Study of laser cutting of copper and copper alloys

Az T Gabdrakhmanov, I H Israphilov, L N Shafigullin and T F Gabdrakhmanova

Kazan Federal University, 423800, 68/19 Mira avenue, Naberezhnye Chelny, Russia
ATGabdrahmanov@kpfu.ru, veyron000@mail.ru

Abstract. The processes of interaction of laser radiation with a surface layer of copper under laser irradiation, as well as the main factors affecting the absorption capacity of copper during surface treatment with a laser beam, are considered.

1. Introduction

Among laser technologies used at the present time in machine-building industries, a gas laser cutting of metallic and non-metallic materials become widely used [1-6]. The using of laser cutting in the blank production appears to be most efficient [7-10]. A wide range of thicknesses and grades of cut materials, almost any parameters of cut parts allow to manufacture parts of different sizes and geometric complexity.

It is possible to cut sheet material along a complex contour with an error from 100 to several micrometers using laser cutting technology.

Modern laser cutting systems allow to cut of thin-sheet materials at a speed of up to 120 m / min with an error of no more than 100 microns. It is necessary to increase the laser radiation power for maximize increase the thickness of the sheets to be cut and the cutting speed, so in recent years, the laser cutting technology has been commercialized at the power level of 5-6 kW.

Laser cutting of carbon and stainless steels is well studied. Cutting metals of the copper group has its own characteristics due to the high thermal conductivity of the material. Copper also has a large coefficient of heat capacity. It is imposes certain requirements on the equipment. In preparation for the process, it should be borne in mind that the laser cutting of copper the more difficult the thicker the plate. It is necessary to choose the right parameters of power and speed of the beam. The general rules are: the size of the laser spot should be as small as possible, and the power - high. It is possible to achieve a flat line of cut when the conditions of technology are observing. As a result of high-quality cutting, the edges of the product are not deformed. The copper sheet absorbs the radiation poorly. For this reason, the copper rolled cut at minimum speeds.

The research material was copper. The blanks were in the form of strip blanks with a thickness of 1 mm.

2. Experimental studies

The cutting was performed using a LS-2 serial laser unit with a power of 2 kW manufactured by IRE-Polus with an IPG d38 f100W-150-200 optical head with a focal length of 150mm. The cutting of metal samples was carried out with the installation of the focal plane on the workpiece surface. The speed of movement of the instrument varied from 5 to 30 mm / s. The laser head was not installed at a right angle to protect the laser from reflected radiation.
After cutting, the structure of the cutting surface, its geometry were studied and determined the roughness in accordance with GOST 2309-73; 2789-73. The height parameter Ra is selected as a quantitative indicator of the degree of roughness. The cut surfaces were photographed in studies using a digital camera and a microscope with magnifications from 50 to 200. A characteristic feature of the heat-affected zone is the presence of barb - residues of molten metal crystallized on the bottom (base) surface of the workpiece.

The barb deteriorates the quality of the laser cut and makes it necessary to remove the operation. The specific features of the power tool - a huge energy density, concentrated on a small area of the material – it leads to high rates of heating and cooling of this area (up to 106 K/s). At the same time, the possibility of non-diffusion mechanisms of transformations is increased, there is a sharp structural and chemical heterogeneity and the effect of structural heredity is manifested clearly.

The laser cutting modes of copper are presented in table 1.

| Table 1. Laser cutting modes. |
|-----------------------------|
| Mode | Working gas | Gas pressure p, atm | Laser radiation speed v, mm/s | Laser power N, W |
|------|--------------|---------------------|-------------------------------|------------------|
| 1 Air | 7 | 18 | 1000 |
| 2 Air | 7 | 30 | 1200 |
| 3 Air | 7 | 25 | 1000 |
| 4 Oxygen | 13 | 18 | 1000 |
| 5 Oxygen | 13 | 30 | 1000 |
| 6 Oxygen | 13 | 30 | 800 |

The quality assessment criteria are: b - the width of the cut, h - the heat-affected zone, l - the size of the barb. Table 2 shows the quality parameters of the cutting surface dimensions.

| Table 2. The cutting quality parameters. |
|-----------------------------------------|
| Sample no. | Roughness Ra, µm | Barb l, mm | Heat affected zone N, mm | Cutting Width b, mm |
|------------|------------------|------------|------------------------|---------------------|
| 1 | 1,528 | 0,430 | 1,402 | 0,196 |
| 2 | 0,608 | 0,171 | 1,273 | 0,159 |
| 3 | - | - | - | - |
| 4 | - | 0,257 | 0,837 | 0,267 |
| 5 | 0,891 | 0,289 | 0,618 | 0,235 |
| 6 | 1,106 | 0,225 | 1,040 | 0,253 |

The surface of the laser cut is characterized by a certain microgeometry, which is represented by a set of periodically recurring irregularities (waviness, striation, roughness) described by a set of parameters characterizing the average and maximum height of the irregularities, their width, and the distance between them. The view of the cut surfaces under various laser cutting conditions is shown in Fig. 1.
Figure 1. The surface of the laser cut copper 1 mm thick (left to right): cut edge × 200, top view × 50, in the section × 50; a) mode 1; b) mode 5;

3. The conclusion

For laser cutting of copper and its alloys, an oxygen-containing medium (air, oxygen) is necessary. When copper is exposed to laser radiation, a thin oxide layer is formed, which has a good absorption capacity, thus starting most of the radiation is absorbed, which leads to heating and removal of the material. This is confirmed by experiments using nitrogen and carbon dioxide as the working gas, without heating the copper billets, even at maximum power, all laser radiation is reflected from the surface. The use of oxygen as a working gas can reduce the power and increase the speed of laser radiation.

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