TECHNOLOGICAL FEATURES LASER CUTTING COPPER AND BRASS

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Abstract

The article discusses the features laser cutting copper and brass, certain requirements for equipment and technology. The advantages using fiber lasers for cutting copper and brass are formulated, such as better absorption laser radiation, high precision cutting small parts, clean and smooth cut without burrs, high cutting speed. The features cutting copper and brass blanks with lasers with a power 1 and 2 kW are studied. Recommendations for laser cutting copper and brass are developed. Copper and brass laser cutting is possible, but much more difficult than other metals. This is partly due to the fact that copper is a highly reflective material. Copper's reflective properties make it difficult for the laser's infrared light to be absorbed, slowing down the cutting process. To get the most out laser cutting copper, you need to consider speed, power, reflectivity, and focal point.

Keywords: laser cutting, copper, brass, cutting quality, fiber lasers.

I. Introduction

Laser cutting copper and brass has its own characteristics due to the high ther-mal conductivity the material. Copper also has a high heat capacity coefficient. This imposes certain requirements on the equipment and technology:

1) Low absorption infrared laser radiation makes cutting these metals difficult;

2) Copper and brass are good reflectors (and therefore poor absorbers) infrared laser radiation in the solid state;

3) Pure copper in the solid state reflects approximately 95% laser radiation with a wavelength ~ 1 μm;

4) The reflectivity copper and brass decreases when the metal is heated, and drops sharply when the metal melts (for example, up to 70% for copper in the molten state). These metals in the molten state absorb significantly more laser energy;

5) Laser cutting copper and brass is more difficult, the greater the thickness the material being processed;

6) The laser spot size should be as small as possible, and the laser power should be high.

II. Statement the research problem

With the right choice laser, optics and cutting process, the laser beam quickly melts the surface reflective materials, then interacts with the more absorbent molten metal and initiates an efficient, stable cutting process. Incorrect choice laser/optics set-up or use suboptimal process parameters can result in the laser coming too close to the solid metal, resulting in excessive light reflection [1]. Too much reflection, in turn, results in an inefficient cutting process and potential damage to the optics.

Fiber lasers are widely used in the industry for laser cutting copper and brass. They differ from CO2-lasers in the way the laser beam is generated. In fiber lasers, the beam is generated inside a thin light guide, which is a glass fiber. Due to this, fiber lasers are more compact, more efficient and more durable than CO2-lasers and are considered preferable for cutting copper and brass [2] [3].

Advantages fiber lasers for cutting copper and brass:

1. Material absorption: Fiber lasers emit a beam with a shorter wavelength, which is more easily absorbed by reflective materials such as copper and brass com-pared to CO2-lasers.

2. Accuracy: The diameter the laser spot fiber lasers is significantly smaller than that CO2-lasers. This allows for higher cutting accuracy, which is especially important when working with small parts.

3. Cut quality: Fiber lasers provide a cleaner and smoother cut, without the for-mation burrs.

4. Processing speed: Due to higher efficiency, fiber lasers allow metal cutting at a higher speed, which increases processing productivity.

In conclusion, fiber lasers are currently a more popular and sought-after solution for metal cutting due to their high efficiency, accuracy and processing speed. However, fiber lasers also have their limitations. They are most effective when cutting thin sheets metal. The maximum material thickness that can be cut with a fiber laser is limited to 10 mm for copper and brass. The limit the material thickness that can be processed depends on the power the emitter and the model the laser machine [4][5] .

The plants manufacture a wide range products from sheet copper. The use laser cutting technology using powerful fiber lasers for this would bring significant ad-vantages in terms productivity and savings on the rather expensive metal. However, the developers such lasers strongly recommend careful development the technological processes for laser cutting copper and brass in order to protect the laser system from damage due to slag and splashes molten metal sticking to the surface the quartz lens during burning and cutting operations [6] [7].

The formation these black spots on the lens can significantly reduce the perfor-mance and quality the cut [6]. As the laser continues to operate, these spots become localized heat absorption centers, which leads to a number cascading problems:

1) Thermal Effect the Lens: Uneven heating caused by the black spots creates a thermal gradient across the lens, changing its refractive properties. This leads to focus drift, where the actual focal point shifts from the intended position, reducing cutting accuracy.

2) Reduced Transmittance: Black spots obscure the laser beam, reducing the overall power transmitted to the workpiece. This can lead to uneven cutting depth and quality across the material.

3) Lens Degradation: Intense heating in these areas can cause microcracks or even thermal degradation the lens, significantly reducing its service life.

