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## MULTILAYER LASER CUTTING OF STEEL PLATES

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**Abstract:** A laser is a monochromatic, coherent, convergent beam of electromagnetic radiation with wavelengths from ultraviolet to infrared. Almost all types of materials can be machined with a laser. The laser beam has a very high energy density. In laser cutting, a laser beam is used as a tool, under the influence of which the machined material melts and evaporates. In this way, a precise cut is created with minimal mechanical stress. During laser cutting of material, a heat affected zone is created right next to the cut. For simultaneous cutting of multiple layers of sheet metal - where several sheets are stacked and cut at the same time - laser cutting offers a flexible alternative to traditional punching or mechanical cutting. This is particularly important in the production of parts of small series, complex geometries and from materials that are difficult to process with conventional machining processes. This paper presents the results of research on the possibility of multilayer laser cutting of steel plates. The influence of the traverse speed and number of plates was analyzed. One, two and three plates with a thickness of 4 mm, from S355J2+N (Č0563), were cut with the recommended traverse speed and the traverse speed higher and lower than the recommended values. The width of the cut and the roughness of the machined surface were analyzed, as well as the possibility of cutting through all layers.

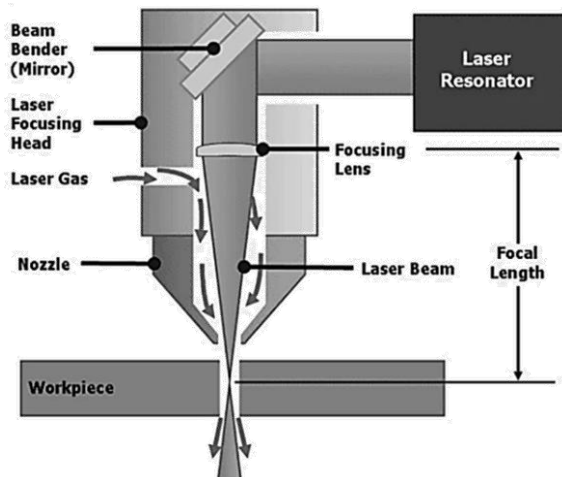
**Keywords:** laser beam cutting, multilayer, cutting width, surface roughness.

### 1. INTRODUCTION

Unconventional machining methods use electrical, chemical, light, magnetic, nuclear and other forms of energy for machining of materials. This energy is directly supplied to the process - the cutting zone.

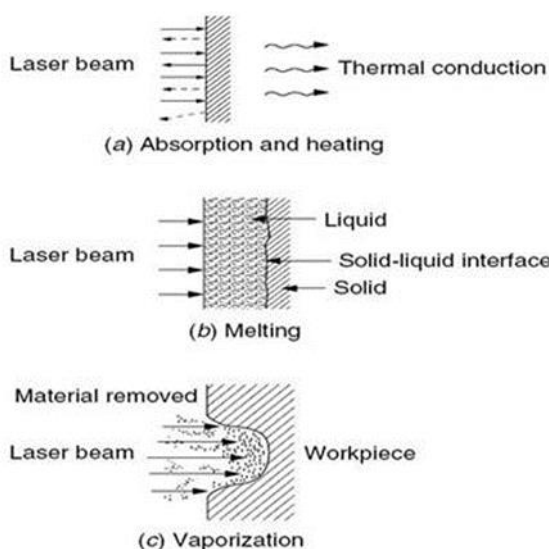
Laser is the abbreviation of light amplification by stimulated emission of radiation. A highly collimated, monochromatic and coherent light beam is generated and focused to a small spot [1]. In this way, a very high energy density is achieved ( $10^6$  W/mm<sup>2</sup>). Laser gas, which is most often a mixture of oxygen and nitrogen, is supplied to the cutting head and surrounds the laser beam and the

cutting zone during cutting. The laser beam is focused on the workpiece, which is heated, melted and partially vaporized, thus cutting the material. The molten material formed during the cutting process is removed from the cutting zone by the laser gas. Figure 1 shows the principle of laser operation.



**Figure 1.** The working principle of the laser [2]

During laser beam cutting, part of the laser beam is reflected from the surface of the workpiece. The remaining part of the energy of the laser beam is absorbed and thus the material of the workpiece is heated. When the material is heated enough, it begins to melt and vaporization occurs, Figure 2.



