CO2 LASER HEAD NOZZLE FLOW ANALYSIS AND MODERNIZATION

CO2 LĀZERA GALVAS SPRAUSLAS PLŪSMAS ANALĪZE UN MODERNIZĀCIJA

Authors: **Ilja SUCKOVS**, email: ilja.suckovs@inbox.lv
Raitis RUDZISS, email: rudziss.raitis@gmail.com
Mentor: **Mg.sc. ing., guest lecturer Edgars ZAICEVS**,
Rezekne Academy of Technologies, Atbrivosanas aleja 115, Rezekne, Latvia

Abstract. *With the passage of time and the development of technology, more applications are found in CNC controls with CO2 laser equipment. Laser machines with a CO2 source are increasingly distributed in woodworking and synthetic materials processing. Laser equipment makes it possible to produce high-quality and geometrically accurate products. The quality of the surface to be processed is directly related to the air flow intensity, which prevents sublimated particles burn to processed surface. The aim of the study is to increase air flow intensity by upgrading the internal design of the head nozzle. Simulations are created for modernized head nozzle that help to analyze the resulting data. Cutting and engraving is performed for wood material in working range for the head nozzle tests.*

Keywords: *CO2 Laser, flow simulations, wood cutting, wood engraving, CO2 laser head nozzle, 3D printer.*

Introduction

Today, as laser technologies developing rapidly, more applications are found in CNC controls with CO2 laser equipment. Laser machines with a source of CO2 are increasingly distributed in woodworking and synthetic materials processing. Laser equipment makes it possible to produce high-quality and geometrically accurate products. The quality of the surface to be processed is directly related to the air flow intensity, which prevents sublimated particles from burning on the treated surface.

Objective of work:

- Improving the efficiency of the CO2 laser air nozzle by developing an improved geometrical shape of the nozzle;

Research work tasks:

- Create the 3D model of the CO2 laser air nozzle in the “Solidworks” program environment and perform flow simulation of the nozzle;
- Having regard to the simulation data create an improved 3D model for the air nozzle, which will increase the air flow rate as turbulent flows decrease;
- Create air nozzle prototype using a DLP 3D printer.
- Make nozzle prototype testing;
- Analyze the results and make conclusions;

Materials and methods

Theoretical justification

The CO2 Laser machine is primarily intended for cutting and engraving on non-metallic materials such as wood or plastic and rubber products. During cutting or engraving, around the area where the laser beam forms micro particles of sublimated material threated material get burn also sublimated material absorbing beam energy. This has a significant impact on the quality of processing. During laser operations, the laser beam treatment area is exposed to an air flow that blows micro particles out of the processing area.

Description of the structure of the laser equipment

The CO2 airflow supply of the airflow is implemented using the compressed air system. The air supply system begins from a compressor located outside the CO2 laser equipment. The

https://doi.org/10.17770/het2021.25.6799

compressed air flows in a rubber pipe into a laser focusing head. The deployment pipe system into moving portal takes place by inserting the pipes into the cable chain.

Air compressor parameters:

- capacity of 140 l/min;
- maximum pressure of 0.35 bar;
- power 160 W

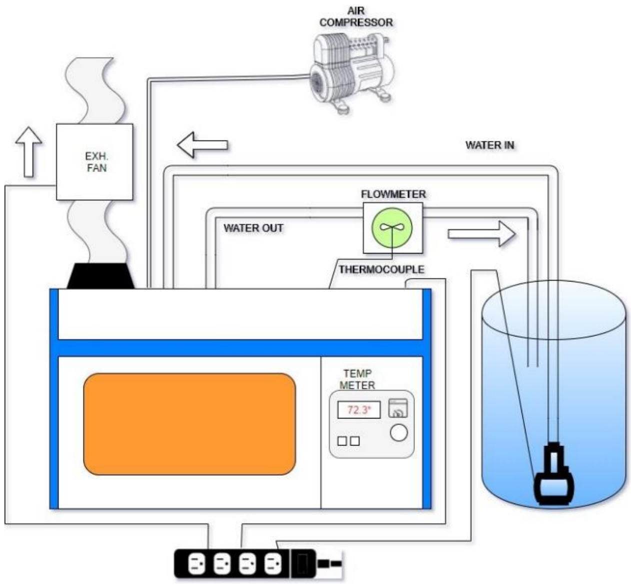

Fig. 1 **(CO2 principal scheme)** [https://www.pinterest.com/pin/852517404435292700/]