4) Focal Length Change: As the central area the lens overheats due to black dots, it can cause a local change in the curvature the lens, effectively reducing the focal length. This interferes with normal cutting operations, especially in precision work.

5) Beam Distortion: The presence black dots can introduce aberrations into the laser beam prile, resulting in uneven energy distribution and may result in wider kerfs or poor edge quality.

III. Research cutting copper and brass with fiber lasers

Features cutting copper with a 1 kW laser. Table 1 shows the maximum possible cutting speed copper with a thickness 1…3 mm, produced by a 1 kW laser.

Table 1. *Maximum speed laser cutting copper [3]*

Sheet thickness h, mm	1.0	1.5	2.0	3.0
Cutting speed v, m/min	1.00	0.70	0.50	0.15

The copper surface was installed in the focal plane the lens with a focal length $f = 200\ mm$ and a light spot size $d_1 \approx 350$ µm. Cutting was carried out in a compressed air environment supplied to a single-jet nozzle with a through-hole diameter 1.8 mm under a pressure 8 atm. Since the air contains 20% oxygen, the temperature the liquid phase layer increases along with the heating from the laser beam according to the reaction [3] [8]:

$$Cu + 0{,}5O_2 \rightarrow CuO + 150\ kJ/mol$$

With the specified settings, the copper thickness $h = 3.0\ mm$ is the maximum possible for cutting with a fiber laser with a power 1 kW. The width the laser cut when processing sheets with a thickness $h = 1.5 \ldots 3\ mm$ is 400 µm. The burr height at all thicknesses at the cut exit does not exceed 20 µm.

Using a focusing lens with $f = 145\ mm$ and setting the metal surface below the focal plane at a distance $\Delta f = 2\ mm$ reduces the cutting width, since the diameter the light spot radiation localization does not exceed $d_1 \approx 200\ \mu m$. Using a higher-power laser increases the cutting speed and depth. There is no burr on the surface the cutting zone, the roughness index $R_a = 0.8\ \mu m$, the cutting quality is satisfactory.

The surface the cutting zone for copper sheets 2 mm thick is shown in Fig 1 [4] [8].

Figure 1:. *Side surface a cut in a copper workpiece 2 mm thick*

The absence burrs and grooves on the surface the cutting zone is explained as follows. The laser radiation power density in the focal plane with a beam diameter $d_1 \approx 350$ µm is $W = 1{,}04 \cdot 10^6\ W/cm^2$. Since this value power density W is close to the evaporation threshold, an increased layer liquid phase is formed on the side surface the cut, which cannot be completely removed from the cutting zone. As a result, grooves are not formed on the side surface [9].

Cutting L63 brass with a 1 kW laser. The maximum possible speed laser cutting brass quickly decreases with an increase in the thickness the workpiece. As can be seen from the graph (Fig. 2), the thickness the L63 brass workpiece, equal to 5 mm, is the limit for cutting with a 1 kW fiber laser. In this case, the maximum possible cutting speed will decrease to approximately 0.4...0.5 m/min.

