

LASER CUTTING OF SOFT STEEL IN INDUSTRIAL PARTS MANUFACTURING

Professor Gîrdu Constantin Cristinel, *Transilvania University
of Braşov,, ROMÂNIA*

Professor PhD Eng. Drăgoi Mircea Viorel, *Transilvania University
of Braşov,, ROMÂNIA*

Lecturer PhD Eng. Mileşan Mihaela, *Transilvania University
of Braşov,, ROMÂNIA*

Lecturer PhD Eng. Rădulescu Constanţa, *University „Constantin Brâncuşi,, from
Târgu-Jiu, ROMÂNIA*

ABSTRACT: An interesting study on the cutting of flexible steel using the CO₂ laser is discussed in this paper. We used a rigorous mathematical model resulting from the experiments performed to determine the cutting speed, the deviation from the circularity of the disks, the geometry of the slit under more efficient conditions. I used a complete plan to make the cut. The focal position influences the cut, respectively the measured sizes. In the measurement process we used for Kerf the scanner and the electronic micrometer, and for the laser-cut surfaces the roughness meter and the durometer. The cutting process has been improved due to the use of the mathematical model. They were highlighted and calculated the cutting speed, the conicity due to the elliptical shape of the cut piece geometry when debiting the piece, conditions for minimizing the slit / cut channel. The relationships resulting from the part geometry indicate the circularity, data for the calculation of errors, the speed of work in stationary and dynamic piercing. The study is complex and varied because it can be supplemented with statistical data processing programs. The results of this article indicate the deviation from the circularity, the ellipse that approximates the piece, the composition of the speeds, the geometric modeling of the piece. All these relationships obtained accurately and accurately reproduce the dimensional accuracy of the pieces. By choosing the formulas expressed we can validate the calculation by comparing the measured values of the output parameters.

KEY WORDS: laser cutting, laser cutting parameters, CO₂ laser, laser melting, circular laser cutting, laser piercing

1. INTRODUCTION

The most recent works in 2019 in the field of laser cutting and processing are revolutionary researches that contribute with new discoveries to the development and deepening of the technology, so we will carefully highlight these studies:

Schwanekamp T. highlights the manufacture of Cr3C2-NiCr coated products by laser beam melting (LCM) technology [1].

Chen C. discusses 4 types of Kerf prefabricated with Argon, Nitrogen, Air, Oxygen gas, but also about porosity in laser welding [2].

Oh., Deong Y studied the cutting of 60mm thick stainless steel using the supersonic nozzle placed at stand-off distance from the top surface of the sheet using a 6KW fiber laser [3].

Ruthkowski researches Ti-Al-C material treated with a CW laser by ablation and welding [4].

S.M., Garcia analyzes the laser piercing for soft steel, stainless steel, monitoring the process with a photodiode installed in the cutting head. At the same time, the relationship between the laser intensity and the process parameters that improve the piercing duration in production has been established, avoiding the waste of time [5].

Saini, S.K. obtains laser-cut holes in zirconia-reinforced alumina (ZTA) to optimize the crater width, surface roughness establishing mathematical relationships between input and output parameters [6].

V.K., Sharma used the Box-Behnken, SSM design, statistics for modeling process parameters in the case of fiber laser cutting of A653 galvanized steel sheets. The result of the research shows that the supply and pressure of the assistant gas influence Kerf [7].

Chatterjee S., uses an Nd-YAG pulsed laser to obtain holes in a 0.5mm Ti6Al4V titanium alloy sheet. Using the Taguchi method indicates that the laser energy and the pulse width influence the circularity at the input and output, but also the taper [8].

Darwish discusses the pressure of the assistant gas in the case of laser cutting using the supersonic nozzle under desired operating conditions, under-expansion, to describe the dynamic characteristics of the output gas [9].