3d Models and simulations

The original air nozzle was dismounted to create a laser air nozzle 3D model with the same geometrical parameters. Using the CAD modeling program Solidworks for a model nozzle made air flow simulation (see Fig. 2 b.).

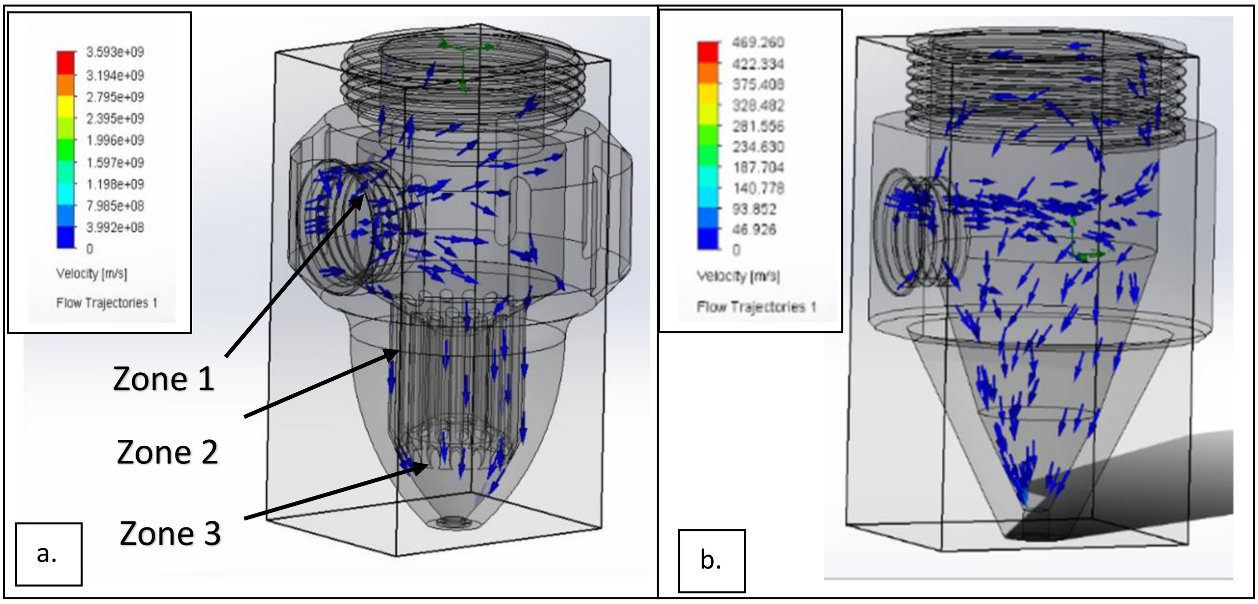

Fig. 3. **Nozzle flow simulation:**
(a) improved nozzle;
(b) the original nozzle;

The air nozzle prototype changes the inner shape. First, the air camera is divided into three zones. The upper area where the air is formed with rounded edges (areas where turbulent flows occur). The first zone fulfils the air receiver function. The second zone, which goes down to several channels to straighten flow and get rid of turbulent flow (Fig.3.a). The third zone compresses the air by using the cone with the smallest diameter (Fig.3. a).

In Fig. 3.a.you can see a simulation of an improved air nozzle.

Following the results of the simulation, it can be concluded that:

- a modernized air nozzle has a higher air outlet speed than the original.
- for the original nozzle theoretical air flow speed using "Solidworks" simulation program is 469.260 m/s, but for an improved nozzle 3593 m/s, which represents an increase of 765%.

