TEXTILE MATERIAL MULTI PLY CUTTING BY LASER

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Abstract: *Multi ply fabric cutting by laser is very challenging because of low thermal conductivity of textile materials. A laser beam can through-cut only limited number of fabric plies placed one above another. In experiment the conditional spread of ten 100% cotton fabric plies was cut by a laser beam to see how cutting speed influences cutting quality. It was established that using a 100 W laser beam all 10 plies could be cut only by lower speeds 30-45mm/s. In the laser cutting process the cut edges of material got coloured. The smaller was processing speed, the wider coloured edges were obtained. After sample washing edge colouring disappeared. Additional laundry process will not be needed processing garments which are dyed as a ready goods or manufacturing denim clothing when vintage look is obtained during washing process.*

Keywords: laser cutting, fabric multi-ply cutting, cutting speed, laser power.

MNOGOSLOJNO KROJENJE TEKSTILNIH MATERIJALA LASEROM

Apstrakt: *Krojenje tekstilnih materijala laserom je komplikovano zbog njihove niske termalne provodljivosti. Snop lasera može da preseče samo ograničenu količinu slojeva materijala. U ovom eksperimentu krojeno je 10 slojeva 100% pamučnog tekstilnog materijala snopom lasera, kako bi se razmatrao uticaj brzine pomeranja lasera na kvalitet krojenja. Korišćenjem lasera snage 100W svih 10 slojeva materijala je iskrojeno samo brzinama 30-45mm/s. U toku procesa krojenja krajevi materijala su dobili braon boju koja se javila kao posledica paljenja sitnih čestica prašine. Posle pranja iskrojenih uzoraka, nepoželjno obojenje krajeva je nestalo. Dodatno pranje iskrojenih delova nije potrebno ukoliko se krojenje laserom koristi za izradu odevnih predmeta koji se boje na kraju procesa proizvodnje ili pri izradi odevnih predmeta od denima kada se završnim pranjem dobija konačni izgled dugotrajnih gotovih proizvoda.*

Ključne reči: krojenje laserom, mnogoslojno krojenje tekstilnih materijala, brzina krojenja, snaga lasera.

1. INTRODUCTION

Laser cutting is used to process different origin materials, such as, metal, glass, stone, plastic, ceramic, rubber, wood, leather, others [1]. During the last 20 years the different laser treatments are also used processing textiles. The textile materials can be through cut, kiss cut, engraved and marked by laser. The laser treatment has got the wide application in denim material and ready good finishing as a sustainable finishing method [2]. Processing of textile materials by laser have several important benefits and because of them many industry companies develop new and advanced equipment based on use of different laser technologies.

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2. TEXTILE CUTTING BY KNIVES

Traditionally through-cutting of textile materials is performed by differently shaped knives. Industry is using automated cutting systems for single ply and multi ply cutting [3,4,5].

2.1. Automated single ply cutting by knives

In case of single ply cutting rotary and drag knives are used. Powered and freely moving circular knives can cut simply shaped lines in efficient way. The drag knives are used to cut complicated shapes, corners and small circles. Drills and needles are used to created small holes (control points) in the fabric. A hard work surface is necessary to support cutting process. To eliminate material displacement during cutting process, a powerful vacuum system presses down the material on the working surface [6].

Single ply textile cutting by knives has several disadvantages. The most important ones are: more than one differently shaped knives and other tools are used, cutting has to be stopped while a cutter changes the knife, knives also have to be sharpened creating a brake in the cutting process, knives have to be changed when they get worn-out, the vacuum systems pressing down the cut material use a lot of energy.

2.2. Automated multi ply cutting by knives

Multi ply cutting is performed by an oscillating knife. The single knife can perform whole cutting process, however, brakes are needed in the work process to sharpen the knife. The cutter uses one additional motor to ensure oscillation of the knife (movement up-down). Drills and needles are used to created small holes (control points) in the fabric. A much more powerful vacuum system has to be used to press down many fabric plies in the material spread on the work surface to avoid their mutual displacement. The cutter has a knife cleaning and cooling system to avoid heating of the knife and its contamination with cut and melted fabric parts [7].

3. TEXTILE CUTTING BY LASER

Comparing with knife cutting the laser cutting has several important advantages. All cutting process is performed by only one tool - a laser beam. This tool does not have to be sharpened, cannot worn-out. There are not needed brakes in the work process to change a cutting tool or to sharpen it. A laser beam does not have direct contact with a processed material, therefore it cannot drag or displace the fabric place on the cutting surface [2].