**Figure 2.** Physical processes that take place during laser beam machining [1]

### Multilayer laser cutting

Today, the laser is most often used for cutting almost all types of materials according to predefined contours. In order to achieve higher productivity of the cutting process, more and more attention is paid to simultaneous cutting of several layers of material. Multiple layers of steel can be laser cut, but there are limitations depending on the thickness and type of steel. In principle, it is possible to cut multiple layers if they are well attached and if the maximum power of the laser is sufficient to cut through the total thickness of the material. The most common problems that occur during multi-layer laser cutting of steel are:

- Deformation of the material due to heating, which is especially pronounced when cutting thin sheets or cutting complex contours,
- Fusion of layers of material to be cut and
- Change in the microstructure of the processed material - appearance of heat affected zone [2].

All parameters of the laser cutting process, like power, speed, laser gas pressure, and focal position affect the possibility of cutting multiple layers of material. In practice, it is easiest to set the traverse speed. Higher traverse speeds reduce kerf width and surface roughness but may cause incomplete cuts if traverse speed is too fast. Slower traverse speeds improve edge quality but increase thermal load and cycle time.

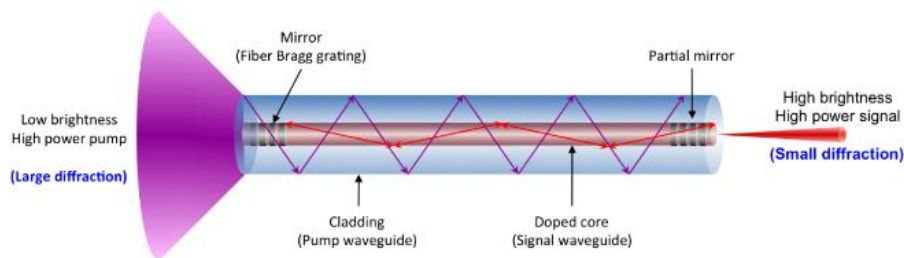
### Fiber lasers

Fiber lasers use an optical fiber as an optical resonator. Optical fiber gives the name to this type of laser. The laser beam is obtained in an optical fiber whose core is enriched with some of the rare chemical elements such as ytterbium (Yb), erbium (Er), thulium (Tm), neodymium (Nd), dysprosium (Dy), holmium (Ho), praseodymium (Pr). The optical core of the optical fiber is the active material of the laser. By illuminating the core, ions are excited, that

is, stimulated emission of light by excited ions of the elements of the core.

Fiber lasers are increasingly used for metal cutting due to the higher efficiency of energy absorption on metal surfaces, higher cutting speeds and lower operating costs compared to CO<sub>2</sub> lasers. Fiber lasers can cut materials up to five times faster and consume approximately

50% less energy [3]. Their streamlined design with fewer moving parts reduces maintenance costs and downtime. Figure 3 shows the working principle of the fiber laser.



**Figure 3.** Schematic diagram of fibre laser [4]

The high-power pump light flows through an optical fiber consisting of two main components: a core and a cladding. The core is made of silicon glass and provides a path for the light. This core is covered by an mantle. When light reaches the mantle, it is all reflected back into the core. After that, the light reaches the doped core.

## 2. EXPERIMENTAL RESEARCH

The goal of the experiment realized within this paper was to analyze the possibility of laser cutting of multiple layers of material. The tests were performed on a TruLaser 3040 laser cutting machine from the Trumpf company at the "Wacker Neuson" company in Kragujevac. This type of laser is characterized by high flexibility and economy, as well as excellent quality. Figure 4 shows the company's laser machine.



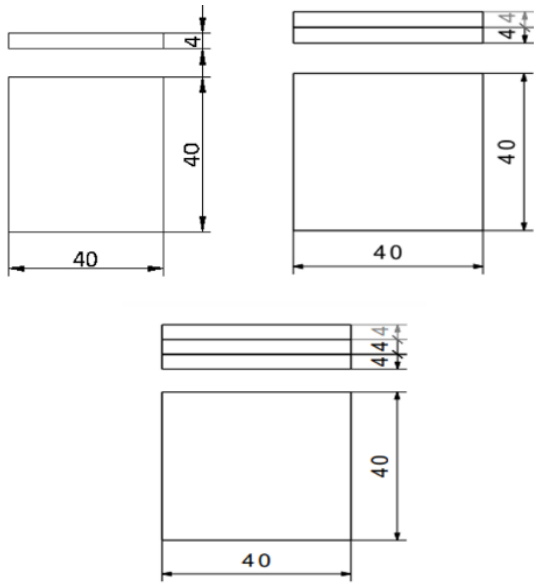
**Figure 4.** Trumpf TruLaser 3040 laser

The power of the machine is 6 KW. For the purposes of the experiment, plates with a thickness of 4 mm, material marked S355J2+N (Č0563) were used. The characteristics of material are given in table 1.