Nozzle creation

The air nozzle is made using the DLP-type 3D printer "ANYCUBIC Photon". A DLP-type 3D printer supports excellent slice adhesion because the average slice thickness is 50 microns (0.05 mm). The air nozzle is made of polyamide resin. When the air nozzle is manufactured, it is hardened under the UV tube to the full hardening of the polyamide. In Fig. 4a, you can see the original nozzle on the CO_2 laser head, Fig. 4b modernized air nozzle.

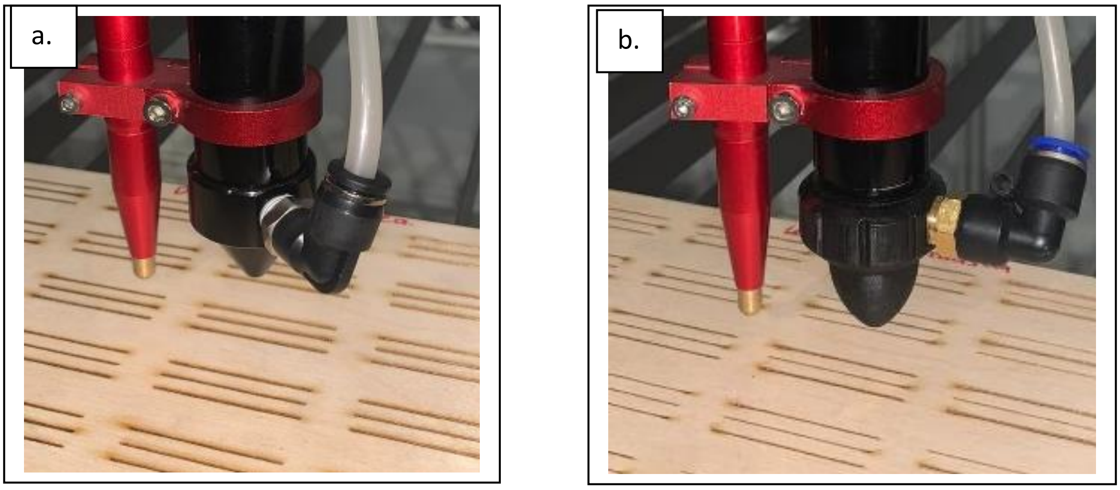

Fig. 4 **Air nozzle:**
(a) the original nozzle;
(b) improved nozzle;

Air nozzle testing is done on two operations, cutting and engraving. This allows you to compare the improved air nozzle with the original. The operation of the air nozzle is tested in different operating ranges. Using 2 variable parameters, speed of movement and laser beam power results in rectangular shape matrix gradients for engraving and 3 line-shaped cuts for each range for cutting. Power range from 20% to 90% with a step of 15% and range of travelling speed from 10 mm/s to 30 mm/s with a step of 5 mm/s used for cutting. But for engraving power range is from 5% to 25% with a step of 5% and range of travelling speed from 60 mm/s to 220 mm/s with a step of 40mm/s.

Results and their assessment

Measurements are performed using the laser scanning 3D microscope "OLYMPUS OL 5000". This type of laser-microscope is capable of detecting surface terrain and creating a surface topographical 3D model.

Laser scanning microscope parameters:

- base error in X, Y direction for measurements with MPLAPON X10 LEXT lens 0.0027 mm;
- base error in Z direction for measurements with MPLAPON X10 LEXT lens 0.0023 mm;
- lens magnification < 1.5%

In Figure 6, you can see a reference example created by laser microscope LEXT program.

