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OPERATING EXPERIENCE OF CO_2–LASER CUTTING OF METALS AND NON METALLIC MATERIALS

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Abstract:

We presents results of application and some modifications of laser technological complex Hebr - 1A" based on CW CO_2 laser with power of about 1 kW with wavelength of 10.6 µm for cutting of metals and non-metallic materials.

Closed-loop water cooling system based on use of inter connected three water tanks each with capacity of one cubic meters was introduced to provide cost/benefit operation of the system.

The modes of (i) gas laser cutting through material melting by focused beam and melt blowing and (ii)gas laser cutting in the presence of oxidant(oxygen) as assist gas with melt blowing out were applied. Some preliminary researches directed at thermal splitting of non-metallic fragile materials were also conducted.

The focused spot of laser beam $2r_f$ (double radius) and the depth of focus Z_f were estimated as 0.3-0.4 mm and as 3.3-5.8mm correspondingly depending on operation regime. It means that maximum average laser radiation intensity in the focused spot near the surface of materials to be cut is around or less 10^5 W/cm^2 .

Some changes were done in software provided that allowed operation of laser system in a more convenient way and reduce the time necessary to prepare the materials for cutting.

Application of coatings with high coefficients of absorption applied to aluminum alloys and brass allowed cutting of these materials with enough high quality with relatively lower values of power of CO_2 -laser that are usually used for these purposes (see Fig. 1).

Fig. 1. Cutting of holes with diameter of 15mm in aluminum alloy of 2mm width

In the end we present the description of samples that were cut with CO_2 laser system under different regimes of operation.

Introduction

Currently high power technological CO_2-lasers with wavelength of 10.6 μm and power of 4-5 kW and fiber lasers with wavelength of around 1 μm and power of 2-6 KW are considered of mostly used for cutting metal and non-metal materials with width over 2mm [1]. The share of relatively "new" fiber lasers is rising very quickly and 2015 year marked equal share of technological CO_2 and fiber lasers on the market for industrial cutting of materials. Of these types of lasers fiber laser are significantly easier to operate, with that they are still more expensive than CO_2-lasers. In addition, there exists market of outdated technological CO_2-laser systems with power of 1-3kW that can be bought at low prices.

Parameters of "Hebr -1A" laser technological complex

In 2012, "Hebr -1A" laser technological complex based on CW CO_2 laser with power of about 1 kW was installed and put into operation in laser department of A. Alikhanyan National Science Laboratory (Yerevan Physics Institute). This powerful convection type laser system works under continuous excitation regime and is designed for cutting, welding of metals and non-metallic materials for industrial applications and other types of processing. This complex was manufactured in Bulgaria and subsequently it has been upgraded. Reliable computer numerical control (CNC) ETA-17 system is used in order to transfer material or the beam of laser radiation along 3 axes (X-, Y-, Z- axis direction).

"HEBR 1A" technological laser complex

CO_2 - LASER PARAMETERS

The wavelength of laser generation, μm	10,6
Available maximum output power of laser generation, W	900

Stability of rated power, %	± 4
Power smooth regulation limits, W	200-900
Maximum electrical power consumed from electricity lines, kW	35
Excitement regime	continuous
Divergence of laser beam	≤ 3mrad

LASER COMPLEX PARAMETERS

The maximum size of the transfer, mm	
along X axis	1200
along Y axis	2000
along Z axis	60
Positioning accuracy, mm	± 0,01
Feed rates (work velocities) along X,Y axes, m/min	0,1-4

CO_2-laser contour cutting and operation modes

At wavelength of CO2 laser radiation of 10.6 μm metals are characterized by high values of coefficient of reflection at room temperatures. With rise of temperature coefficients of reflection are being significantly increased. Absorption capacity by non-oxidized metallic surface is defined by Hagen-Rubens relation: $A = 112.2\ (\sigma_0^{-1})^{0.5}$, where A – coefficient of absorption; σ_0 - specific electrical conductivity of metal for direct current [4].

For estimation of the focused spot size (double radius) of laser beam $2r_f$ and the depth of focus Z_f the following expressions can be applied for TEM_{00} mode [2, 3]

$$\Theta = \lambda/\pi\, r_n,\ \ 2r_f = 2f\,\Theta = 2f\,\lambda/\pi\, r_b,\ Z_f = \pm 0.46\ \pi r_f^2/\lambda,$$

where Θ - divergence of laser beam (≤3 mrad), $\boldsymbol{\lambda}$ - wavelength of laser generation (10.6 μm), f - lens's focal length of 127mm, r_n – radius of neck of beam in the resonator, r_b - radius of laser beam just before lens. System mode regime is TEM_{00}-TEM_{01}. Additional amendments to estimations should be applied. In this work the focused spot of laser beam $2r_f$ (double radius) and the depth of focus Z_f were estimated as 0.3-0.4 mm and as 3.3-5.8mm correspondingly depending on operation regime. It means that maximum average intensity in the focused spot near the surface of materials to be cut is around 10^5 W/cm^2 .

The modes of (i) gas laser cutting through material melting by focused beam and melt blowing and (ii)gas laser cutting in the presence of oxidant(oxygen) with melt blowing out were applied. O_2 and compressed air under pressure of 1-3 bar were used as an assist gas in the cutting nozzle. Nozzles with diameters 1.7 and 1.3 mm were used during cutting.

Some preliminary researches directed at thermal splitting of non-metallic fragile materials were also conducted. Samples from the glass with width of 5 mm were tested.

To provide cost/benefit operation of the system closed-loop water cooling system based on use of inter connected three water tanks each with capacity of one cubic meters was introduced.

For cutting metal materials the laser complex is provided with the system that maintain the cutting nozzle of laser bean at the definite distance from the surface of material (usually 0.6-1mm) with accuracy of around 50 μm (as stated) through application of capacity sensor. Unfortunately, while cutting non-metallic materials this system is not applicable directly. So special device was developed and applied to maintain the cutting nozzle at definite distance from the surface of non-metallic material. The device was tested for precise cutting of acryl and multi-layer plywood materials at feed rate of 2mm/min with good results obtained.

Computer numerical control (CNC) ETA-17 system is used in order to transfer material or the beam of laser radiation along 3 axes (X-, Y-, Z- axis direction). Some changes were done in software provided that allowed operation of laser system in a more convenient way and reduce the time necessary to prepare the materials for cutting.

Application of coatings with high coefficients of absorption applied to aluminum alloys and brass allowed cutting of these materials with enough high quality with relatively lower values of power of CO_2 -laser that are usually used for these purposes (see Fig. 1).

Fig. 1. Cutting of holes in aluminum alloy of 2mm width

In the end we present the description of samples that were cut with CO_2 laser system under different regimes of operation. In the Table 1 below the values of maximum thickness of cut materials with this laser complex are presented.

Table 1

MAXIMUM THICKNESS OF CUT MATERIALS			
Carbon steel	8 mm	Marble	10 mm
Stainless steel	6 mm	Ceramic tile	6 mm
Wood	30 mm	Aluminum	2 mm
Organic glass	40 mm	Brass	4 mm
Tekstolite	15 mm		

SAMPLES OF WORK DONE WITH CO_2 LASER CUTTING

Stainless steel plate: length - 2000 mm, width - 770 mm, thickness – 1.2 mm

Stainless steel plate: thickness – 1.2 mm

Carbon steel: length - 2000 mm, thickness – 5 mm

Aluminum: thickness – 2 mm

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