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Studying the Effect of Moisture on Wood Drilling Operations Using the Burning by Continuous Wave Laser Method

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Abstract: In this study, drilling operations using the burning by continuous wave carbon wood have been studied and dioxide laser method for the two types, Swedish and Beech compared. The effect of moisture on both geometric dimensions and removing rate has also been investigated. The results showed that the moisture effect differs according to the type of the processed wood. That is, the obtained hole dimensions and removing rate were both less for Beech wood than for the Swedish wood.
Keywords: Wood – Laser – Drilling – Moisture.

Introduction and Experimental

The laser interaction with the material depends on both the used laser beam characteristics, such as power, energy, wavelength, and irradiation time, and the processed material properties, such as reflectivity, absorbance, and thermal conductivity[1,2]. When processing a specified material, the laser is selected so that its wavelength results in low reflectivity and high absorbance for the processed material[1].

The drilling operation is based on focusing a laser beam on the material with the laser beam having energy density high enough to cause material removing by evaporation. This is accompanied with jetting the melted materials out of the nozzle[1].

Laser provides many advantages comparing with the other traditional methods used in cutting operations for the following reasons[1,2]:

1. Cutting by laser needs no direct connection with the processed material.
2. No friction resulting in less bends and distortions in the processed material.
3. Heating resulting from laser is concentrated in certain areas without affecting the whole material.
4. High cutting rates provided by laser that couldn't be achieved by the other traditional methods.

Usually an inert gas current is passed through the hole to help in drifting the melted material so that it doesn't solidify inside the hole. The inert gas current helps also in blowing away fumes to avoid material deposition on lens and mirrors used in directing and focusing the laser beam for more material removing[1].

It is often better to use pulsed laser in performing drilling operations because it provides drilling mechanism similar to that of key hole making. Laser with high energy is used to evaporate certain amount of the material leaving small hole behind. Thus the laser energy that arrives inside the hole is kept in, which in turn helps in increasing the depth of the hole in the material[1].

Carbon dioxide laser is one of the most important lasers used in "cutting by laser" processes because it provides high cutting rates, so that it can be used to cut holes in wood until 50 mm in depth. It can be used to cut materials such as paper, plastics, and wood, in which cases inert gases such as nitrogen and argon are used because of the high absorbance of these material at the wavelength of the carbon dioxide laser[1].

Wood is a very important structural material. It has numerous advantages and a few disadvantages. In addition to being a biological material that is both renewable and readily available, it has an excellent strength/weight ratio and good ductile properties[3,4]. Many species have a high degree of natural resistance to wood degrading organisms and if they don't they can be effectively treated with a wood preservative that is toxic to the wood degrading organisms. Wood is one of the most important natural resources, and it is the main yield of forest investment. Wood is used in house building, wooden furniture manufacturing, and so on.

Natural wood types can be classified as following[3-6]:

Softwood: this type of wood belongs to the class of gymnosperm, such as cypress, pine, and cedar. It is used in the internal carpentry of building.

Hardwood: this type of wood belongs to the class of angiosperm, such as poplar, oak, walnut, oaks, apricots, lemon, olive, mulberry, and so on. It is used in furniture carpentry, decking, and craving.

Heartwood: hard, dark wood surrounding the tree axis.

Sapwood: light wood consisting of live tissues surrounding the heartwood.

There are various types of artificial wood such as[4]:

Lumber: wooden planks sawn from tree trunks, which are classified according to their thicknesses as:

- Wooden boards: less than 5 cm.
- Bond timber: 5-12 cm.
- Timber: more than 12 cm.

Plywood: a type of thin wooden boards glued together by thermal adhesive.

Particle boards: boards made of sawdust of various dimensions dried, mixed with a thermal adhesive material, and pressed in the form of boards with different thicknesses.

Medium Density Fiberboard (MDF)

Plywood: this term indicates a type of wood made of thin wooden boards glued and pressed together.

Drilling has been conducted using continuous wave carbon dioxide laser of the type of JL-70 with the following parameters:

- Maximum output power of 70 W
- Beam diameter of 4 mm with small obtuse angle.

