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EXPERIMENTAL STUDIES ON CO2 LASER CUTTING OF LOW ALLOY STEEL USING OXYGEN AS ASSIST GAS

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ABSTRACT
CO_2 laser cutting of low alloy steel sheets is considered and the effect of cutting speed and material thickness on the kerf width and the surface roughness is examined. It is found that the surface roughness decreases by increasing cutting speed while the kerf width changes slightly with increasing cutting speed. Also the results show that the surface roughness and the kerf width increase by increasing material thickness while the cutting speed decreases by increasing material thickness.
Keywords: laser cutting, low alloy steel, cut quality, oxygen assist gas

1. INTRODUCTION
Laser cutting of metals has become a reliable technology for industrial production. Currently, it is considered as a feasible alternative to mechanical cutting and blanking due to its flexibility and ability to process variable quantities of sheet metal parts in a very short time with very high programmability and minimum amount of waste. Laser cutting does not need special fixtures or jigs for the work piece because it is a non-contact operation. Laser cutting is classified as a typical thermal process that has special advantages over other known thermal processes due to the high quality and very smooth cut surface, narrow kerf width, small heat affected zone, small metal deformation, perpendicular and sharp cut sides, square corners of cut edges and little or no oxide layer [1]. Of particular interest to manufacturers using laser cutting are the maximization of the productivity and the subsequent quality of components made by the laser cutting process. Both aspects are governed by the selection of appropriate laser process parameters, which are unique for each material and thickness. Most work reviewed in the literature considers only one or two characteristic properties of the laser cut surface to describe quality [2]. Kerf width, surface roughness and size of heat affected zone are often used to describe laser cut quality. The assist gas composition used for laser cutting depends on the substrate. From previous research, it has been found that the purity of the assist gas is affected by the quality of the cut [3, 4]. Exothermic reaction is an important heat source in reactive laser cutting, so carbon and low alloy steel is usually cut with oxygen [5]. When using oxygen as assist gas, hydro-dynamical interactions are superimposed by additional effects such as local density and concentration variations of the oxygen at the cutting front, the resulting reaction kinematics, and the change in viscosity of the oxide-melt composite [6]. The assist gas pressure and focus position have strong influence on the quality of the produced cuts [7]. The effect of laser power, cutting speed and oxygen assist gas pressure on the cut quality in laser cutting of refractory materials analyzed in [8]. They found that oxygen assist gas pressure has strong influence on the cut quality. In [9] found that laser output power

and oxygen assist gas pressure have significant effect on the percentage of kerf width variation in laser cutting of thick sheet metals. Increasing laser power and oxygen gas pressure results in increased thermal erosion around the cut section; in which case, the depth of stria increases significantly. Reference [10] found that on increasing the frequency and cutting speed the kerf width and the surface roughness decrease, while increasing the power and gas pressure the kerf width and roughness increase. The same effect of laser power and cutting speed on kerf width during CO_2 laser cutting of steel sheets of different thicknesses is observed in [11].

In laser cutting process, many factors affecting the end product quality. Some of these factors include the cutting speed and the material thickness. In the present study laser cutting of low alloy steel sheets at different cutting speeds and material thicknesses are considered, and hence obtain the optimal cutting speed for different material thicknesses.

2. EXPERIMENTAL SETUP

In order to achieve the stated objective, laser cutting experiments are carried out using low alloy steel sheets of different thicknesses to investigate the effect of cutting speed on the cut quality. The laser used in the experiment is a TRUMPF 3030 CO_2 laser system with a nominal output power of 4000 W. The laser beam is focused using a 127 mm focal length lens. Oxygen assist gas is used coaxially with the laser beam via a 1,4 mm exit diameter nozzle. Experimental studies are carried out at the constant following parameters: laser power of 4000 W, stand-off distance of 1,5 mm, focus position of 2 mm and assist gas pressure of 0,6 bar. Two process parameters have been selected for the present study. These are cutting speed and material thickness. These parameters are varied within the range: the cutting speed from 0,2 m/min to 4 m/min, and the material thickness from 2 mm to 15 mm.

