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EFFECT OF CUTTING SPEED BY LASER ON THICKNESS OF HEAT AFFECTED ZONE OF MILD STEEL S235

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Abstract

The presented article describes the technology of laser cutting. Article describes the characteristics of the laser beam by CO_2 laser, the factors on the process of laser cutting, assistance gas and interaction cut material properties and stability of the cutting process. There is characterized conventionally used material - mild steel S235 and cutting method of laser, including the impact of technological parameters of laser cutting on integrity of cutting edge. Experimental samples of material S235 are cut with different technological parameters of laser cutting and is monitoring heat affected zone in each samples. Heat affected zone is displayed graphically and evaluated the impact of change of cutting speed to thickness of heat affected zone.

1.Introduction

Cutting metals with lasers has become common practice throughout the industrial world. An understanding of its mechanism deserves careful attention to ensure that new improvements can be properly evaluated and implemented. The closest analogy is recognition that laser cutting, as it is predominantly implemented, remains a thermal process. Existing sciences and technologies recognize the merits of short-wavelength ultraviolet (UV) laser - beam ablation techniques that can cut material without imparting any heat into it. Ablation uses photon-induced chemical bond destruction to cut material. For example, excimer lasers emitting UV light at about 0,3 μm wavelength successfully cut and drill ceramics with no significant heat generation. Ablation is, however, no match to thermal cutting when compared in an industrial setting in which other considerations, such as cycle time, productivity, and profitability influence decision - making. From that regard, ablation techniques need further development. Several publications describe the theoretical aspects of heat and mass transfer and present the governing equations for modelling physics and chemical thermodynamics of laser cutting of metals.

Thermal - cutting processes involve a source of heat concentrated on a workpiece s surfaces. Heat is generally transferred locally to the workpiece by conduction, convection, or radiative-absorption mechanism until the metal reaches a liquid or vapor state, which makes it easily removable with help from assist-gas pressure flow. In the case of laser, the heat-transfer mechanism is radiative transfer. The photons of laser-beam light are absorbed by the workpiece, and their energy is converted into heat with an efficiency that varies with the type of metal, wavelength of the laser beam, its polarization, and the temperature of the metal. When laser cutting with oxygen as the assist-gas, the oxygen reacts with most metals, such as steel, in an exothermic-oxidation reaction that advantageously adds more heat to the cutting process.

Laser output ´s advantage is taken from the unique coherence and monochromaticity properties of laser beams- an incident laser beam is focused onto a small spot on a workpiece. The power density is raised above 106 W/cm2 levels, at which most metals can be vaporized. Power densities are directly proportional to laser power. In comparison, the power density of sunlight reaches less than 0,1W/cm2 in earth´s atmosphere.

Only part of the laser power applied to a workpiece is actually used for cutting. The rest is wasted by reflection off the workpiece surface or transmitted through the workpiece by successive partial reflections against the wall of the cut through, also called the kerf. The remaining laser energy absorbed by the metal´s surface and the kerf elevates the temperature around the point of incidence on the workpiece by a simple heat-conduction mechanism. In other words, the energy absorbed locally is partially used to melt and vaporize metal and partially lost by conduction in the workpiece and radiation. Radiation loss is evidenced by the visible plasma plume energy originating from a kerf during cutting. The nozzle standoff distance and focus position are relative to the workpiece surface and set up independently. The nozzle diameter is generally not adjustable on the fly. The set value of the nozzle standoff distance is maintained constant by the Z-axis motion in a closed loop with a height-sensor system. The set value of the focus position is adjusted manually before the start of the cut or on the fly with, for example additional axis servomotor motion for the nozzle assembly only or adaptive-optics system. At constant laser power, as metal thickness increases, the power absorbed locally to melt through the workpiece at a given feed rate becomes insufficient to cut through the metal. Therefore, a portion of the bottom of the workpiece is not in molten form and cannot be flushed away. Molten metal being flushed takes the path of least resistance through the upstream part of the kerf.

Periodical striations along a cut edge can be observed. These striations exhibit a cut section and a "break" section, which is analogous to the jargon used for the mechanical shearing process.

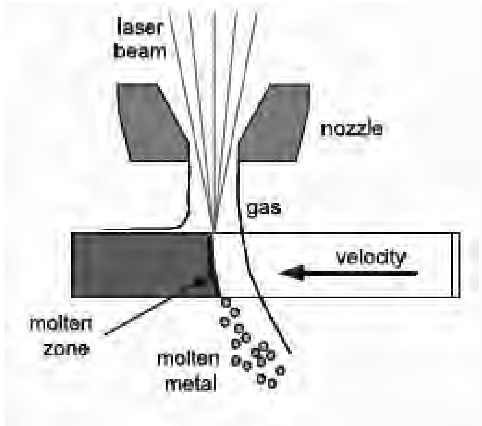

Fig. 1 *Scheme of laser cutting*

2. Experimental conditions

In this work, we prepared samples on laser cutting machine TruLaser L 3030 by TRUMPF. We measured the heat affected zone on samples of S235 steel sheet with thickness of 2 mm.Chemical composition of the steel sheets are given in table.

