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Laser Cutting of Brass Sheet

Enikő Réka FÁBIÁN,[1] Bence CZIGÁNY[2]

[1] *Óbuda University, Bánki Donát Faculty of Mechanical and Safety Engineering Faculty, Institute of Materials and Manufacturing Sciences, Material Science and Deformation Engineering Department, Budapest, Hungary, fabian.reka@bgk.uni-obuda.hu*

[2] *Bay Zoltán Nonprofit Ltd. for Applied Research, Production Division, Department of Production Development, Budapest, Hungary, czbence997@gmail.com*

Abstract

Laser cutting of copper-based alloy sheets is very difficult due to their high reflectivity, which can be modified with graphitization. The optimal parameters for a 2.5 mm thick brass sheet were determined by examining the laser beam parameter variations and the laser cut kerfs. The best characteristics of kerfs were obtained when the surface was graphitized, the laser frequency was 200 Hz, the applied laser speed was 1400 mm/min on 2500 W power and the focal point was under the surface by 0.8 mm. The applied working gas was nitrogen.

Keywords: *brass, laser cutting, kerf.*

1. Introduction

Among laser technologies used at the present time in machine-building industries, gas laser cutting of metallic and non-metallic materials has become widely used [1-5]. Laser offers considerable advantages over conventional techniques due to precision of operation, short processing time, and low cost. The physical processes involved in laser cutting of thick sections are complicated and significantly influence the end product quality. Laser parameters - in particular laser output power, focus on setting of focusing lens, cutting speed, assisting gas, and its pressure - influence the physical processes in the cutting section [6, 7]. Controlling the affecting parameters results in improved cutting quality. Consequently, investigation into affecting parameters in laser cutting process is necessary to improve the end product quality.

Laser cutting of carbon and stainless steels is well studied even in the case of thick sheets [8, 9]. The kerf width variation during CO_2 laser cutting was investigated by Uslan [9], who showed the variation in laser power intensity resulted in considerable variation in the kerf width size during the cutting process, being more pronounced at lower intensities. According to the literature [10] in the case of austenitic stainless steels, the size of the heat affected zone increases with increased workpiece thickness. In these steels the laser pulse frequency has a notable effect on the cut quality; however, this effect is not in a linear form with the kerf size and dross height [10]. Cutting metals of the copper alloys group is difficult due to the high thermal conductivity of the material and large coefficient of heat capacity. The high reflectivity of copper alloys imposes certain requirements on the equipment. In preparation for the process, it should be taken in consideration that the laser cutting of copper is more difficult the thicker the plate [11, 12]. After Daurellio et al. [12] the laser welding of copper sheets is possible by overlapping layers of cupric oxide, CuO, with a small quantity of cuprous oxide, Cu_2O grown under laser beam irradiation. This experimental approach, to increase the copper surface absorption of the laser radiation [12] can be applied at cutting also. The reflectivity of copper and other reflective metals decreases when the metal warms up, and drops sharply once the material melts [13]. According to the literature, the maximum cutting speed is achieved if the focal plane of the beam is positioned at the plate surface for thin sheets, or about one third of the plate thickness below the surface for thick plate [6]. Distance of focus position is the distance from the focal point to the upper surface of the cutting workpiece. The position of the focal point above the workpiece is generally called the positive focal point, the position of the focal point below the workpiece is generally called the negative focal point. The kerf width depends on the focal position [13, 14]. Changing the focus position means changing the spot size on the surface and inside of the board. The focus length becomes larger, the spot becomes thicker, and the slit becomes increasingly wider, which in turn affects the heating area, slit size, and slag discharge capacity.

When piercing and cutting copper, high-pressure oxygen is typically used as the cutting gas to increase process reliability. When oxygen is used, the formation of copper oxide on the surface reduces the reflectivity. For brass, nitrogen cutting gas works fine [13]. As an approximate guide to setting the power, the literature gives different minimum required peak powers for different copper plate thicknesses [13].

2. Materials and testing

As part of the experiment, cutting of copper alloy sheet by Trump TLF 5000 turbo CO_2 gas laser equipment was performed. The effect of varying frequency and cutting speed on the cut slit were monitored. The focal positions applied were –0.8 mm, and –2 mm. Based on the literature [13] the applied power was 2500 W. Some parameters were also tested on graphitized surfaces, which reduces the surface reflection.

During the cutting experiments, the process settings were modified after visual inspection. For light and electron microscopical studies Neophot 2 and Olympus DSX light microscopes were used. The studied sheet was a brass with ~34 % zinc, with 2.5mm thickness.

The kerfs-shape and microstructure near the cut edges were studied on metallographic prepared transverse sections, cut at 25 mm from the laser cutting lines ends, in polished and etched condition. The etchant used was 10 % solution of ammonium-peroxo-disulphate. The laser cutting parameters are shown in Table 1.