KD., Zhang shows the effects of laser pre-treatment of stainless steel using SLM - laser melting technique in tool making due to the temperature drop by 10-15%, respectively the quality of the parts obtained at high cutting speeds [10].

In this paper we have performed a recent study on the circular cutting of soft steel using the CO₂ laser was performed on two steel plates of size 1115x426 [mm] with the thickness $g=10$ [mm], where 224 references/samples were obtained, taking into

account that the length of the laser wave used is $\lambda=10.6[\mu\text{m}]$, the diameter of the laser



Fig. 1. OL37 steel sheet on CO₂ laser

beam before focusing is $D=20\text{mm}$, and the laser spot has a diameter of $d = 0.2\text{mm}$.

The device used in the cutting experiments is the By Speed 3015 CNC laser machine, used to obtain pieces of circular shaped discs made of steel OL37 for the parts manufacturing industry, which indicates that the cutting process is controlled and the cutting feedback is ensured. of the quality of the cut surfaces, fig.1.

The device is equipped with dust collector, water cooling circuits for mirrors, By Vision control control, 15 "screen, keyboard and manual control unit, edge detection accuracy = -0.5mm . The characteristics of the machine that I used in the soft steel cutting experiment are: working table $1500\text{mm} \times 3000\text{mm}$, maximum laser power 4400W , job no. 30002065, workpiece weight 800kg , voltage: $3 \times 400\text{V}$, frequency 50Hz , kW -65. They have been set: material - STW 22, thickness 10mm , focal length of the lens 7.5inch , nozzle type NK1515, focal position $0,00\text{mm}$, on the upper surface of the part, height nozzle - material 0.8mm when cutting, coordinate system of the surface of work - X: 443.54mm , Y: -0.1 , Z: 0.00mm . The installation has a discharge current of 60mA , the composition of the laser gas He 25%, CO₂ 1.1, nitrogen N₂ 12%, the pressure of the gas mixture -125mbar . CO₂ laser thermal cutting is performed with the speed of $2000\text{mm} / \text{min}$, the piercing time of 0.5s , the nozzle-sheet distance in piercing 3mm .

The continuous CW emission cut-off parameters set are: 4000W laser piercing power, 4200W laser cutting power, O₂ oxygen cutting gas type, piercing gas channel 1, cutting gas channel -1, piercing gas pressure. 2.5bar, gas pressure used in 0.5 bar cutting, oxygen gas pressure in standby - 0.6bar, instrument radius used for adjusting 0.2mm, bore diameter 0.3mm.

In the oxygen-assisted laser cutting experiment we used a lens with focal length $F = 19.05\text{cm}$. Applying the fundamental formula of the lens results:

$$\begin{aligned}\frac{1}{F} &= \frac{1}{x_2} - \frac{1}{x_1} \\ x_1 &\rightarrow \infty \\ \frac{1}{F} &= \frac{1}{x_2} \\ x_2 &= F\end{aligned}\quad 1.1$$

The focus is at the x_2 distance of the lens equal to F . The lens convergence is $C = 1 / F = 0.05$ diopter. The laser beam is designed as a parallel beam having the same power before and after the lens is crossed:

$$I = \frac{P}{S} = \frac{4P}{\pi D^2} \quad 1.2$$

$$I_0 = \frac{P}{S_0} = \frac{4P}{\pi d^2} \quad 1.3$$

$$I_0 = \frac{D^2}{d^2} I = \frac{400\text{mm}^2}{0.04\text{mm}^2} I = 10^4 I \quad 1.4$$

The lens increases 10^4 times the intensity of the laser radiation.

2. THE MATERIAL STUDIED - OL37

OL 37 - is a steel used in Romania for the manufacture of industrial parts and metal profiles for construction called soft steel - carbon steel. Steel is a type of iron alloy that has a low carbon content. This material is arm) through the intermedium of part of the steel category next to OL44 used in the manufacture of high demanding construction elements, OL 52 with the highest mechanical properties and stainless steels. Table 1 describes this type of general-purpose steel - STAS 500 / 2-80.