Tab.1 *Chemical composition of steel S235*

Chemical composition of steel S235				
Elements	C	Mn	S	P
Composition %	< 0,17	< 0,107	< 0,045	< 0,045

Cutting operations were conducted in the following conditions:

- *pressure of assistant gas – 0,45 MPa,*
- *assistant gas – O_2 - 3.5,*
- *diameter of the nozzle – 0,8 mm,*
- *position of focus point – -1 mm,*
- *cutting power – 1200 W.*

3. Results

On Figures 2-5 are displayed images of the microstructure and thickness ofheat affected zone for each sample on the cutting edge. The samples are polished and etched by 2% nital.

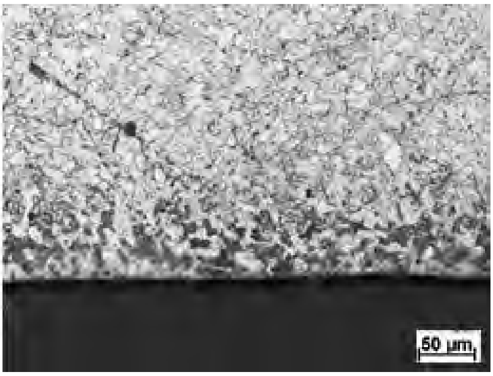

Fig. 2 *HAZ by the cutting speed – 2,5m/min*

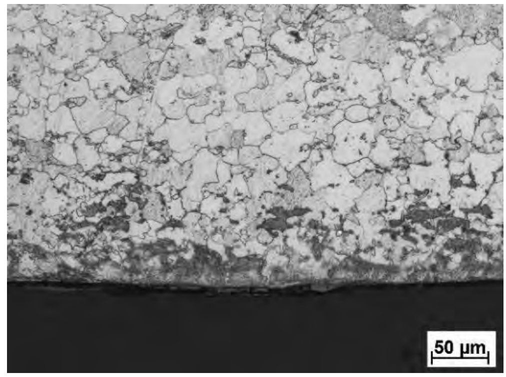

Fig. 3 *HAZ by the cutting speed – 5m/min*

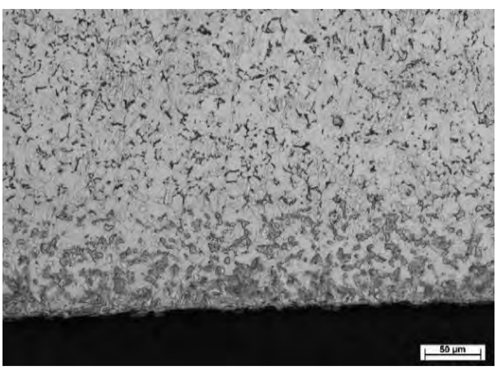

Fig.4 *HAZ by the cutting speed – 6m/min*

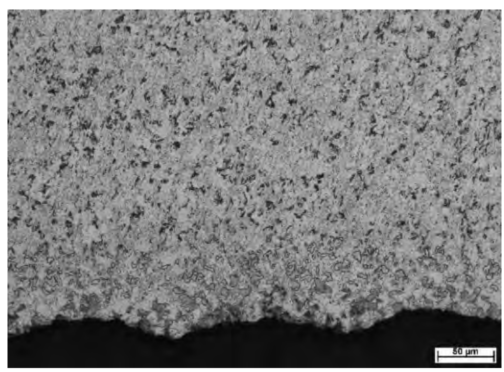

Fig.5 *HAZ by the cutting speed – 8m/min*

Thickness of heat affected zone was measured of three different samples for each cutting speed by laser technology. We used to evaluate the arithmetic average of the measured values. The results of individual measurements are given in table.