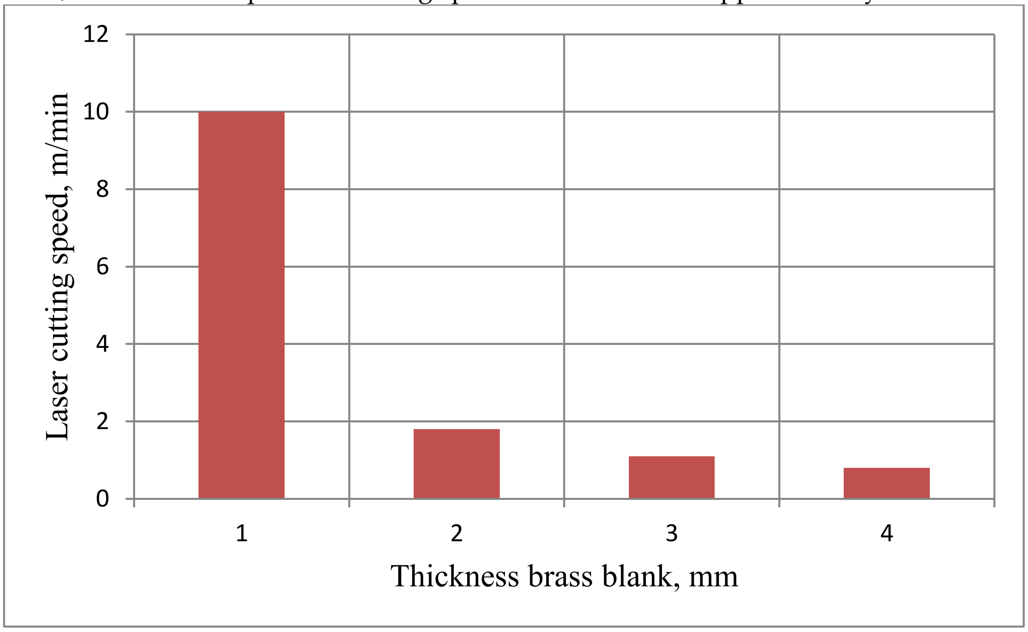

Figure 2: *Maximum speed laser cutting brass L63 depending on the thickness the brass blank*

The cutting width in a 3 mm thick brass blank is 250 μm, while in a 4 mm thick blank it is 270 μm. The cutting width in a 3 mm thick brass blank is 150 μm less than the cutting width in copper the same thickness. The cutting speed a brass blank is 10 times greater than the cutting speed a copper blank. This is explained by the fact that the absorption coefficient on the copper surface changes periodically [9]. First, the absorption coefficient on the copper surface decreases and then increases again. This process is associated with the periodicity the process removing the liquid phase from the surface in the cutting zone and the subsequent restoration its layer, which requires additional energy. In laser cutting brass, a similar dependence is manifested to a much lesser extent.

From the data shown in Fig. 2 it follows that under constant cutting conditions, the maximum cutting speed and depth a brass blank are greater than on copper, which is explained by the presence 30% zinc in brass [8] [10].

Figure 3: *Side surface the cut in 3 mm thick brass*

When zinc interacts with pure oxygen, its oxidation reaction begins. In the cutting zone, heat is released from two oxidation reactions copper and zinc [11], so the total heat is approximately 3 times greater than when cutting copper.

With a brass blank thickness 1 mm, there is no burr at the exit from the cutting zone. The burr height at thicknesses 2.5 mm, 3 mm and 4 mm does not exceed 50 μm. On the side surface the cut in a brass blank 3 mm thick (Fig. 3) there are no grooves, the cut surface looks rougher.

Cutting brass L63 with a 2 kW laser. Parts made brass 2 mm thick are shown as an example in Fig. 4 [8].

Figure 4: *Example contour cutting a part made 63 brass with a thickness 2 mm*

Laser cutting was carried out under the following conditions. The radiation was focused by an objective with $f = 145\ mm$. The surface the brass was installed below the caustic constriction at a distance equal to $\Delta f = 3\ mm$. To remove the liquid phase, a two-jet nozzle NK15-15 was used, providing a cutting gas pressure 16 atm. The cutting width was 0.35 mm, which ensured improved removal the liquid phase. The cutting speed was 3.5 m/min.

To cut parts with a more complex configuration from brass blanks with a thickness 3 mm and 5 mm, an objective with $f = 200\ mm$ was used. Compressed air or nitrogen was used as the cutting gas, supplied to the two-jet nozzle NK25-20 under a pressure 16 atm [8] [12].

The maximum possible cutting speed 5 mm thick brass did not exceed $v = 1\ m/min$. At this speed, the cutting width at the entrance decreased to 250 μm. Due to the need to cut a complex contour, including rounded sections with a radius 10...15 mm and internal cutouts with an acute angle at their apex, the cutting speed was reduced relative to the maximum possible to 0.7 m/min. At this speed, the cutting width was equal to 150 μm. Removal the liquid phase from the cutting zone with a width 150 μm becomes impossible even at a compressed air pressure 16 atm. Part the liquid phase remaining on the surface the cutting front accumulates in its lower zone [13]. Slowly flowing out it, it welds to the surface the brass and, solidifying, forms a burr. The height the burr on 3 mm thick brass parts did not exceed 0.05 mm, and on 5 mm thick brass it did not exceed 0.15 μm. In both cases the burr is easily removed.

Fig. 5 shows a photograph the side surface a 5 mm thick cut made in a compressed air environment. In a compressed air environment the side surface the cut has a dark gray color and corresponds to $R_a = 3.2\ \mu m$.