Table 1 - Description of the chemical and mechanical composition of OL 37

MARK		Chemical composition				Mechanical characteristics	
STAS 500/2-80	Quality class	C	Mn	P	S	Rp0.2 [N/mm ²]	Rm [N/mm ²]
OL37	1;1a;1b	0.25	0.85	0.065	0.065	210-240	360-440
	2	0.22	0.85	0.055	0.055	210-240	360-440
	3	0.19	0.85	0.050	0.050	210-240	360-440
	4	0.19	0.85	0.045	0.045	210-240	360-440

3. THE EXPERIMENTAL METHOD

The experiment was designed and planned for two OLC plates 37. On the first plate I, the cutting experiment was performed with the focal position ($f = 0$), meaning on the upper surface of the sheet metal, where 120 discs were obtained from 120 cuts. circular laser (15 disks / length, 8 disks / width).

For the next cutting experience II with CO₂ laser installation, the lenses with the

focal position $f = -5\text{mm}$, $f = -10\text{mm}$, $f = +3\text{mm}$ were used and 120 discs were obtained from 120 circular cuts (15 holes / L length and 8 holes), resulting in a total of 240 references that were subsequently studied through research on the processed parts, where the result is useful to measure the negatives of the discs, the roughness, the hardness of the cut surfaces.

The laser power input parameters were varied between [2700-3600] W, the focal position of the lens $f_0 = 0\text{mm}$ on sheet I, $f_1 = -5\text{mm}$, f_2

$\pm 10\text{mm}$, $f_3 = - + 3\text{mm}$ on sheet 2, the cutting speed will be between $[1100-1800]\text{ mm/min}$ and

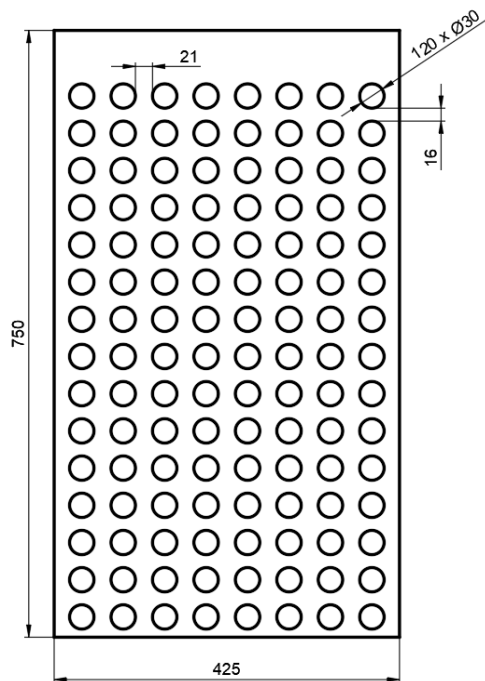


Fig.2 Experimental design of sheet 1 OL37

the low pressure of the assistant gas of O_2 , $[0,1-1,2]\text{bar}$ to obtain measurements and researches in the field of cutting technology of the parts made from OL37.

4. CUTTING METHOD

In the cutting experiences with CO_2 laser installation, a lens with a focal length of 7.5 inches and a focal position for the OL37 sheet varied with $f = -5\text{mm}$, $f = -10\text{mm}$, $f = +3\text{mm}$, $f = 0\text{mm}$. The minus sign - shows that the focal spot is located inside the board and the plus sign shows that the focus of the laser radiation has been achieved above. The description of the position of the focal point on the part is shown in fig.2, 3 and 4: Laser and gas melting.