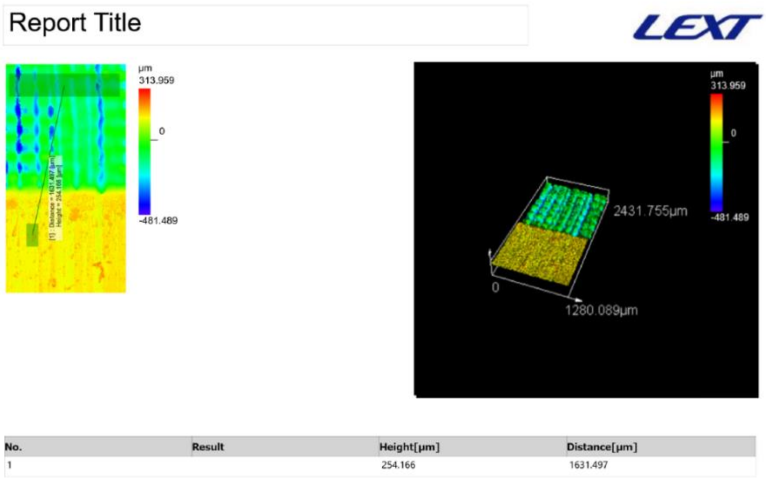

Fig. 6. **LEXT software report**

The study measures the width of the cut, including the burning surface. In case of engraving, the depth between the raw surface and the aftertreatment surface. Air nozzle testing is performed on a 4 mm veneer for specially designed laser cutting. Using the original nozzle creates rectangular shape matrix gradients for cutting and engraving, the test was repeated using an improved air nozzle. Each sample was analyzed on the Laser microscope. In Tables 1-4, you can see results. Table graphics 1-4 are created for data analysis.

Origination nozzle/cutting (width) mm					
	10 mm/s	15 mm/s	20 mm/s	25 mm/s	30 mm/s
90%	0.797	0.759	0.752	0.715	0.633
75%	0.768	0.739	0.737	0.703	0.624
60%	0.760	0.730	0.700	0.692	0.621
35%	0.670	0.667	0.656	0.657	0.546
20%	0.658	0.606	0.538	0.531	0.504

Table 1. **(original nozzle cutting)**

Improved nozzle/cut (width) mm					
	10 mm/s	15 mm/s	20 mm/s	25 mm/s	30 mm/s
90%	0.572	0.568	0.557	0.527	0.497
75%	0.563	0.562	0.543	0.497	0.483
60%	0.530	0.526	0.525	0.486	0.456
35%	0.485	0.435	0.433	0.396	0.378
20%	0.391	0.350	0.306	0.303	0.272