The laser beam melts a cut fabric if it has synthetic origin or burns it out if the fabric has natural origin. In case of synthetic textiles, melted cut material edges cool down and get hard, thus cut fabric edges cannot fry anymore. Cutting natural origin textiles cut edges use to get lightly coloured because of material burning process. Hard material edges or coloured edges are disadvantages of laser cutting process manufacturing clothing. Although the material melting protects the fabric edges from frying, the hard edges can irritate human skin getting in direct contact with it. The coloured edges of cut components can reduce esthetic value of ready garments [2].

3.1. Single ply cutting by laser

Laser single ply cutters are already available in a market and are successfully used by industries that use textile materials, such as, auto and furniture industries. Their use in clothing industry is less beneficial. Large orders (in different quantities and garment sizes) and very different textiles materials are usually processed manufacturing garments. Therefore any type of single fabric ply cutting method currently has limited application. Currently single fabric ply laser cutting is used processing digitally printer fabrics and fabrics with intricate patterns (stripped, checked, others).

3.2. Multi ply cutting by laser

Because of necessity to cut large number of identical textile goods, multi ply cutting (manual or automated) is traditionally used in clothing industry. However, multi ply cutting by laser for clothing industry is very much challenging. Traditional textile materials have low thermal conductivity [8]. Therefore the heat generated by a laser beam can through-cut only limited number of fabric plies placed one above another [9]. In case of synthetic origin fabrics melted material edges can glue together several fabric plies making difficult their further mutual separating [9,10].

4. EXPERIMENT

The experiment was performed to evaluate possibilities of using a laser beam as a cutting tool processing a multi-ply fabric spread.

4.1. Object of research

A 100% cotton fabric was selected for the research. The main characteristics of the material are:

main thread - linear density Tt=22 tex; basic density 240 thr/10cm; weft thread - linear density Tt=22 tex; weft density 240 thr/10cm; plain weave; mass 110g/m^2 [11,12,13]. The samples were previously degreased and washed. The material was conditioned at a temperature of 20±2°C and a relative humidity of 65±4% for 24 hours before conducting the experiments according to a standard "Textiles – Standards atmospheres for conditioning and testing" [14]. The measurements were carried out using the following equipment: Precisa Balances Series 320 XT and BINDER KBF.

4.2. Laser equipment

The processing of the textile samples was carried out on a CO_2 laser system with a beam output power of 100W. In the system, the laser beam was deflected by help of movable mirrors in the XY plane on a working surface 400x600 mm. The main characteristics of the used laser system are showed in Table 1. The parameters of the laser cutting process are presented in Table 2 and graphically in Figure 1.

The laser system was controlled by a computer that allows setting the average power (Pa, W) by setting a percentage of the maximum power and cutting speed (V, mm⁄s).

Table 1: Characteristics of the laser system used

№	Laser type / Parameter		CO_2
1	Wavelength	$\lambda, \mu m$	10,64
2	Average power	P_a, W	100
3	Impulse power	P_p, kW	100
4	Impulse energy	E_p, mJ	2
5	Pulse duration	τ_p, ns	20
6	Pulse rate	f, kHz	0,20-50
7	Minimum focal spot diameter	d_f, mm	0,15
8	Beam quality	M^2	1,5-2
9	Positioning accuracy	μm	< 100
10	Engraving Area	mm	400x600
11	Cutting Speed	mm/s	0,2-400
12	Efficiency	%	20

Table 2: Laser cutting process parameters

		f, kHz			
Pa (W)		20	30	40	50
100	Ep (mJ)	5,00	3,33	2,50	2,00
	Pp (kW)	250,0	166,7	125,0	100,0
	qs (W/cm^2)	1,42E+09	9,44E+08	7,08E+08	5,66E+08
70	Ep (mJ)	3,50	2,33	1,75	1,40
	Pp (kW)	175,0	116,7	87,5	70,0
	qs (W/cm^2)	9,91E+08	6,61E+08	4,95E+08	3,96E+08
40	Ep (mJ)	2,00	1,33	1,00	0,80
	Pp (kW)	100,0	66,7	50,0	40,0
	qs (W/cm^2)	5,66E+08	3,77E+08	2,83E+08	2,26E+08