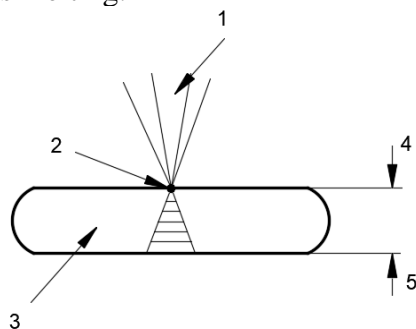


Fig. 3. Position focal is on the piece

The physical meaning of the numbering indicates to us: 1 - laser light, 2 - laser spot, 3 - piece, 4 - upper edge of sheets, 5 - lower edge of sheets.

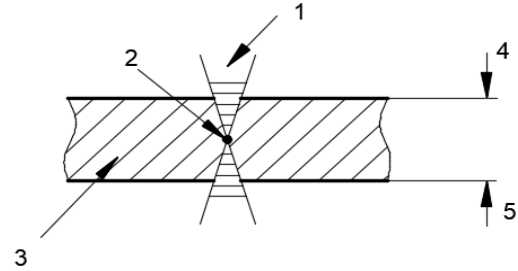


Fig.4. The focal position is in the middle the piece

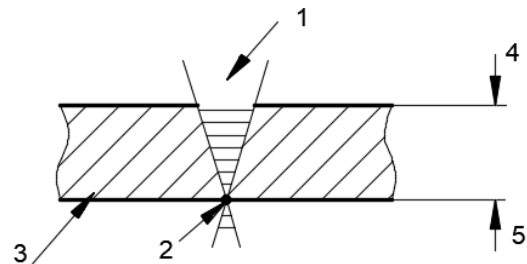


Fig.5. The focal position is on the lower edge

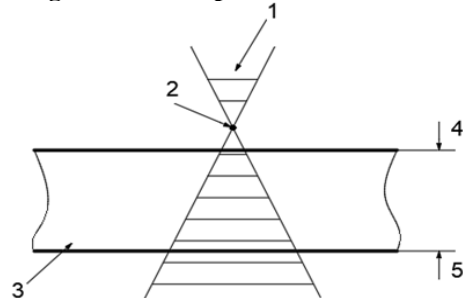


Fig. 6 The focal position is above the piece

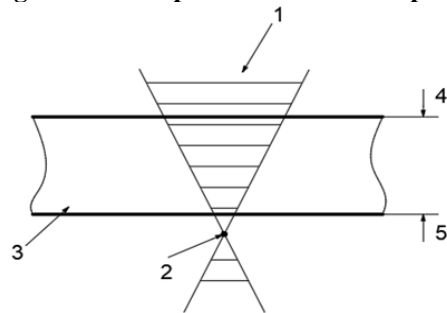


Fig. 7 The focal position is under the piece

The taper appears through the focusing position in which the slot geometry is in V, X, V reversed.

The laser radiation until the lens enters, propagates in a straight line, being a parallel beam, and until focusing in V, in the form of a cone-filled trunk with light, after which it changes its position where the focal spot becomes the source of light rays. in the

form A which form a beam with a certain angular deviation.

To know the cutting must be discussed: the direction of the melt flow, the ejection angle of the melt the angle at the bottom of the cutting front, the width Kerf at the top and bottom of the piece, the geometry of the slit.

5. EXPERIMENTAL DATA

Measurements were made of the average cutting width obtained from the difference between the plate and the cut piece at the lower edge and at the upper edge. The experiment was designed with a fixed parameter laser power and vary the pressure of the O₂ assistant gas and the cutting speed of the laser.

The result is a classic cutting plan, table 2, where two parameters have been varied to the minimum and maximum values of the assistant gas pressure and the cutting speed.