Table 2. **(improved nozzle cutting)**

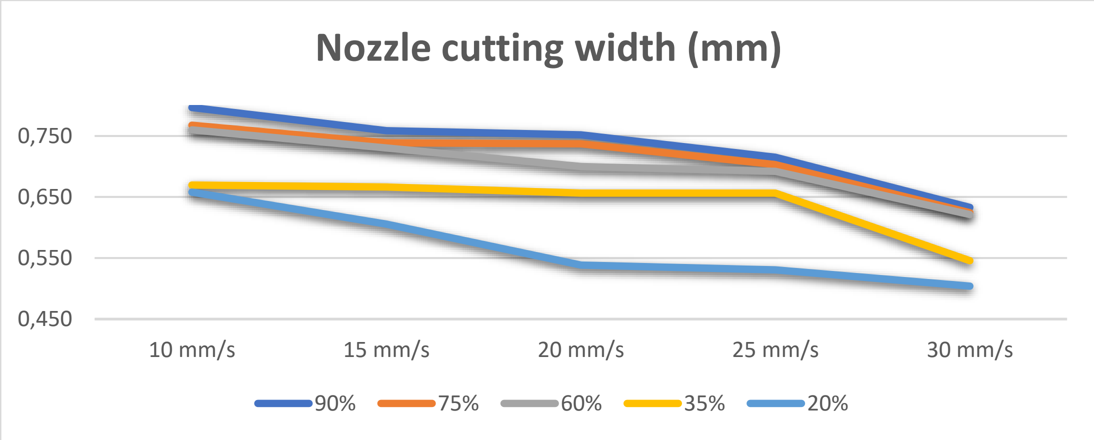

Chart 1. **(original nozzle cutting width)**

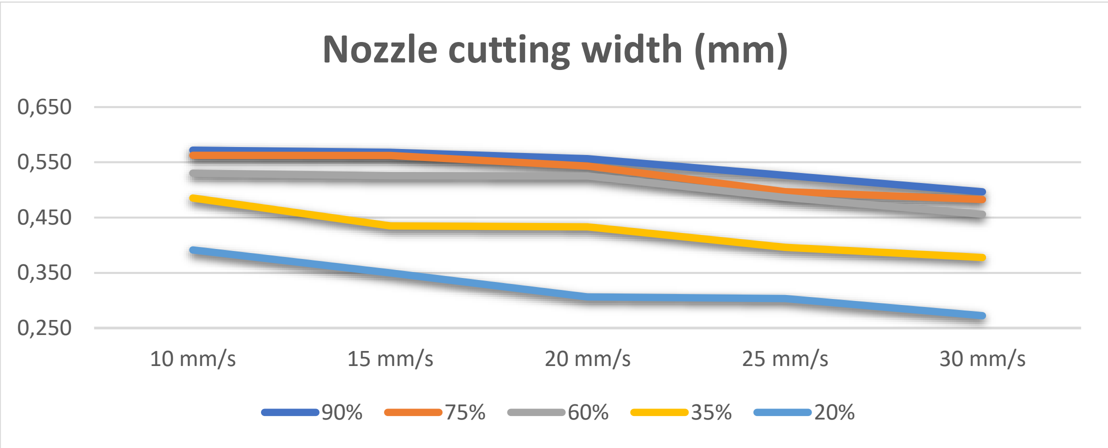

Chart 2. **(improved nozzle cutting width)**

By comparing the parameters from tables 1 and 2, you can see that the cutting width decreased in all work range. The cut width interval with the original nozzle from 0.5 mm to 0.8, the cut width using the modernized air nozzle is between 0.27 mm and 0.57 mm.

Original nozzle/engraving (depth) mm					
	60 mm/s	100 mm/s	140 mm/s	180 mm/s	220 mm/s
25%	2.729	1.256	0.724	0.601	0.551
20%	1.555	0.884	0.633	0.477	0.452
15%	0.914	0.738	0.479	0.329	0.262
10%	0.541	0.307	0.188	0.157	0.128
5%	0.105	0.067	0.032	0.016	0.006

Table 3. **(original nozzle engraving depth)**

Improved nozzle/engraving (depth) mm					
	60 mm/s	100 mm/s	140 mm/s	180 mm/s	220 mm/s
25%	1.967	1.71	0.925	0.791	0.545
20%	1.349	0.79	0.509	0.445	0.359
15%	0.91	0.617	0.39	0.322	0.254
10%	0.408	0.264	0.155	0.139	0.13
5%	0.035	0.025	0.018	0.015	0.011

