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LASER CUTTING OF STAINLESS STEEL THIN SHEETS WITH PULSED Nd:YAG LASER

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Abstract: *The parameters of laser cutting mainly depend on material and from thickness. In case of a given material and thickness many settings can be chosen. In this article we examine the laser cutting of 0,4 mm thickness stainless steel sheets with pulsed Nd:YAG laser. We examine the effect of cutting speed on cut quality in case of three different combinations of pulse energy and pulse frequency.*
Good cut quality and relatively high cutting speed can be achieved with 800 Hz and 20.7 mJ setting, we can cut higher speed, but poor cut quality with 400 Hz and 49 mJ setting.

Keywords: *Laser cutting, Pulsed Nd:YAG laser, Cut quality*

1. INTRODUCTION

The main production method for thin sheet workpieces is laser cutting. These workpieces can be cut by Nd:YAG [1] laser with 20-50 μm kerf width, by fiber laser (for example Ytterbium mono mode fiber laser) [2], with 12 μm kerf width, or by water-jet guided Nd:YAG laser [3], with narrow kerf width too. The narrower the kerf width the lower the energy input for the workpiece, because of melting lower amount of material. Lower energy input means narrower heat affected zone, lower heat-caused distortion and more accurate workpiece profile.

Nowadays the most commonly used laser for thin workpiece cutting is Nd:YAG laser with 1064 nm wavelength. It has got different configurations: either with conventional flash lamp excitation, (for example Lasag KLS 246) or with lased diode excitation having better efficiency, or with Q-switch: capable for emitting high energy pulses.

Thawari made a full analysis on the higher power pulsed Nd:YAG laser cutting of Ni-base superalloys [4]. Beside a laser system a positioning system is necessary for thin sheet workpiece fabrication [5]. This positioning system clamps the workpiece and moves it relatively to the laser spot forming the structure of the workpiece. The positioning system for workpiece fabrication ensures two perpendiculars a translation and an adjustment of the mutual position of the work piece and the laser spot [6-7].

2. EXPERIMENTS

Objective: discovering relationships between cutting speed, pulse frequency, pulse energy and cut quality. Applied laser system: LASAG KLS 246 pulsed Nd:YAG with 20 W average power. Work piece positioning system produced by Aerotec Ltd. allowing two perpendicular translations in horizontal plane plus rotation around horizontal axis programmed with CNC code.

C	0,07
Cr	18,31
Ni	10,06
Mn	1,76
Si	0,99

Tab. 1. Chemical composition of AISI 304L austenitic stainless steel

The applied material was AISI 304L austenitic stainless steel sheet with 0,4 mm thickness, the chemical composition of the material can be seen in Tab. 1.

The stainless steel sheets were cut 10 mm long cuts with different laser settings. Tab. 2 shows the laser processing parameters used for this experiment. The laser cutting experiment was made with the aid of oxygen gas. The pressure of oxygen was 5×10^5 Pa. The exothermic reaction of oxygen and the material made the cutting faster.

	Laser setting “I”	Laser setting “II”	Laser setting “III”
Pulse frequency	100 Hz	400 Hz	800 Hz
Average power	12.5 W	19.6 W	16.6 W
Pulse width	0.3 ms	0.1 ms	0.05 ms
Pulse energy	125 mJ	49 mJ	20.7 mJ
Processing speed	1-16 mm/s	0.5-32 mm/s	2-20 mm/s
Focus position	At the top of the sheet		

Tab. 2. Laser processing parameters

Laser setting „I” means low frequency, high-energy pulses with varying cutting speed. Laser setting „II” means medium frequency, medium energy pulses with varying cutting speed. Laser setting „III” means high frequency, low energy pulses with varying cutting speed.

3. RESULTS AND DISCUSSION

Using low frequency laser setting „I” and medium frequency laser setting „II” 3 different region can be observed depending on the cutting speed (Tab. 3)

- In region „A” the cutting speed is low - because of this there is a large overlap between the laser pulses causing good-quality straight-edge kerf with low dross adherence (Fig. 1).
- In region „B” the cutting speed is higher - because of this there is a small overlap between the laser pulses causing poor-quality kerf with striations and more dross adherence (Fig. 6 and 9). In region „C” the cutting speed is high - because of this there is no overlap between the laser pulses causing independent holes in the material: it is the no-cut region (Fig. 4 and 5).
- The “C” region in 100 Hz and 125 mJ laser setting the diameter of the entry holes are almost the same as the diameter of the exit holes (Fig. 4 and 5), but in 400 Hz and 49 mJ laser setting the diameter of the entry holes are bigger than the diameter of the exit holes (Fig. 7 and 8).