The controlled parameters have been the top surface kerf width and the surface roughness. A visual inspection of each cut is carried out to ensure that no pitting and burrs are present in the cut area. Surface roughness on the cut edge is measured in terms of the average roughness *Ra*, using the SurfTest Mitutoyo stylus instrument. Roughness is measured along the length of cut at approximately the middle of the thickness. The top surface kerf width is measured using a ZKM universal two-coordinate microscope.

3. RESULTS AND DISCUSSION

The effect of cutting speed on the surface roughness and the kerf width at different material thicknesses of 6 mm, 8 mm, 10 mm and 15 mm is shown in figures 1 and 2, respectively.

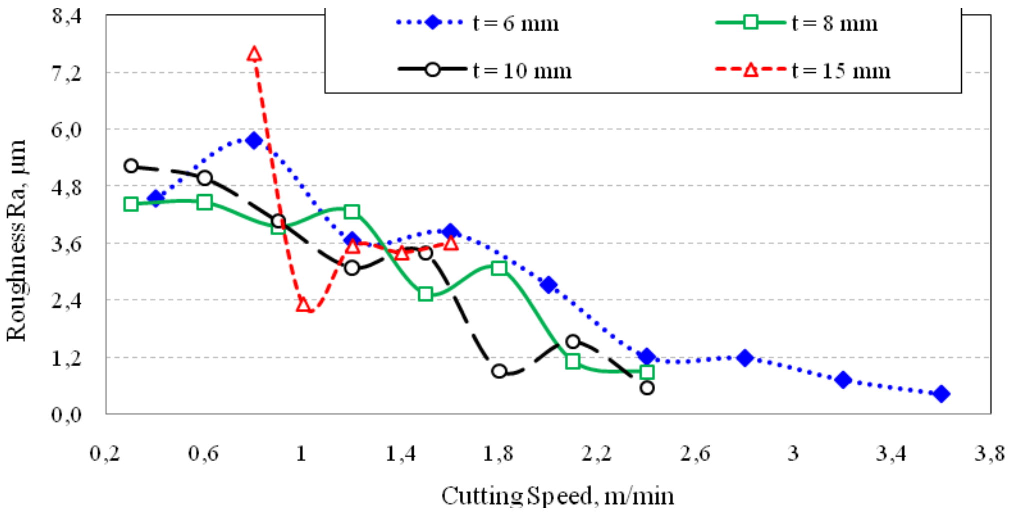


Figure 1. The effect of cutting speed on surface roughness at different material thicknesses

In figure 1 can be seen that surface roughness decreases by increasing cutting speed, but the dross is appeared along the backside of the cut. Also it can be concluded that the surface roughness slightly changes at the different material thicknesses.

In figure 2 can be seen that kerf width slightly changes by increasing cutting speed. Also it can be seen that kerf width increase by increasing material thickness, except during cutting of steel sheet thickness 15 mm. The cutting speed decreases by increasing material thickness; it can be seen in figures 1 and 2.

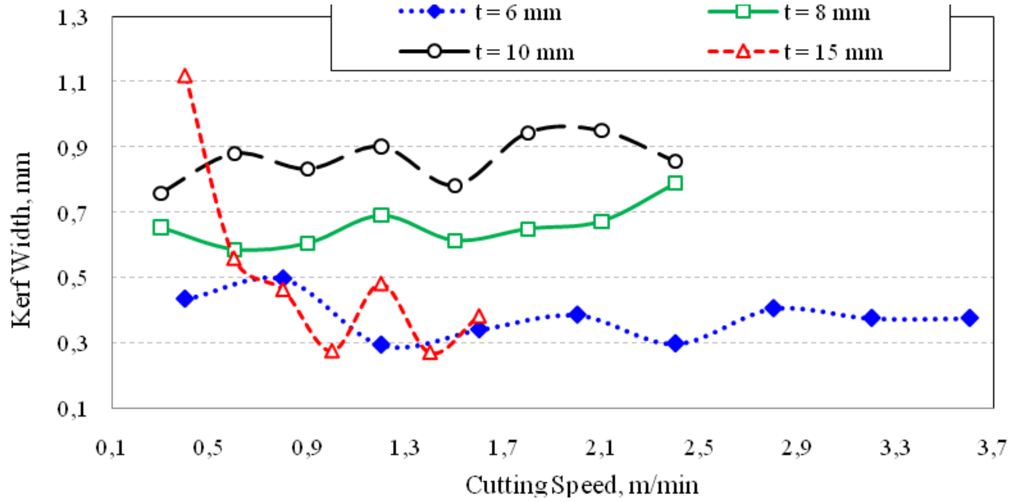
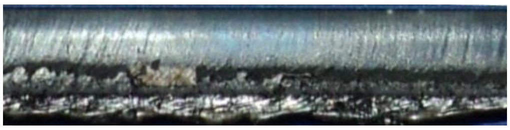