The laser beam was focused on the wood target at an incidence angle of 90 and exposure time of 40s. The target were installed on an metal holder at a distance of about 10 cm from the laser source. Two series of samples were prepared. Series one is consists of dry and wet samples of drilling Swedish wood. Series two is consists of dry and wet samples of drilling Beech wood. The schematic of the experimental setup are shown in Fig. 1.

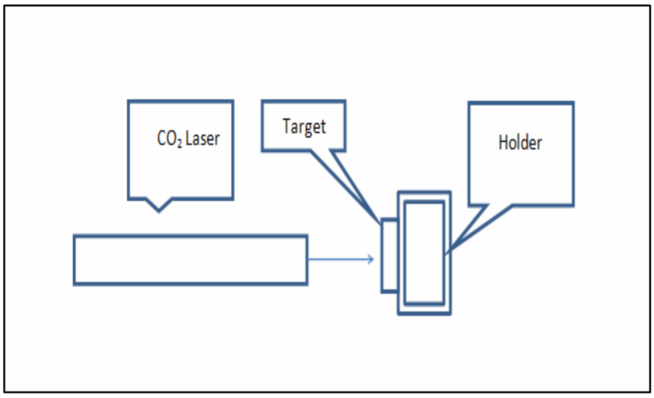


Fig. 1. Schematic and of the experimental setup

Results and Discussion

Special wattmeter has been used to adjust the power for these lasers types. That is to determine the power at each available input voltage.

Table 1 shows the obtained results. Power density has been computed through dividing the power by the beam sectional surface area.

Table 1. The power at each available input voltage

V (v)	P (w)
130	36.5
135	46.5
140	48.7
150	51.5
160	57.1
170	60.5

Based on the results in table 1, power adjustment curve for continuous wave carbon dioxide laser can be plotted. The obtained curve is shown in figure 2.

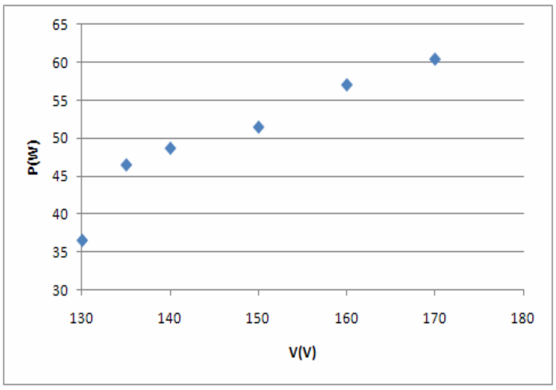


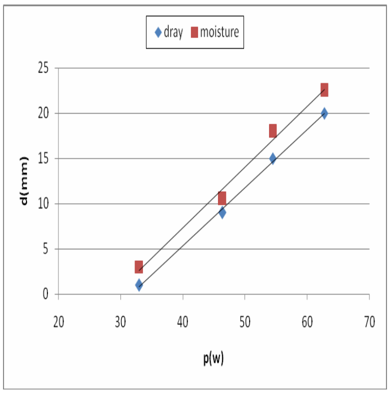
Fig. 2. power adjustment curve for continuous wave carbon dioxide laser.

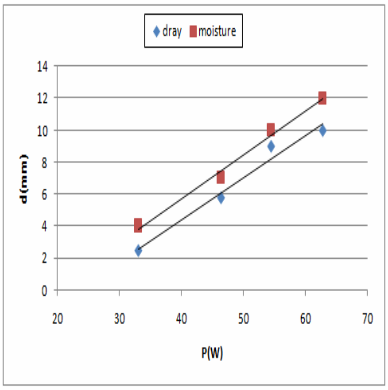
Figure 3 shows a sample of the prepared specimens, which is a model of specimens of Beech wood prepared using CO_2 laser beam power and exposure time of 40S.

Fig. 3. Image of the key-hole of dray Swedish sample prepared at 36.5 W.

We can see that the longitudinal section of the specimen has the shape of a good symmetric circular cone, with radius of base equal to 4 mm, and height of 12 mm.