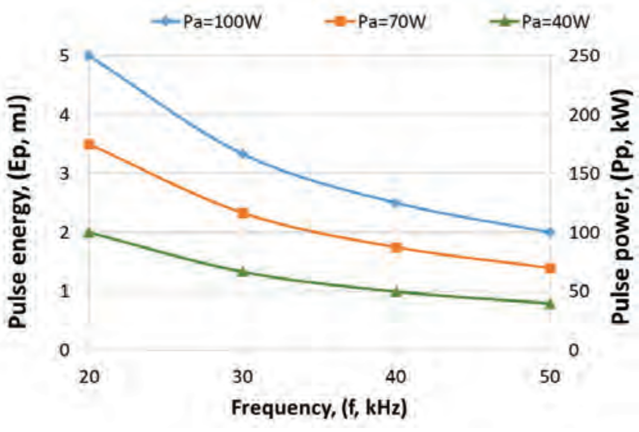

Figure 1: Characteristics of the laser source

4.3. Laser cutting process

10 textile samples with dimensions of 100x100 mm were prepared from above described cotton fabric. They were placed one above other conditionally representing fabric spread created to cut a garment manufacturing order. To see the impact of the laser processing speed to cutting quality, straight parallel lines (30mm long) were cut in the prepared fabric spread changing cutting speed (Fig.2). The cutting speed was varied in the range V=30-100 mm⁄s, increasing it in steps of 5 mm⁄s. Constant parameters of the cutting process were: average power Pa=100 W, defocusing ΔW_d=0mm, pulse rate 20kHz.

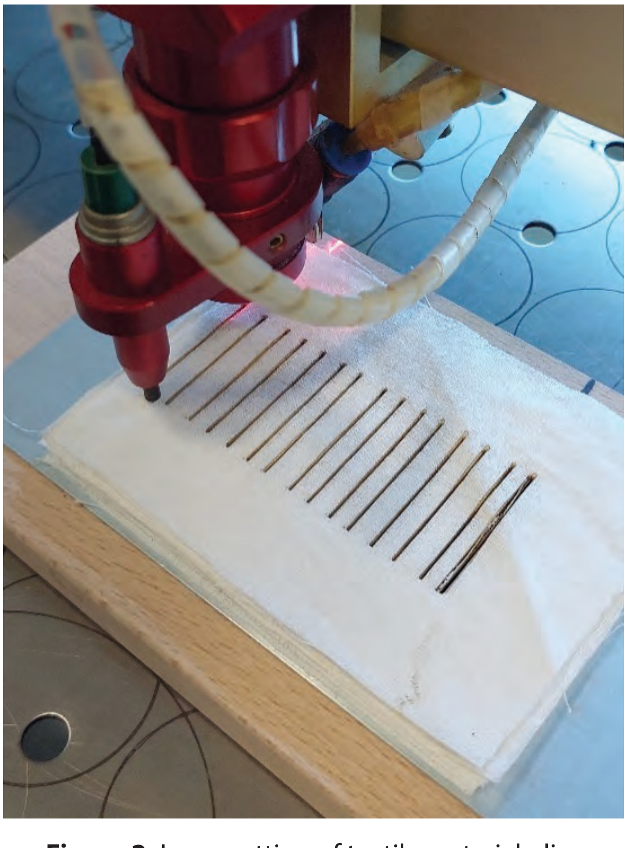

Figure 2: Laser cutting of textile material plies

The results of the experiment are presented in a Figure 3 where the top fabric ply is seen and in a Figure 4 where the bottom fabric ply is showed. The top fabric ply was fully through-cut by a laser beam of all tested speeds. The bottom fabric ply in the fabric spread was fully through-cut using only 4 lowest speeds - 30, 35, 40 and 45 mm⁄s (see Table 3 and Figure 6). In figures 3 and 4 it is also seen that the laser beam created different width coloured/burnt cut edges. The smaller was processing speed, the wider coloured edges were obtained.

