Effect of CO_2 Laser on morphological properties of Leather

U Venkateswarlu[1*], M Muthukrishnan[1], R Ramesh[2] and NK Chandrababu[2]

[1] *Bio-physics Lab, Central Leather Research Institute, Adyar, Chennai-600020, India*

[2] *Tannery Division, Central Leather Research Institute, Adyar, Chennai-600020, India*

Abstract: - *In this study we investigated, the effect of CO2 laser engraving on surface morphology of various leathers like nappa, suede, buffalo, milled and softy. The system consists of 100W CO2 laser with variable speed. The influence of power and speed of laser beam will be discussed in terms of depth of engraving, degree of etching, porosity and water vapour permeability of leathers. The CO2 Laser ablation behavior of leather is very sensitive to these parameters. The degree of etching, porosity and water vapor permeability increases with laser energy.*

Keywords: *CO_2 Laser, Engraving, Leather, Porosity, Water vapor permeability*

1. INTRODUCTION

Leather industry has been using several techniques for upgrading the quality of leathers over the years. Surface defects on leathers are a major cause of poor grading and rejections. Some techniques were applied on the flesh side to improve the texture by a process of modifications and cater to different end use; others try to improve upon the defective grain surface itself by different finishing techniques. The advent of CO2 lasers for cutting non-metallic and biological material has paved way for its use in leather industry for surface improvement through engraving. The present study describes the initial attempts to understand the role played by the inhomogeneous matrix of leather in laser engraving. Metallic and nonmetallic materials are cut and /or surface treated by different types of lasers for different end uses [1]. While cutting applications performed on the surface of various non-metallic materials like textile, leather, plastic etc., ensure accuracy and increased productivity, engraving is done with the view to improve the value of the base materials [2]. Laser engraving is the process by which a laser source is used to burn a text, logo or design onto the material surface. This is done by the local heating caused by the absorption of laser radiation, leading to modification of microstructure, and the physical, mechanical and other properties thereof. In our study, the laser beam is focused on leather surface for vaporizing / removing unwanted materials according to our desired design through computer control. The performance of engraving on leather can be improved considerably by proper selection of laser parameters, operating parameters and suitable leather. This paper presents the work carried out in the area of laser engraving on different leathers using different laser power and speed with special reference to the physical structure of the matrix of the leather.

2. METHODS

In this study, we have selected a computer controlled CO2 laser engraving machine having power of 100W with varying speed up to 600mm/sec. For porosity studies on different leathers, adjacent regions to the etched portions were used as controls. Leather being a highly anisotropic material, samples had been taken from adjacent to the region of laser engraved area to overcome the inhomogeneity in sampling. However, for depth measurements and permeability measurements, the same sample is used prior and after etching. In addition to porosity measurements, structural assessment using light / scanning electron microscope were also carried out to characterize leathers. The permeability studies were carried out prior to and after etching to understand the laser effect on leather matrix interactions.

2.1. Porosity

For this study, each sample in 3cm dia. was cut surrounding to the engraved portion. The weight of the leather samples were measured in air and then in liquid paraffin. The samples were immersed in liquid paraffin and kept under mild vacuum in a vacuum desiccator for 24 hours to ensure complete penetration of paraffin, then used to measure the weight at atmospheric pressure [3]. The porosity of the leather was calculated using the below formula.

Porosity = [1 – {(wt. in air – wt. in liq) / (volume in cc X specific gravity)}] ------- (1)

2.2. Water vapour permeability

Six samples of each 34mm diameter were cut from leather. These samples were used as control to study the water vapour permeability test [4]. The same samples were used to study the water vapour permeability after it was engraved with laser on grain surface with different power ranging from 5 to 30W at constant speed.

3. Results and Discussion

3.1. Microscopic observation

During laser engraving process on leather, we can burn or form any text / logo or design based on power of the laser that can be controlled by computer. The quality of the final imprint depends on the selection of suitable leather and laser parameters like power and speed of operation. This will reflect on observation of microscopic images of leathers engraved of different power and speed [5]. The topographic difference between controls verses engraved surface were used to calculate the depth of engraving part using traveling microscope. A digital depth meter was attached to the traveling microscope to focus the upper surface (not engraved) and the lower Laser etched surface. It was observed that the degree of etching increased with increasing laser output power and decreases with increasing speed of laser head movement. The complementary effect of speed and power on the structural view of the etched junction of cow softy leathers at two extreme combinations viz., 5W at 100mm/sec and 30W at 600mm/sec are presented in Fig-1 & Fig-2. It can be seen that the grain layer is almost removed and the upper most fiber bundles of chromium have been exposed in both the cases and depth of etching appears to be in the range of 200 to 300 microns. This is clearly seen from the figure 2.