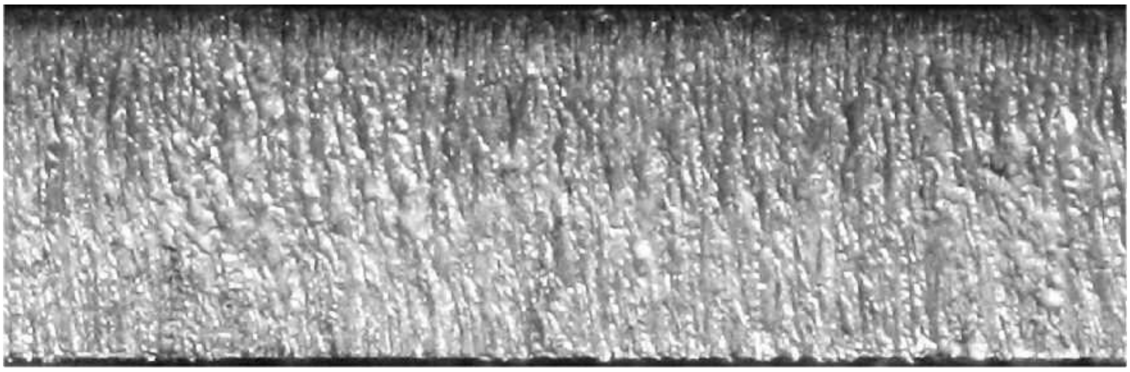

Figure 5: *Side surface the cut in 5 mm thick brass [8]*

IV. Recommendations for laser cutting copper and brass

When cutting materials such as copper and brass with fiber lasers, it is recommended to slightly reduce the feed rate - by about 10…15% to ensure a higher-quality burn-through the material. For a quick burn-through the material, it is recommended to use maximum power. This is important because the metal being processed has the greatest probability reflecting laser radiation at the beginning the cutting process, because as the metal heats up, its reflectivity decreases [8] [14].

Below are approximate values power required for cutting copper sheets different thicknesses:

Table 2: *Required power required for cutting copper sheets*

Thickness copper sheets, mm	1.0	2.0	3.0	4.0	6.0
Required minimum power, W	1000	1500	2000	3000	4000

In addition, such a factor as the position the focus is quite important. The optimal focal length is determined for each specific material separately. It is necessary to select a focal distance so that it is as close as possible to the surface being processed, but not to such an extent that the cutting quality suffers. Correct selection the focal length ensures maximum efficiency the cutting process.

You can also improve the quality cutting metal materials by using an gas jet, such as air, oxygen, nitrogen and argon [15]. These gases can perform various functions during the cutting process: removal molten material and smoke from the cutting zone, cooling, protective function (nitrogen is used to prevent oxidation when cutting copper blanks), protection optical elements from combustion products, stabilization the cutting process, etc. For example, the use oxygen leads to the formation copper oxide in the processing zone, which reduces its reflectivity.

V. Summary

Copper and brass laser cutting is possible, but much more difficult than other metals. This is partly due to the fact that copper is a highly reflective material. Copper's reflective properties make it difficult for the laser's infrared light to be absorbed, slowing down the cutting process.

To get the most out laser cutting copper, you need to consider speed, power, reflectivity, and focal point. All these factors help make laser cutting copper and brass easier. There are several factors to consider when using fiber lasers to cut copper and brass:

1. Laser Power. When using a fiber laser for cutting, power is a consideration. This is one the most important factors when cutting copper and brass. The more powerful the fiber

lasers, the better the quality the copper and brass cutting will be. Pulsed CO_2-lasers have significantly higher power density, but a fiber laser is best suited for cutting copper and brass because it has a wavelength $\lambda = 1.06\ \mu m$ and can absorb more energy quickly.

2. Power Setting: Ideally, you want to use the highest possible peak power to reduce the amount time the material is in its most reflective state.

3. Cutting Speed: To use fiber lasers and achieve excellent copper cutting, you need to consider the cutting speed. To optimize the speed, you need to consider the thickness the workpiece and the power the laser machine. It is always a good idea to start with a slower speed to ensure that you can get the laser through the piercing hole before you start laser cutting.

4. Gas Jet: One the main factors when cutting copper and brass is the gas jet, as it moves the compressed gas into the cutting area. This gas also protects the lens from the vaporized metal from the cutting area when the metal is in a liquid state. This also helps ensure the required quality, productivity and speed metal cutting.

5. Reflection Detector: When laser cutting metals such as copper and brass, special attention should be paid to the laser beam. If too much light is reflected from the copper cut by the laser, it can cause damage to the machine. The reflection detector monitors the infrared laser light emitted by the fiber laser and the radiation it produces. If too much radiation hits the fiber laser lens, the detector will turn f the machine.

6. Focusing Position. When cutting copper and brass, it is necessary to set the focus the laser beam as close to the top the surface as possible, which will reduce the amount evaporated material coming into contact with the laser head, increase the specific power and accelerate the melting the metal.

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