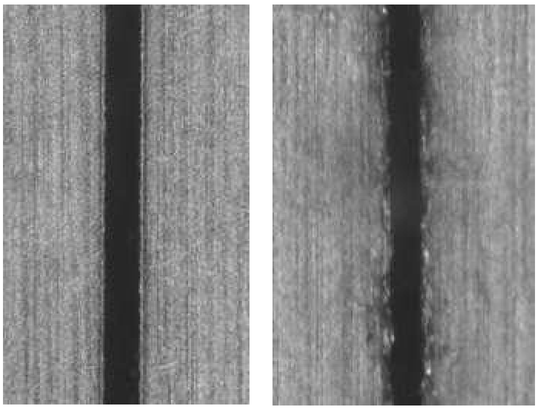


Fig. 1. Entry (left) and exit (right) side of a good quality cut.

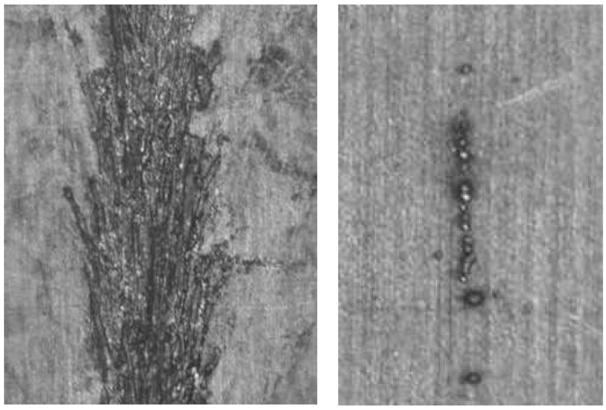


Fig. 2. Entry (left) and exit (right) side at 800 Hz, 20 mm/s. There is no cut, but spattering.

Using high frequency laser-low pulse energy setting „III” 2 different regions can be observed depending on the cutting speed (Tab. 3): In region „A” the cutting speed is low because of this there is a large overlap between the laser pulses causing good-quality straight-edge kerf with low dross adherence (Fig. 1).

The former „B” region is missing because one laser pulse is too week to make a hole across the material so with low pulse overlap there is no cut, but the no-cut region is the “C”. In This “C” region the pulses makes holes not crossing the material, and the assist gas blows the molten material from these holes causing spattering at the bottom of the sheet (Fig. 2).

Fig. 3 shows the cross section of this “C” region cut: some of the molten material is blown into the hole. Tab. 3 summarizes the result: shows the effect of the pulse frequency and the cutting speed on the cut quality.

Fig. 3. Cross section of the kerf at 800 Hz, 20 mm/s laser setting (no cut).

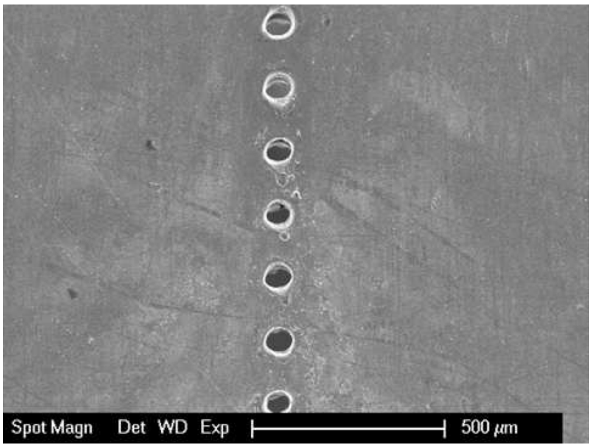


Fig. 4. There is no cut. Laser pulses drilled individual holes. 100 Hz, 16 mm/s; *entry* side.