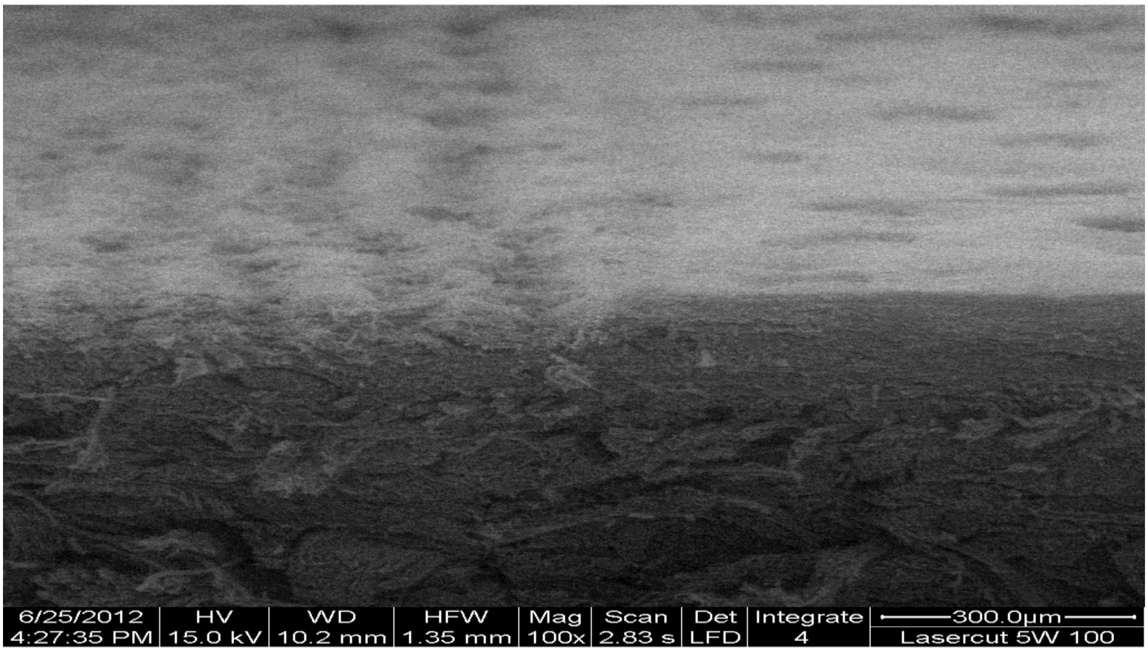

Fig -1: SEM of Cow softy leather at Laser power 5W and speed of 100 mm/sec

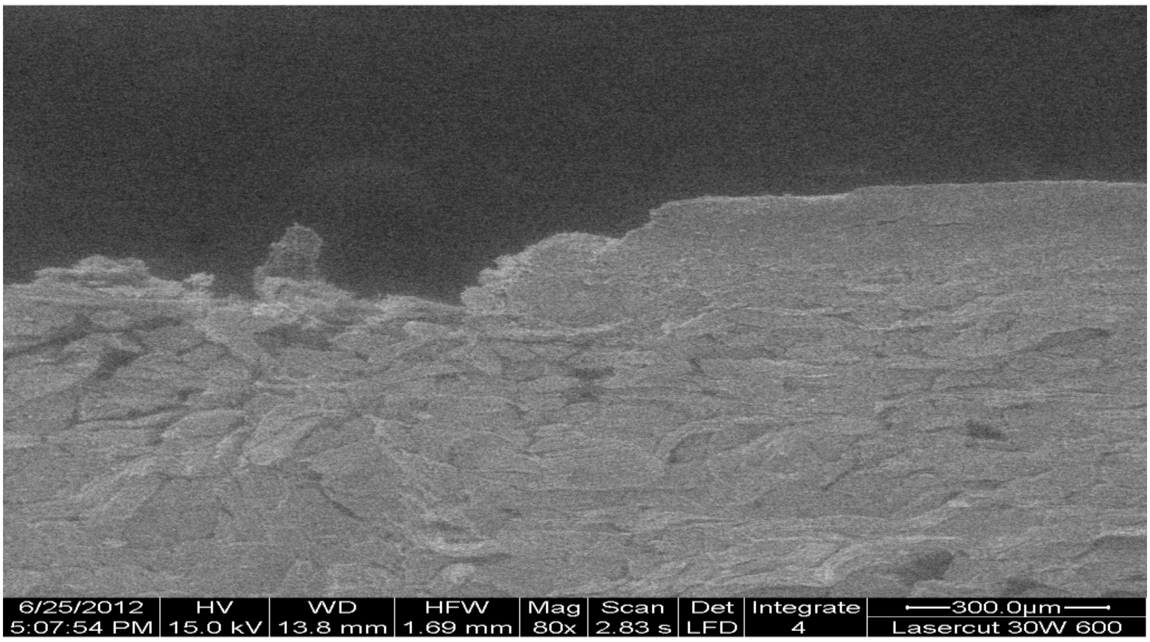

Fig -2: SEM of Cow softy leather at Laser power 30W and speed of 600 mm/sec

To measure the actual degree of etching by laser, the depth of etching from the surface is measured with microscope using the focal plane as mentioned above. The hides appear to show less variation in the depth of etching with increasing power unlike with the skins. Among the skins, the nappa leather shows less depth of etching at lower powers but increases drastically beyond 20W; whereas the suede leather shows a uniform increase in depth matching with increase in power. This result suggests that in addition to matrix compactness presence or absence of grain has a role to play in etching at least at lower