If the energy input proved insufficient, the molten brass flowed back to the plate surface.

Table 1. *The cutting parameters*

Nr.	f (Hz)	v (mm/min)	Focus (mm)	Graphite	Success
1	600	2250	–0.8	no	no
2	600	2000	–0.8	no	no
3	600	1800	–0.8	no	no
4	600	1600	–0.8	no	no
5	600	1400	–0.8	no	partial
6	200	1400	–0.8	no	partial
7	200	1400	–2	no	no
8	200	1400	–0.8	yes	yes
9	200	1600	–0.8	yes	no
10	200	1200	–0.8	yes	yes
11	200	1500	–0.8	yes	no
12	200	1000	–0.8	yes	yes

3. Results

By visual inspection (Figure 1) it was observed that at a cutting speed of more than 1400 mm/min, the 2.5 mm brass plate is not cut through the full plate thickness, molten material appearing on the surface of the plate. Slit appearance on the bottom part of sheet in the case of a 1400 mm/min cutting speed depended on the other parameters. Applying the focal spot on the bottom side of the sheet (cut nr. 7), with similar parameters

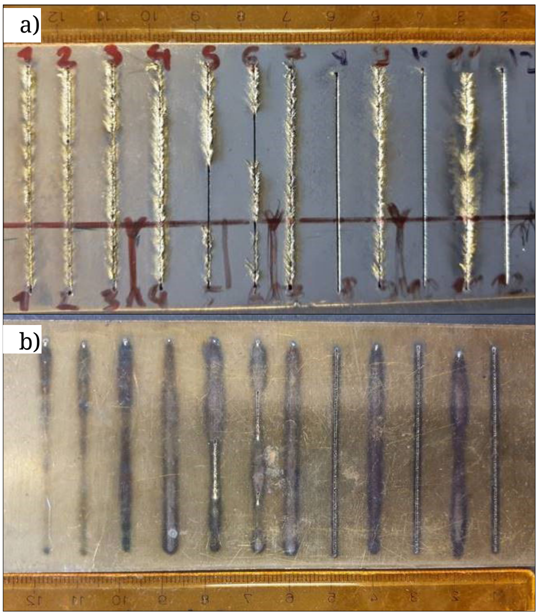

Figure 1. *The laser parameter effects at d = 2.5 mm sheet, P = 2500 W. a) crown face b) root face*

as cutting line 6 (f = 200 Hz, v = 1400 mm/min) a large amount of melted material came back on the surface. Cutting a gap through the full plate thickness was possible at 1000-1400 mm/min cutting speed when the focal spot was at 1/3 part of sheet thickness (Figures 1–2), and the reflection was reduced by graphite paint.

On the transversal section it can be seen that the melted zone became bigger as the cutting speed decreased (Figure 2) Studying the metallographic prepared samples after etching, it became visible that the melted material, and the slag remain inside of the slit when the frequency was high, even if 1400 m/min speed was applied (Figures 2–3).

The frequency reduction gives smaller quantity remnant material on the slit surface after cutting (Figures 3–4).

Regarding the cutting of graphitized brass sheet, a smaller quantity of remelted material was observed on the cut edge (Figure 4), and for this reason the roughness at this surface is smaller (Figure 4. c, d).

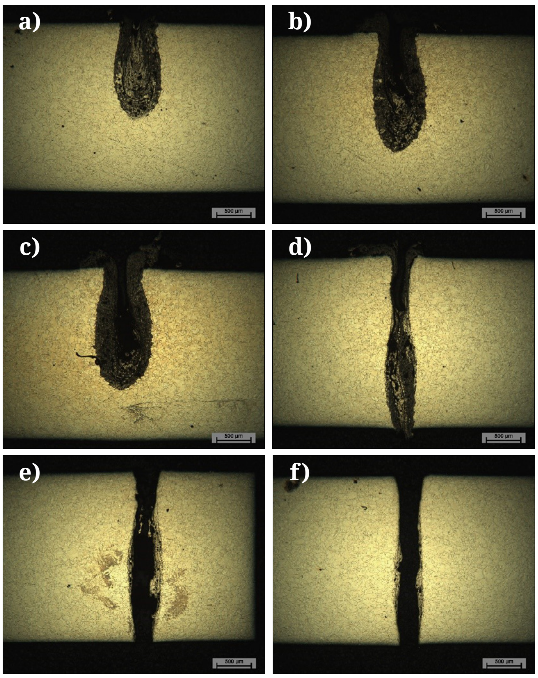

Figure 2. *The kerf appearance. on metallographic samples, at P = 2500 W and f_p = −0.8 mm*
a) f = 600 Hz, v = 2000 mm/min,
b) f = 600 Hz, v = 1800 mm/min,
c) f = 600 Hz, v = 1600 mm/min,
d) f = 600 Hz, v = 1400 mm/min,
e) f = 200 Hz, v = 1400 mm/min,
f) f = 200 Hz, v = 1400 mm/min, graphitized.