Table 4. **(improved nozzle engraving depth)**

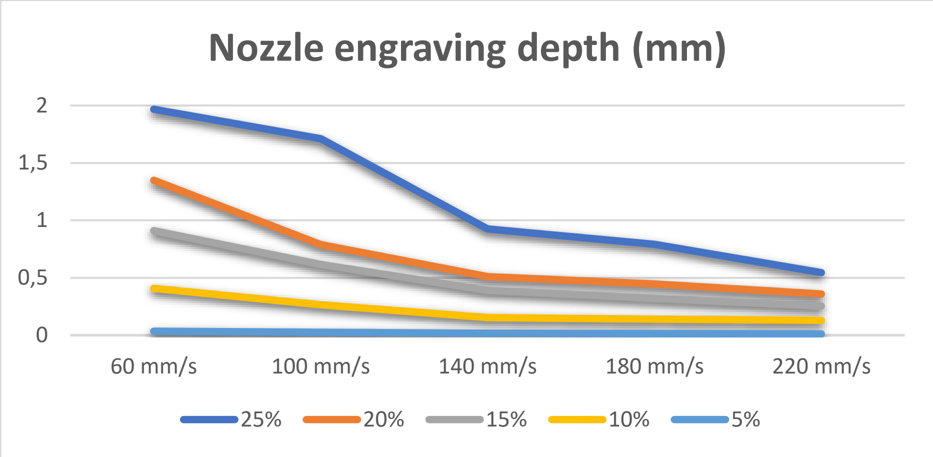

Chart 3. **(Modernized nozzle engraving depth)**

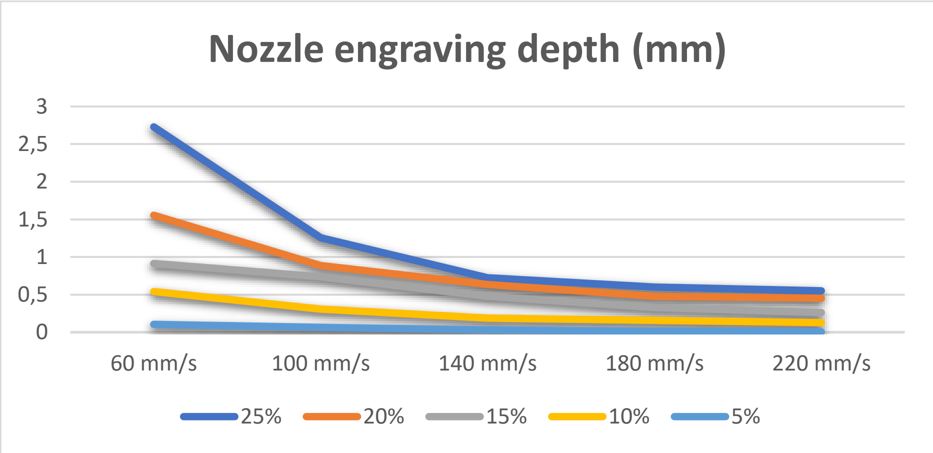

Chart 4. **(Original nozzle engraving depth)**

By comparing the parameters from tables 3 and 4, you can see that the depth of engraving decreased throughout the work range. The engraving depth with the original nozzle from 0.06 mm to 2.7, engraving depth using the modernized air nozzle from 0.11 mm to 1.9 mm.

Conclusions

1. The modernized air nozzle pattern reduces internal air turbulent flows and transforms it into laminar flows, which represent the highest flow rate on the nozzle out.
2. Simulation results using 3D CAD program "Solidworks" show an increase in theoretical airflow output rate of 765%. (469.260 m/s before and 3593 m/s after)
3. The use of a modernized air nozzle to cut wood, reduced the cut width in all working ranges.
4. The use of a modernized air nozzle in wood processing reduced depth in all operating ranges, which concludes that the laser beam is producing fewer burns on the surface.
5. The upgrading of the CO2 Laser machine with the improvement of the internal geometry of the air nozzle is economically beneficial because it does not require the replacement of the expensive components and it can be easily installed instead of the original nozzle.

Literature

1. Lydia Sobotova and Miroslav Badida "Laser marking as environmental technology" *published by De Gruytern Open. 2017 p. 303-336.*

2. Senthil Kumar “Laser cutting Process – A Review” *International journal of Darshan institute on engineering research & emerging technologies Vol. 3, from. 1,* 2014.
3. Lazov Lyubomir, Dolchinkov Nikolay Todorov, Ivanov Jordan Shterev, Peneva Madlen Nikolaeva, Bojhanova Denitsa Angelova “Study of Laser Cutting and Marking on the Filt with the Help of a CO2 - Laser” *Enviroment. Technology. Resorces. Resecne. Latvia. Proceedings of the 12 th International Scientific and Practical Conference. Vol III, 143-147.*
4. F. Kayatz S. Wagner A. Schul “Optimization of Design Parameters of CIA Spray Cleaning Nozzle Using Genetic Algorithm” *proceeds of the 4 th International Conference on Computational Engineering (ICCE 2017) in Darmstadt.*
5. Imani, R.J., Ladhani, L., Pardon, G., van der Wijngaart, W. and Robert, E. “The Influence of Air Flow Velocity and Particle Size on the Collection Efficiency of Passive Electrostatic Aerosol Samplers” *Aerosol Air Qual. Res. 19: 195-203.2019.*