powers. It is probable that the sudden drop seen in the Fig-3 could indicate a considerable damage caused to the grain surface beyond 20W.

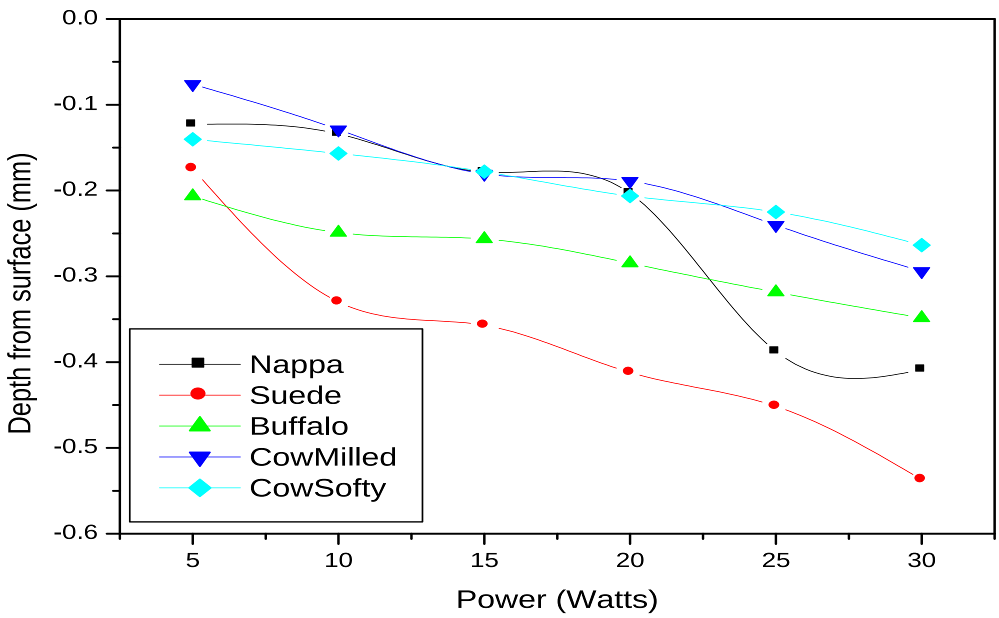

Fig -3: Effect of Laser power on depth of etching on leathers

However with the surface of the suede leather being already non uniform due to the opening up of the nap, the determination of the focal plane can become tedious and may lead to erroneous results. Hence the degree of etching is determined by the loss in weight of the leather circles prior to and after etching using different laser powers. This clearly affirms the role of matrix especially the texture – compact or loose. Sheep Nappa leather which has the most loosely woven structure shows the maximum percent loss followed by Suede leather, Buffalo leather, Cow leathers (milled and softy) as shown in Fig-4.