***Tab.2** Results of measurements of the thickness of the HAZ with different cutting speeds*

Cutting speed (m/min)	2,5	5	6	8
1.	110 µm	95 µm	100 µm	75 µm
2.	108 µm	100 µm	90 µm	70 µm
3.	106 µm	96 µm	94 µm	80 µm
average	108 µm	97 µm	94 µm	75 µm

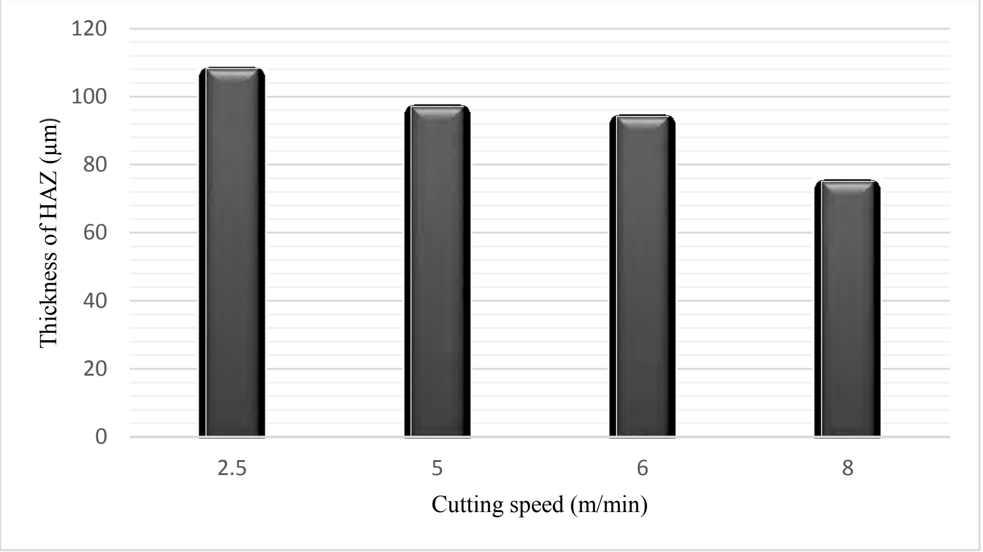

***Fig.6** Graphical illustration of results of measurements of the thickness of the HAZ with different cutting speeds*

4.Conclusion

This paper deals with the description and evaluation of experimental results obtained by to observed and compared heat affected zone on the samples from steel S235 which was cutted with different technological parameters of CO2 laser.From the measurement results is possible inferred, that heat affected zone by laser cutting is relatively small, the maximum measured value of the steel S235 of 2 mm thickness is 108µm which was measured with application of cutting speed of 2,5 m/min.The smallest measured thickness of heat affected zones is 75µm and has been measured with the cutting speed 8 m/min. The mutual comparison each samples, from each is cutting with different cutting speed is possible to say that with increasing cutting speed is thickness of heat affected zone decreasing. This is caused that higher cutting speed gives to material smaller amount of heat. On each of the samples wasn´t monitored change in grain size in the structure.

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Literature

1. DOPJERA, D., MIČIAN, M. (2014) The detection of articullary made defects in welded joint with ultrasonic defectoscopy Phased Array. In: Manufacturing Technology, Vol. 14, No. 1, pp. 12-17, ISSN 1213-2489
2. KOŇÁR, R., MIČIAN, M. (2014) Non-destructive testing of welds in gas pipelines repair with Phased Array ultrasonic technique. In: Manufacturing Technology, Vol. 14, No. 1, pp. 42-47, ISSN 1213-2489
3. KOŇÁR, R. - MIČIAN, M. - HOPKO, A., (2011) Analysis of boundary conditions for the simulation of welding at the repair of gas pipelines with steel sleeve. In: Communications : scientific letters of the University of Žilina. - ISSN 1335-4205. - Vol. 13, No. 4 (2011), s. 36-39.
4. NOVÁK, P., ZMINDAK, M., PELAGIC, Z. High Pressure Pipelines Repaired by Steel Sleeve and Epoxy Composition. In: Experimental Stress Analysis 2013, 51st international conference proceedings, June 11-13-2013, Litomeřice, Czech republic, 2013, ISBN 979-80-7414-579-7
5. KOŇÁR, R., MIČIAN, M. Numerical simulation of residual stresses and distortions in butt weld in simulation program Sysweld. In: Comunications: scientific letters of the University of Žilina. Vol. 14, No. 3. pp. 49-54. ISSN 1335-4205. Žilina.
6. KOŇÁR, R., MIČIAN, M., STRAŠKO, J. Numerical simulation of temperature fields in sysweld simulation programme. In: International journal of applied mechanics and engineering, Vol. 15, No. 2, pp. 423-431. ISSN 1425-1655
7. RADEK, N., ANTOSZEWSKI, B. Influence of laser treatment on the properties of electro-spark deposited coatings. In: Kovove Materialy - Metallic Materials 47, pp. 31-38, 2009
8. KOVANDA, K., HOLUB, L., KOLAŘÍK, L., KOLAŘÍKOVÁ, M., VONDROUŠ, P. Experimental verification of FEM Simulation of GMAW bead on plate welding. ManufacturingTechnology Vol.12, No. 12, pp. 30-33.