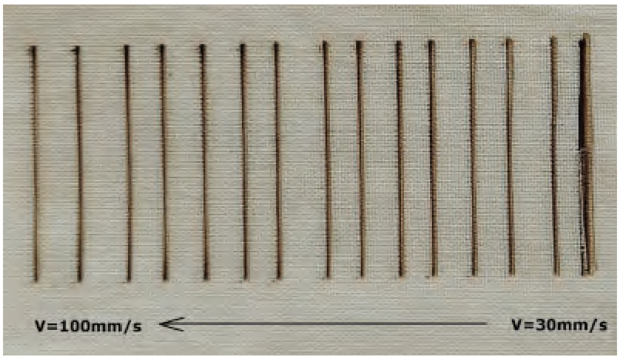

Figure 3: Cut samples - top side

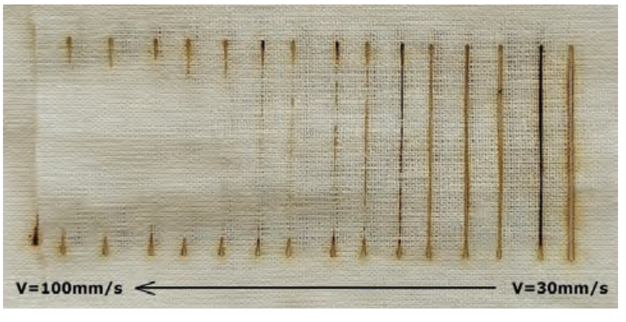

Figure 4: Cut samples - bottom side

For better quality evaluation of the cutting, the tested fabric spread was cut in the middle, perpendicularly the laser beam cut lines (see Figure 5). Through-cutting results of all fabric plies are shown in a Table 3 and Figure 6.

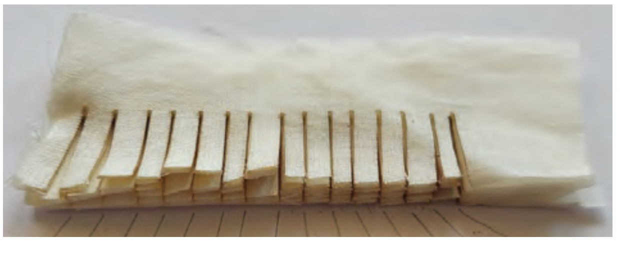

Figure 5: Counting the cut layers

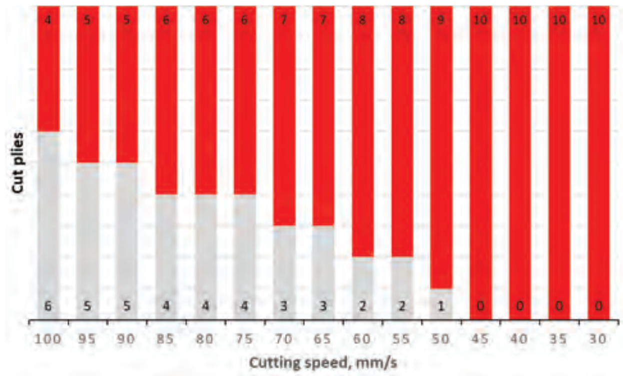

Figure 6: Laser cutting summary data

4.4. Colouring of the cut fabric edges

In the laser cutting process the cut edges of a textile material can get coloured. The reason of this negative effect is evaporation of processed material and/or charring of its cut edges. One more experiment was performed to evaluate the coloured edges on different lays of single fabric spread and to see possibilities to remove them.

Samples with dimensions of 80x80 mm were made from the above described 100% cotton textile material to create a fabric spread from 10 material plies. The cutting speed V=40 mm⁄s was chosen as it ensured good through-cutting results in the first experiment (other parameters: average laser power Pa=100 W, defocusing ΔW_d=0 mm, pulse rate 20 kHz). By help of a laser beam a 40x40mm square was cut in the prepared fabric spread (Fig.7).

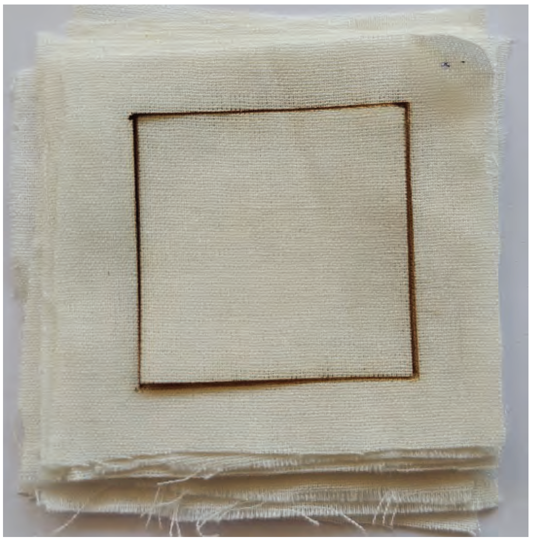

Figure 7: Samples after laser cutting

Table 3: The number of fully through-cut layers of the textile material

Cutting speed, mm/s	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30
Cut plies	4	5	5	6	6	6	7	7	8	8	9	10	10	10	10

The results of the experiment revealed equal distribution of colouring at the edges through the all plies. The affected area covered no more than 1 mm around the cut sample edges. The exact edges were not charred they were only a little brownish.