Table.2 Experimental data

Piece	Power	pressure	Speed	Cutting with Kerf. circular K _a
Nr.	watt	bar	mm/min	mm
2.	3000	0.6	1200	0.975
5.	3000	0.6	1600	0.930
9.	3000	0.4	1200	1.245
8.	3000	0.4	1600	1.16
10.	3000	0.8	1200	1.255
14.	3000	0.8	1600	1.365
15.	3000	1.0	1200	1.255
19.	3000	1.0	1600	1.215
20.	3000	1.2	1200	1.495
24.	3000	1.2	1600	1.235

The cutting width was measured using the electronic chisel at SC. MIRFO SA. With this data we can calculate the effect of the cutting parameters on the cutting width, using the value -1 for minimum and 1 for maximum for speed. Laser-assisted thermal cracking coaxially assisted with the laser beam of the dynamic oxygen gas jet has a good quality of soft steel sheet. The focal position f of the laser light is a prerequisite for quality kerf. The contribution of the focal position together

with the effects of their variable laser parameters results in a pierced channel having the value between 0.45mm and 0.65mm. By the way we choose the f we have a glossy surface without burrs, pieces without melting on the edges, low roughness and porosity. Focal position adjustment is a new method of CO₂ laser irradiation in continuous working of soft steel to characterize surfaces subjected to oxidation, increased hardness, chemical composition analysis. For these reasons, the focus was on the focus mode and the position towards the material studied. The experiment was performed with the focal position $f = 0$ at the top surface of the piece, so the focal spot was on the piece. Over 120 circular pieces with a diameter of approximately 30mm were obtained from 120 circular cuts. 12 tests were performed but the pieces remained in the OL 37 board. The OL 37 board has the dimensions of 750mmX425mm and the thickness of 10mm. The circular diameter remaining in the plate is approximately 31mm. The pieces are cut according to a cutting plan that is made from left to right. There are 15 series with 8 pieces, one after the other. The laser has penetrated into the material through a bore hole larger in diameter than the width of the slit cut to the right profile. After crossing, it starts in a straight line until it enters the circular section. Good pieces with glossy surfaces are 11,31,26,66, 75,80,81,9,10,44 and 34 very good. The pieces have grooves, craters on rough surfaces, with uneven surfaces, parallel striations, a notch where the laser comes in and out. It is observed surfaces with unevenness, ovalization and the existence of a groove on the piece (ex. 14) at $\frac{3}{4}$ from the upper edge. It can be concluded that there are situations in which the laser cutting is having problems on the cutting surface, there are stripes at the top that flow vertically down the bottom of the piece, and at $\frac{1}{4}$ the glossy surface appears on the lower edge, so the laser has its oddities, forming fiber strips on the cutting surface with thin, parallel or thick parallel strips. In most cases the parts must be processed in order to increase the quality or to perform hardness measurements. Studying and inspecting the surface of the plate it is found that the pieces 1,2,3,4,5,

6,7,8,9,10,11,12,13,14,15,16,17,18,19 have surfaces of Cuttings appreciated as being good. At 20-29 surfaces with notches, unevennesses, not accepted. 30-50 are similar and identical as those from 1 to 19. 51-60 is not accepted as being similar to 20-29, as well as 60-68. 69-80 finer surfaces, 80-100 have bumps, notches, thick striations so it is not accepted.

6. CONCLUSION

Cutting speed is a very important parameter in laser processing, giving better results at higher cutting speeds.

- The conical shape of the pieces is due to the laser melting, the divergence of the laser beam, the penetration of the laser radiation into the material, the oxygen gas, the burning reaction of Fe in the presence of Oxygen.

- The pressure of the assistant gas helps the combustion and blows the melt to leave the cutting slot.

- The mathematical model helps the operator to make better quality pieces.

- The cutting of the pieces is due to the geometry of the laser beam that has a conical shape.

- The burning of the material in the slot is much better at a greater distance from the position of the focus.

The paper deals with and investigates laser drilling with the focal position $f = 0$ on steel material that can be thermally processed by laser and which develops internal thermal stresses, melts and vaporizes the material. The optimal solution through tests is good because for different f we can optimize laser cutting. The proposed model with $f = 0$ is validated by performing measurements regarding Kerf, the cutting depth, the height of the roughness associated with the variable laser parameters, the pressure, the cutting speed and the laser power. We can synthesize the quality of the cut as being directly proportional to the focal position, dependent on it, being an important factor in laser beam cutting.