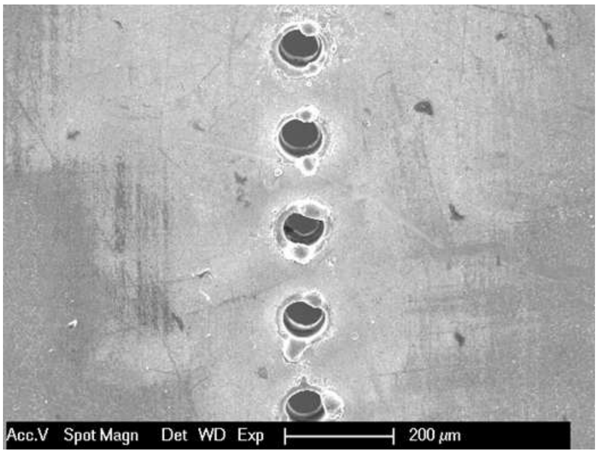


Fig. 5. There is no cut because of the laser pulse drilled individual holes.
100 Hz, 16 mm/s, *exit* side.

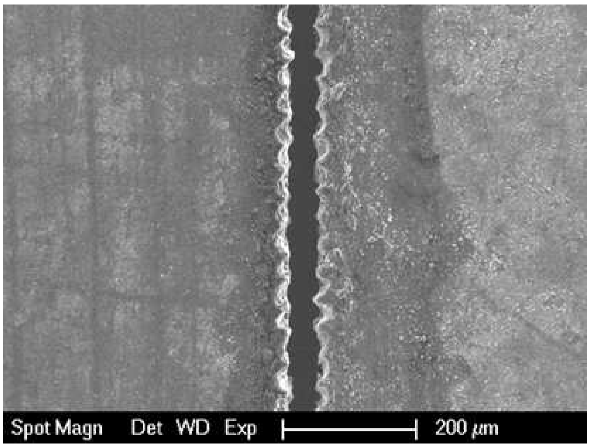


Fig. 6 – Poor quality cut at 100 Hz, 4 mm/s, *entry* side

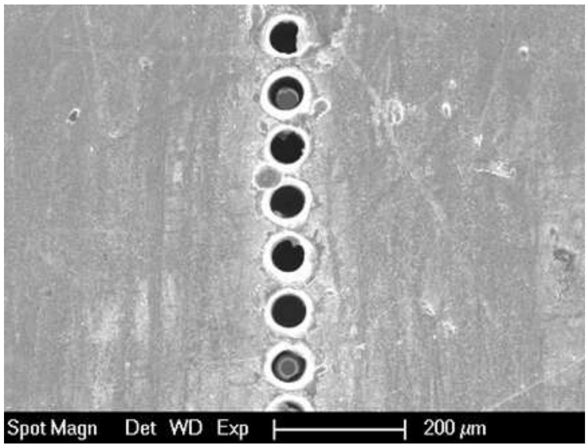


Fig. 7. There is no cut. Individual holes.
400 Hz, 32 mm/s, *entry* side

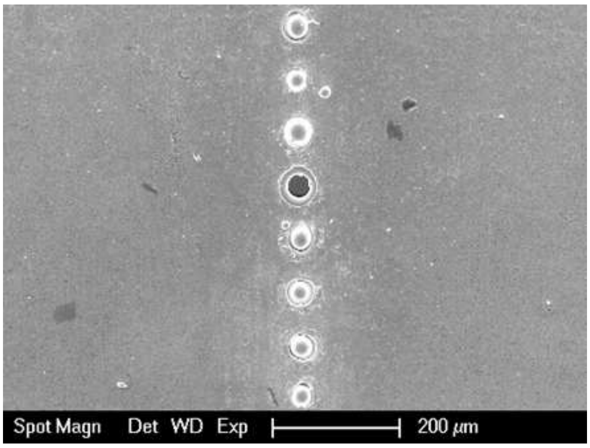


Fig. 8. There is no cut. Laser pulses drilled individual holes. 400 Hz, 32 mm/s, *exit* side