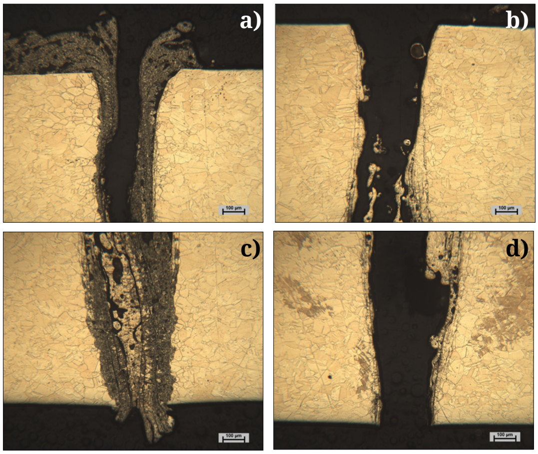

Figure 3. *Frequency effect on the remnant material in cutting gap, v = 1400 mm/min, f_p = –0,8 mm, no graphite*
(a, c) f = 600 Hz
(b, d) f = 200 Hz

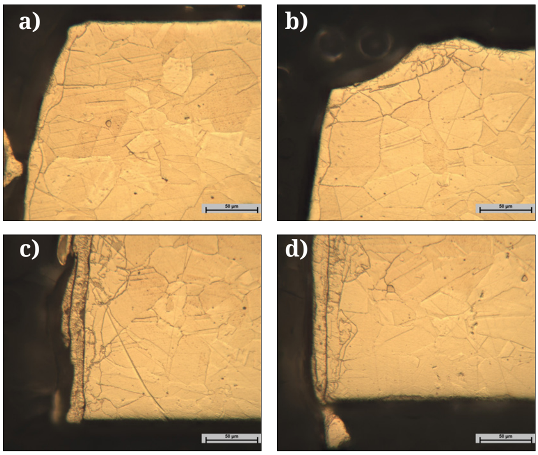

Figure 4. *Melted zone appearance on the cut edge P = 2500 W, v = 1400 mm/min, f_p = −0.8 mm f = 200 Hz*
(a, c) no graphite,
(b, d), graphitized

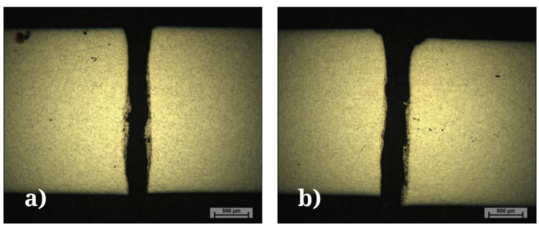

Figure 5. *Cutting speed effect on the cut slit, f_p = −0.8 mm, f = 200 Hz,*
a) v = 1400 mm/min
b) v = 1000 mm/min

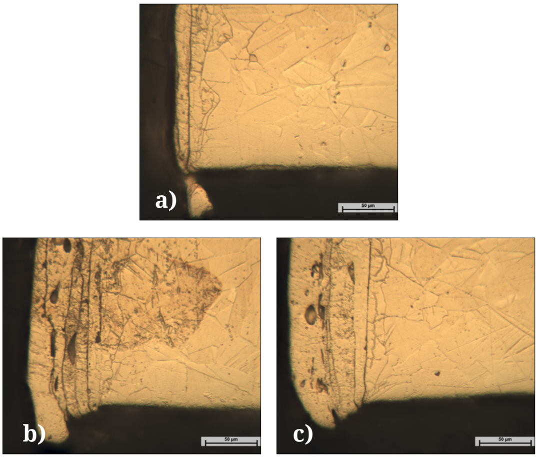

Figure 6. *Cutting speed effect on the cut slit*
f_p = –0,8 mm f = 200 Hz
a) v = 1400 mm/min
b) v = 1200 mm/min
c) v = 1000 mm/min

Decreasing the cutting speed, the cut slit became wider, but more parallel (**Figure 5**), on the cut edge more remelted material remained (**Figure 6**).

4. Conclusion

Cutting a gap through the full plate thickness was possible at 2500 W, when the cutting speed was 1000-1400 mm/min and when the focal plane was at –0.8 mm and the frequency was 200 Hz. The beneficial effect of graphite painting, in addition to protecting the laser equipment by reducing the strong light reflection, was also observed in the cutting-edge roughness.

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