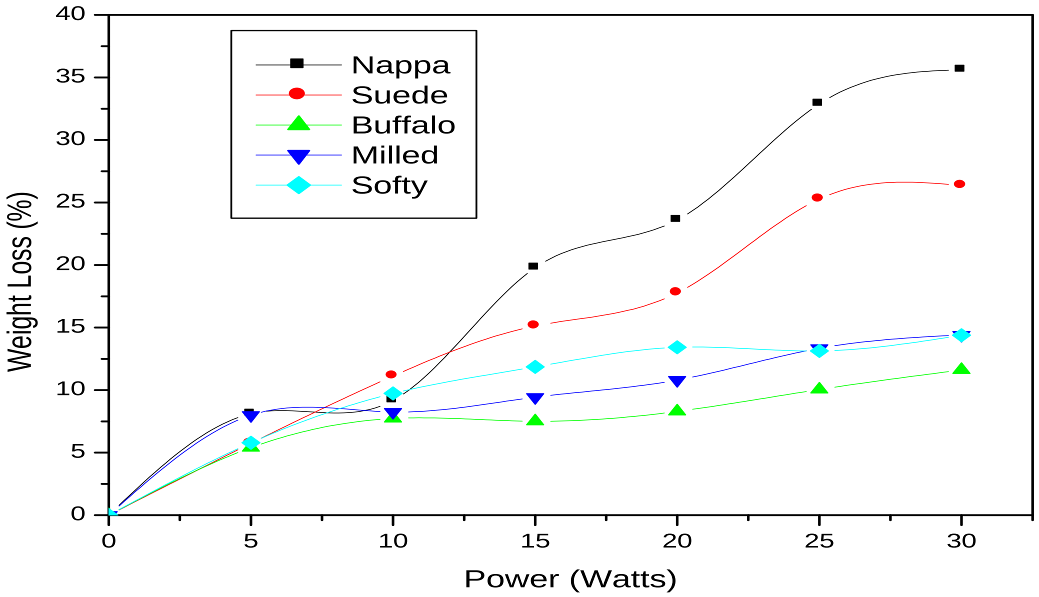

Fig-4: Effect of Laser power on weight loss of leathers

In general there is a clear distinction between the skins and the hides. To ascertain this further, porosity which is an indicator for the matrix compactness is correlated with the weight loss due to etching. Once again a similar trend separating the hides (Buffalo, cow milled, cow softy) and skins (nappa, suede) is observed. An interesting feature that emerges is the distinct separation of the suede and nappa leathers as it is customary to fill the matrix to get a good nap for the former type of leathers leading to less porosity as shown in Fig-5.

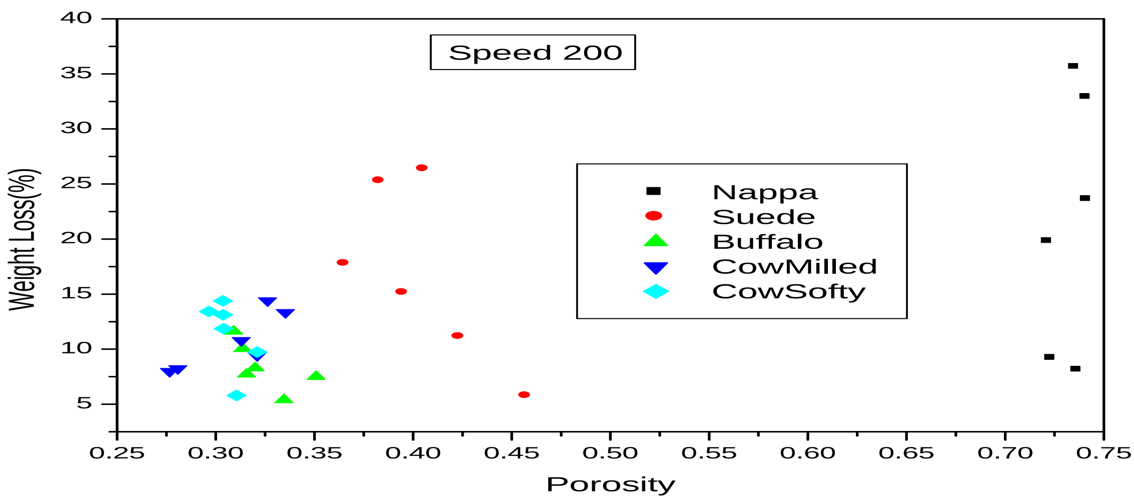

Fig-5: Effect of Laser power and speed on porosity of leathers

3.2. Water vapour permeability

The water vapor permeability of leather at normal conditions depends on thickness, grease content, relative humidity and temperature. The grain layer of the leather appears to be the first stratum to become saturated with respect to water vapor permeability. The finish on the grain layer also has an influence on water vapor transmission. The values of water vapour permeability of these leathers before and after etching are shown in Table-1.