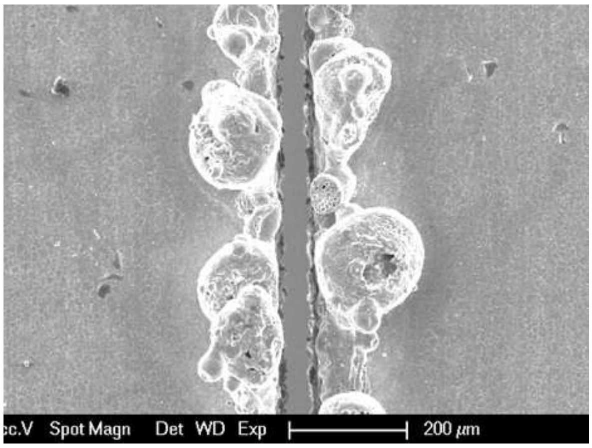
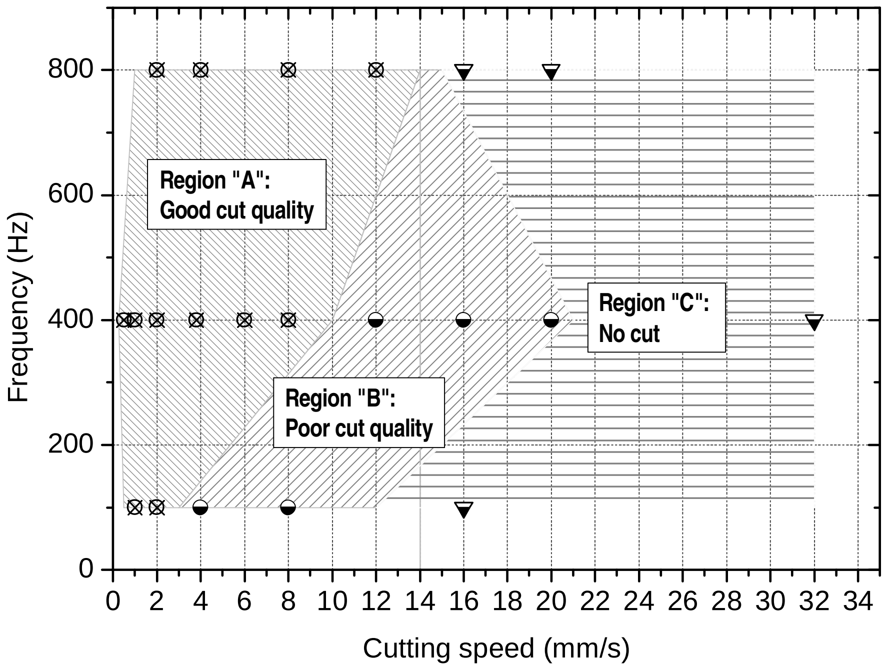


Fig. 9. Poor quality cut at 100 Hz, 4 mm/s, *exit* side, strong dross adherence can be observed



Tab. 3 The effect of cutting speed on cut quality at various frequencies

At 800 Hz laser setting a good quality cut can be made up to 12 mm/s cutting speed. Over this speed we cannot cut the material. At 400 Hz laser setting a good quality cut can be made up to 8 mm/s cutting speed; from 8 mm/s to 20 mm/s a poor quality cut can be made, over 20 mm/s the is no cut. At 100 Hz laser setting a good quality cut can be made up to 2 mm/s cutting speed; from 2 mm/s to 8 mm/s a poor quality cut can be made, over 8 mm/s the is no cut. In the region of poor quality cut ("B") sometimes cutting failures occur because of the non-uniformity of laser-drilled holes little bridges occur in the kerf (Fig.10).

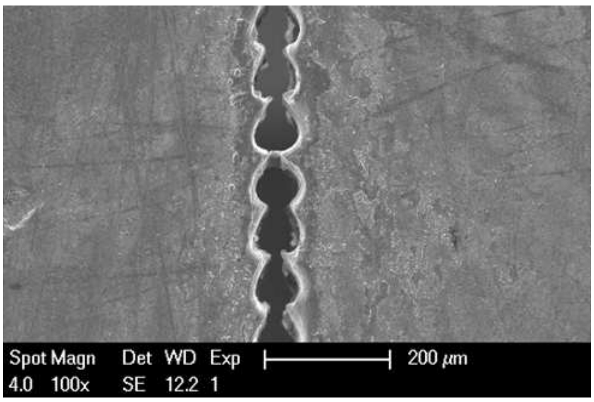


Fig. 10. Little bridges in the kerf

4. CONCLUSION

The effects of the laser cutting parameters on cut quality were analysed. The following consequences can be drawn:

Good cut quality and relatively high cutting speed can be achieved with 800 Hz and 20.7 mJ and 12 mm/s setting, we can cut higher speed (20 mm/s), but poor cut quality with 400 Hz and 49 mJ setting. Since 100 Hz and 125 mJ setting allows low cutting speed, better to use it for materials with larger thickness. Future plans: examination of the role of pulse width; analysis of the cutting of thinner materials with lower energy pulses.

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