability, and wrinkle recovery. Since the aesthetic performance of a garment is governed by the quality of fabric used, the silhouette of the garment can be altered according to the change in fashion trends through the application of laser treatment on fabrics. In the case of 100% cotton woven fabrics, the fabrics were found to have a better drapability and wrinkle recovery after laser treatment. As for the cotton/polyester blended fabrics, the stiffness of the fabrics was found to be relatively higher after laser irradiation. With the appropriate control of laser processing variables, laser treatment may resolve such problems in some pliable fabrics during the production stage.

CONCLUSION

In this paper we have discussed, in details that the unique properties of the laser beams and hence seen that the laser-based techniques can replace the conventional and non-laser techniques, in many situations for producing many types of fabrics and clothing, including denim, cotton, polyester etc., with better finish of the product, better quality of the surface and design of the fabrics, computer-supported automated and fast processes, with faster speed, with larger volumes and hence making it a more economical technique.

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