Table-1: Water vapour permeability ($mg/cm^2/hr$) of control leathers and Laser exposed leathers

Control sample					
Power (Watt)	Cow softy	Nappa	Suede	Buffalo	Cow milled
5	1.515	9.182	11.215	6.12	5.289
10	1.351	9.060	10.527	6.662	4.794
15	1.644	7.551	14.901	5.434	4.449
20	1.779	10.43	14.294	6.669	3.749
Laser Etched sample					
Power (Watt)	Cow softy	Nappa	Suede	Buffalo	Cow milled
5	4.769	12.736	14.875	7.367	7.045
10	7.793	14.991	17.129	8.955	8.504
15	8.319	17.030	16.468	8.745	8.816
20	8.688	20.868	17.414	8.488	8.598

The values of water vapour permeability are plotted against the laser power and the results are shown in Fig-6 and Fig-7.

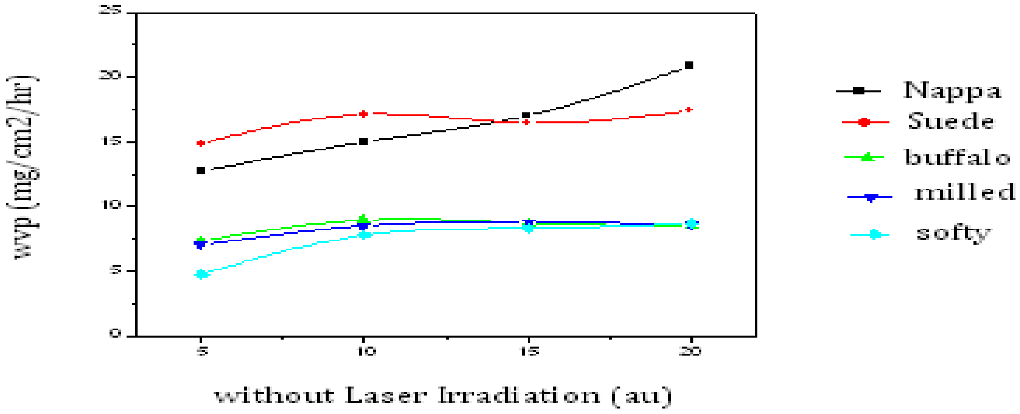

Fig-6: Water vapour permeability of control leathers

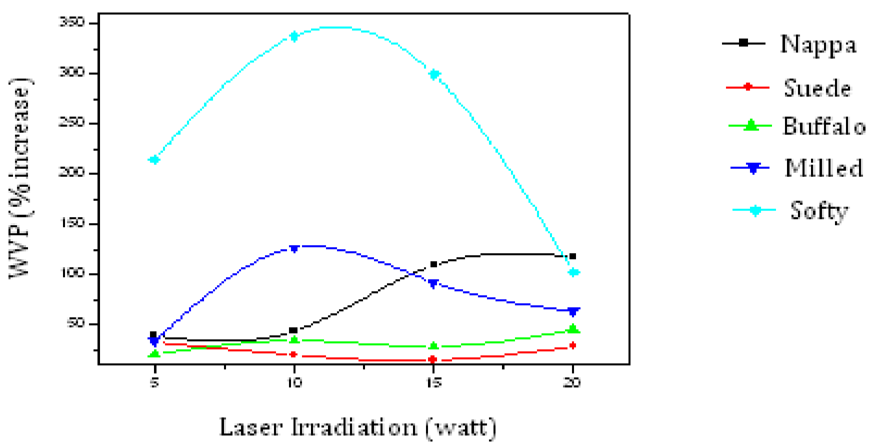

Fig-7: Effect of Laser power on water vapour permeability of leathers

The results shows similar trend of etched skins being separated out from the hides in their degree of permeability. Here again the presence of grain in nappa leather seems to resist permeability at lower powers. Interestingly, it may be noted that the degree of permeability is not proportionate to the power. In general after the initial increase the degree of permeability seems to level off in most samples except nappa. In our earlier study on laser cutting, we observed a slight gelatinization of the proteinaceous matrix of leather was observed [6]. It is probable that this process could hamper easy permeability of water vapour in leathers. When we compare the laser etched samples with adjacent controls by plotting the percent increase due to etching, the rate of increase seems to show different trends. Buffalo and Suede leathers show very little variations, whereas for nappa and cow milled samples the permeability either reduces or levels off at higher powers and in the case of cow softy, the difference is enormous. The factors like location and gelling of the leather at high powers could contribute to these observed variations.

4. CONCLUSIONS

Thus from the above study, it is clear that the physical nature of the matrix is an important determinant in the degree of laser etching and this knowledge is bound to equip the intended user while designing laser engraving on leather. However, further studies on the chemical nature of the matrix altered by the type of tanning, and post tanning filling operations as well as a comprehensive information on the laser interaction with the varying matrix topography would reduce wastage due to the trial and error methodology currently employed.

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