Figure 2. The effect of cutting speed on kerf width at different material thicknesses

In figure 3 and 4 are shown the photographs of samples thickness of 10 mm and 15 mm

Material thickness: 10 mm Cutting speed: 0.3 m/min	R_a = 5.23 μm Kerf width: 0.76 mm
	
Comment: Dross along the backside of the cut, the wavy surface of cut, Low cutting speed	

Material thickness: 10 mm Cutting speed: 2,1 m/min	R_a = 1.52 μm Kerf width: 0.95 mm
	
Comment: Dross along the backside of the cut High cutting speed	

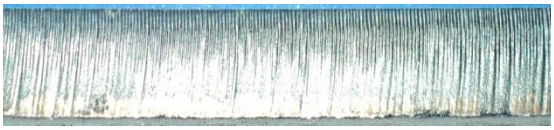
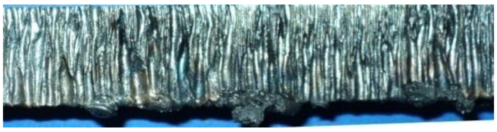
Material thickness: 10 mm Cutting speed: 1.5 m/min	R_a = 3.39 μm Kerf width: 0.78 mm
	
Comment: **Optimal cutting speed**	

Figure 3. The photographs of cut samples – material thickness of 10 mm

Material thickness: 15 mm Cutting speed: 0.4 m/min	R_a = --- μm Kerf width: 1.12 mm
	
Comment: Dross along the backside of the cut Too large surface roughness	

Material thickness: 15 mm Cutting speed: 0.6 m/min	R_a = --- μm Kerf width: 0.56 mm
	
Comment: Too large surface roughness	

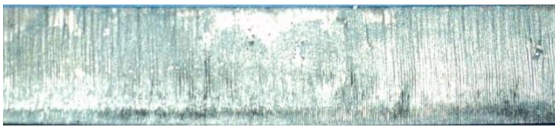
Material thickness: 15 mm Cutting speed: 1 m/min	R_a = 2.31 μm Kerf width: 0.28 mm
	
Comment: **Optimal cutting speed**	

Figure 4. The photographs of cut samples – material thickness of 15 mm

The cutting thin steel sheets of 2 mm and 3 mm in pre-selected parameters was not possible. There was a weld along the backside of the section, due to the excessive heat input into material (too high laser power of 4000 W) and low assist gas pressure of 0.6 bar, which was insufficient to blow molten material from the cutting zone.

4. CONCLUSION

The effect of cutting speed and material thickness on the quality characteristics of laser cut low alloy steel specimens studied in this paper. Based on the conducted investigations, the following could be concluded:

- Surface roughness decreases with increasing cutting speed, but the dross is appeared along the backside of the cut.
- Kerf width changes very slightly with increasing cutting speed in laser cutting of preselected thicknesses of the examined material.
- Surface roughness and kerf width increase by increasing material thickness.
- Cutting speed decreases by increasing material thickness.
- Based on the above conclusions, for laser cutting of low alloy steel sheets of 10 mm and 15 mm thick, it is recommended the optimal cutting speed of 1.5 m/min and 1 m/min, respectively.
- During laser cutting the examined material thickness less than 10 mm, it is recommended cutting at a laser power less than 4000 W.

Effect of laser power and assist gas pressure, as well as other cutting parameters on the cut quality in laser cutting of low alloy steel, it is recommended to further investigations and a comparison with the plasma cut quality.

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