The recommended values of the parameters of the laser cutting process have been adopted. The parameter that was varied during the experiment is the traverse speed. The cut samples are 40x40 mm tiles.

In the experiment, four tile samples were cut on one, two and three layers of material. In these experiments, the plates-layers are tightly joined, with no gap between them. After laser cutting, the quality of the cut was investigated, the width of the cut and the surface roughness were measured.

For analyzing the possibility of cutting multiple layers of material using a laser in order to achieve savings in laser operation time and material savings, three experiments were performed. The first experiment involves cutting a sample of 40x40 mm tiles on one layer of 4 mm thick material. Four tiles were cut at different traverse speeds, while the other parameters were unchanged and kept as recommended. The second experiment involves cutting a tile of the same dimensions from two layers of material, while in the third, cutting was done from three layers of material, Figure 5.



**Figure 5.** Samples for the first, second and third experiment

With the help of the Trutops software, the input parameters for cutting the material were set and only the traverse speed was varied.

**Table 1.** Material properties

| Material designation | Chemical composition |        |      |         | Mechanical properties |
|----------------------|----------------------|--------|------|---------|-----------------------|
|                      | C %                  | Mn %   | Si % | P, S %  |                       |
| S355 J2+N (Č0563)    | ≤ 0.22               | ≤ 1.60 | 0.55 | ≤ 0.035 | ≥ 355                 |

Table 2 provides data on the conditions for cutting the tiles and marking the samples. Traverse speed is expressed in % in relation to the recommended value. The pressure of the working gas (mixture of nitrogen and oxygen) was 0.7 bar.

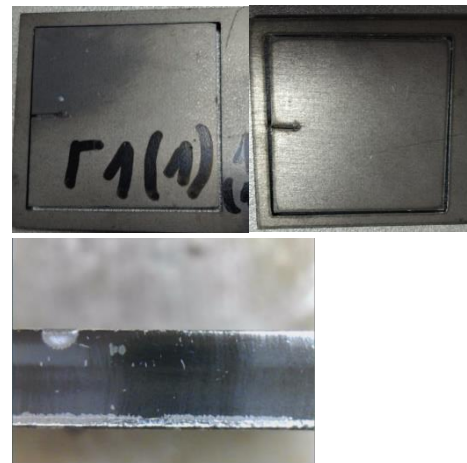
**Table 2.** Traverse speed and laser power in experiments

| Exp. No. | No of layers | Sam. No. | Thic. [mm] | P [KW] | Rec. traverse speed [mm/min] | Traverse speed [%] |
|----------|--------------|----------|------------|--------|------------------------------|--------------------|
| E1       | 1            | 11       | 4          | ~3.2   | 3300                         | 85%                |
|          |              | 12       | 4          |        |                              | 100%               |
|          |              | 13       | 4          |        |                              | 110%               |
|          |              | 14       | 4          |        |                              | 120%               |

|    |   |    |    |      |      |      |
|----|---|----|----|------|------|------|
| E2 | 2 | 21 | 8  | ~4.6 | 2830 | 85%  |
|    |   | 22 | 8  |      |      | 100% |
|    |   | 23 | 8  |      |      | 110% |
|    |   | 24 | 8  |      |      | 120% |
| E3 | 3 | 31 | 12 | ~6   | 2050 | 85%  |
|    |   | 32 | 12 |      |      | 100% |
|    |   | 33 | 12 |      |      | 110% |
|    |   | 34 | 12 |      |      | 120% |

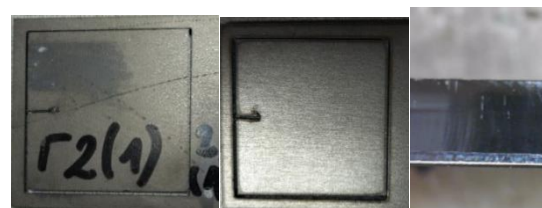
### 3. RESULTS AND DISCUSSION

First experiment - Figure 6 shows sample number 11 from the upper and lower side and cut surface. One layer was cut, with a speed of 85% of the recommended one. The plate has been cut successfully. No burr was observed from the bottom side.