Figure 4 shows the variations in depth for different laser power values for the Swedish wood samples.





a **b**

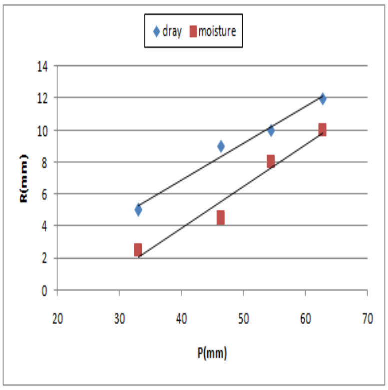
Fig.4 The variation of depth as a function of power.

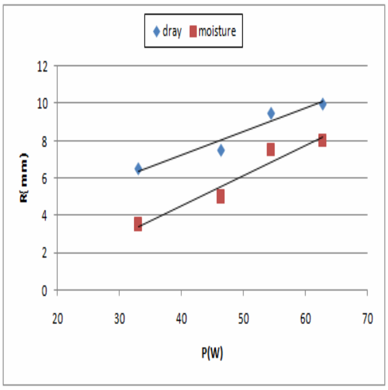
(a) Swedish wood **(b) Beech wood**

The figure indicates a linear relationship between burning depths and power values for both dry and wet samples, with higher depth values for the case of wet samples. This can be interpreted as a result of the molecular decomposition of water inside the hole due to the high increase of temperature because of the thermal energy retention resulting from the thermal insulation properties of wood. The molecular decomposition of water provides additional amounts of oxygen that activates burning and help in increasing the depth of the hole.

Comparing with figure 1, it is clear that laser gives deeper holes in the case of Swedish wood than for Beech wood. This can be interpreted as a result of the higher volumetric mass of Beech wood comparing with that of Swedish wood.

Figure 5 shows the variations in diameter for different laser power values for the Swedish wood samples.





a **b**

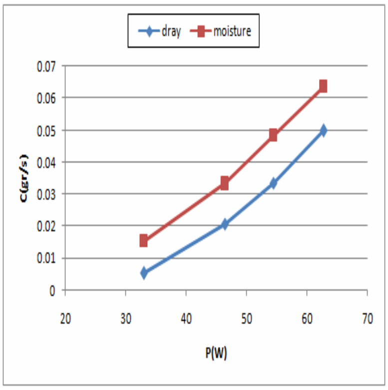
Fig.5 The variation of diameter as a function of power.

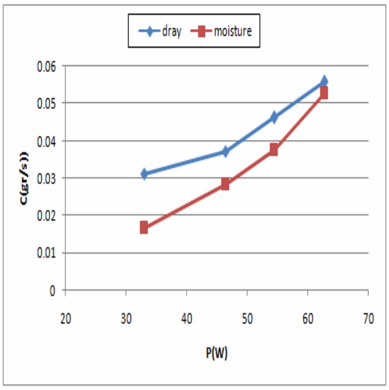
(a) Swedish wood **(b) Beech wood**

The figure indicates that moisture contributes to the reduction of the surface spread of burning. The figure indicates also a decrease in diameter of about 20% for the case of wetted samples.

Comparing with the previous figure, it is clear that variations in density don't affect the surface spread of burning.

Figure 6 shows the variations in removing rate for different laser power values for the Swedish wood samples.





a **b**

Fig.6 The variation removing rate as a function of power.

(a) Swedish wood **(b) Beech wood**

The figure shows that the removing rate increases with the increase in power values, and that moisture causes increasing in removing rate also.

Figure 6 shows the variations in removing rate for different laser power values for the Beech wood samples.

The figure shows that the removing rate increases with the increase in power values, and that moisture causes decreasing in removing rate. This can be interpreted as a result of the decrease in burning rate due to the moisture and the high density of the wood.

Conclusion

The primary conclusion from this study is that the dimensions of the hole caused by carbon dioxide laser can be controlled for various types of Swedish and Beech wood by varying the laser power. We conclude that the values of the geometric shape parameters of the hole can be estimated in advance. The study demonstrated also that moisture has a large effect on the geometric dimensions of the hole, and that this effect is related to a large extent to the type of the used wood.

Acknowledgments

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