7. REFERENCE:

1. Schwanekamp, T; Marginean; Reuber, M., 2019, Laser beam melting of Cr3C2-NiCr,

INTERNATIONAL JOURNAL OF REFRACTORY METALS & HARD MATERIALS, Volume: 85, DOI: 10.1016/j.ijrmhm.2019.105069

2. Chen, C; Gao, M; Mu, HY; Zeng, X.Y., 2019, Effect of kerf characteristics on weld porosity of laser cutting-welding of AA2219 aluminum alloy, *APPLIED SURFACE SCIENCE*, Volume: 494, Pages: 1036-1043, DOI: 10.1016/j.apsusc.2019.07.259

3. Oh, Seong Y.; Shin, J.S.; Kim, T.S.; Park, H.; Lee, L.; Chung, CM; Lee, J. - 2019, Effect of nozzle types on the laser cutting performance for 60-mm-thick stainless steel, *OPTICS AND LASER TECHNOLOGY*, Volume: 119, Article Number: 105607, DOI: 10.1016/j.optlastec.2019.105607

4. Rutkowski, P.; Huebner, J.; Kata, D.; Chlubny, L.; Lis, J.; Witulska, K.; 2019, Thermal properties and laser processing of hot-pressed materials from Ti-Al-C system, *JOURNAL OF THERMAL ANALYSIS AND CALORIMETRY*, Volume: 137, Pages: 1891-1902, DOI: 10.1007/s10973-019-08107-w

5. Garcia, SM; Ramos, J.; Lamikiz, A; Figueras, J.; 2019, Influence of Process Parameters in Laser Piercing, *APPLIED SCIENCES-BASEL*, Volume: 9, Article Number: 3231, DOI: 10.3390/app9163231

6. Saini, SK; Dubey, A.K.; Upadhyay, B.N., 2019, Study and optimization of recast layer thickness and surface quality in laser trepan drilling of ZTA, *INTERNATIONAL JOURNAL OF ADVANCED MANUFACTURING TECHNOLOGY*, Volume: 103, Pages: 2977-2989, DOI: 10.1007/s00170-019-03704-3

7. Sharma, V.K.; Kumar, V.; 2019, Study on material transfer and surface properties during fiber laser cutting of A653 galvanized steel sheet, *JOURNAL OF THE BRAZILIAN SOCIETY OF MECHANICAL SCIENCES AND ENGINEERING*, Vol.: 41, Article Nr: UNSP 341, DOI: 10.1007/s40430-019-1842-4

8. Chatterjee, S.; Mahapatra, S.S; Bharadwaj, V; Choubey, A.; Upadhyay, B.N.; Bindra, K.S., 2019, Drilling of micro-holes on titanium alloy using pulsed Nd:YAG laser: Parametric appraisal and prediction of performance characteristics, *PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS PART B-JOURNAL OF ENGINEERING MANUFACTURE*, Volume: 233, Pages: 1872-1889, DOI: 10.1177/0954405418805604

9. Darwish, M.; Orazi, L.; Angeli, D., 2019, Simulation and analysis of the jet flow patterns from supersonic nozzles of laser cutting using Open FOAM, *INTERNATIONAL JOURNAL OF ADVANCED MANUFACTURING TECHNOLOGY*, Volume: 102, Pages: 3229-3242, DOI: 10.1007/s00170-019-03346-5

10. Zhang, K.D.; Guo, X.H.; Sun, L.N.; Meng, X.F.; Xing, Y.Q., 2019, Fabrication of coated tool with femtosecond laser pretreatment and its cutting performance in dry machining SLM-produced stainless steel, *JOURNAL OF MANUFACTURING PROCESSES*, Volume: 42, Pages: 28-40, DOI: 10.1016/j.jmapro.2019.04.00.