To try to remove the colouring of material edges on the cut squares, subsequent washing process was performed. The fabric samples were washed using washing cycle for cotton textiles (temperature 60°C, washing time 2h 30min.) in a domestic laundry washing machine. After sample washing and drying it was established that the colouring was completely removed from all 10 fabric samples (see Fig.8). It can be explained that the edges were only contaminated with material evaporations which were removed easily.

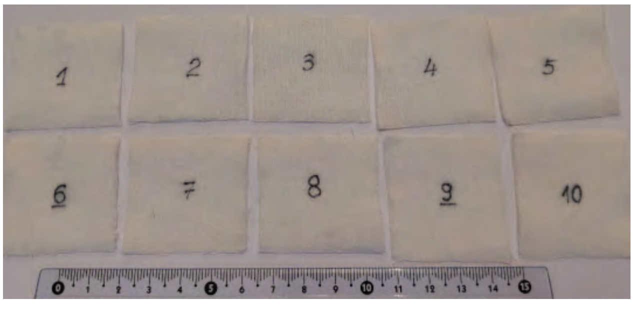

Figure 8: Laser cut samples after washing

5. DISCUSSIONS

The 1st experiment proved that it is possible to use laser cutting also for multi-ply fabric spreads. However, critical and very important could be correct selection of processing parameters (laser power, cutting speed) and number of fabric plies which can be through-cut in high quality. Obviously, the laser cutting will not be used for high fabric spread cutting as it is done using knives as a cutting tool. The number of fabric layers in a spread will depend on different specific qualities and thermal conductivity of every processed textile material [8]. To find these parameters precisely data base of previously successfully processed, the same or very similar textile materials, could be used. Advanced sensitive testing methods and software to test new fabrics directly by laser cutting equipment also should be developed.

Laser multi-ply fabric cutting could be acceptable only for low fabric ply cutting. However, this restriction will not be problem processing small manufacturing orders which become more and more typical in fashion industry during the last years [4,6].

As the 1st experiment showed, disadvantage of the process was also coloured edges of the cut fabric. During the washing process of the samples (2nd experiment), brown part of edges were washed off. It means that cutting certain 100% cotton fabric, its edges were just contaminated with material evaporations, not charred. New disadvantage - additional work process (washing) and time was needed to eliminate the coloured fabric edges. However, it could be acceptable not increasing work amount manufacturing two specific kind of clothing: garments which are dyed and also washed as a ready goods (t-shirt, shirts) and garments which are washed as a ready goods to obtain used vintage look (denim clothing) [15].

6. CONCLUSIONS

Natural origin 100% cotton textile material was tested to see possibilities to use laser cutting method processing multi-ply fabric spreads. The following conclusions were done on the bases of the research conducted:

1. Comparing with curently widly used knife cutting method, laser cutting ensure several serious advantages: higer work productivity, qualitative cutting of small and complicate shape components and very light textile materials, no-contact cuting.
2. Curently laser is used on single fabric ply cutting systems for cutting digitally printed fabrics and fabrics with intricate patterns. However, single ply cutting in clothing industry is not efficient.
3. Multi-ply fabric cutting by laser is problematical because of low thermal conductivity of textile materials. Processing synthetic origin fabrics melted edges of material plies can glue together.
4. Experiment proved that it is possible to through-cut by laser beam also more than one fabric ply. However the number of processed plies is limited. It depends on qualities of textile material and laser cutting process parameters.
5. To ensure qualitative laser cutting process of low fabric spreads, laser cutting equipment should have a bate base of parameters used in previous cutting processes, as well as, advanced testing methods to test processed fabrics directly on a laser cutting system.
6. Laser cutting process could have an advantage - coloured edges of cut components. During the laundry process they can be eliminated, if contamination with material evaporations is the reason of coloration. Additional laundry

process will not be needed processing garments which are dyed as a ready goods or manufacturing denim clothing when vintage look is obtained during washing process.

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