**Figure 6.** Sample 11, the upper and bottom side and the cut surface

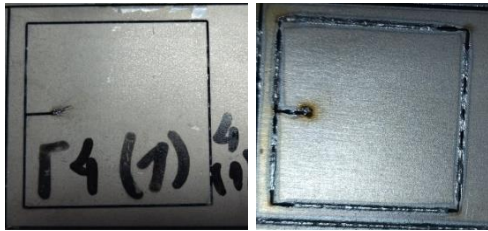
Figure 7 shows sample number 12, the top and bottom side and the cut surface. One layer of steel was cut with 100% of the recommended traverse speed. The plate has been cut successfully. No burr was observed from the bottom side.



**Figure 7.** Sample 12, the upper and bottom side and the cut surface



Figure 8 shows sample number 14 from the top and bottom side. One layer was cut with a speed of 120% of the recommended traverse speed value. Due to the high travers speed and the impossibility of removing the molten material, the sample was not successfully cut on the lower side, the molten material was retained. The plate was not separated, so there was no measurement of the cut surface topography.



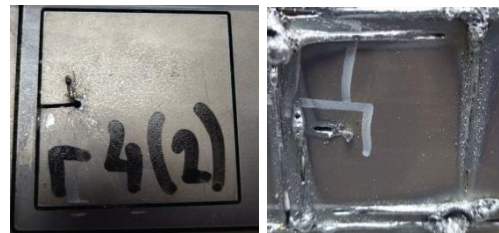
**Figure 8.** Sample 14, the upper and bottom side

Figure 9 shows sample number 21 from the top and bottom side, as well as the cut surface. Two layers of material were cut with a traverse speed of 85% of the recommended value. Cutting was successfully performed on the top and bottom of both tiles. The appearance of burr on the lower plate can be observed.



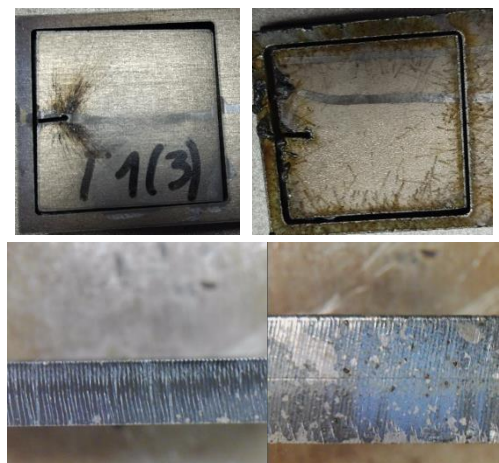
**Figure 9.** Sample 21, the upper and bottom side and the cut surfaces

Figure 10 shows sample number 24 from the top and bottom side. Two layers were cut with a traverse speed of 120% of the recommended one. At this speed, there was no cutting of the layers, but partial cutting and melting of part of the material. Also, it can be seen from the bottom side a large retention and deposition of molten material. In this case, it was not possible to separate the samples from the plate, so the surface topography was not measured.



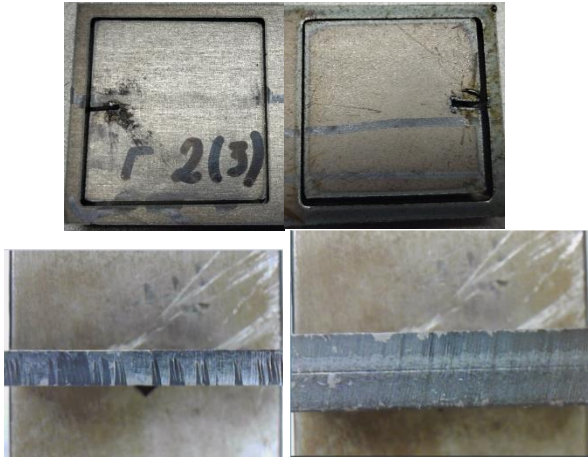
**Figure 10.** Sample 24, the upper and bottom side

Figure 11 shows sample number 31 from the top and bottom side, as well as the cut surfaces of the top layer and the bottom two layers. The cutting of the samples was done with a traverse speed of 85% of the recommended one. All three layers were cut, however, the samples of the second and third layers were joined, and it was not possible to separate them.



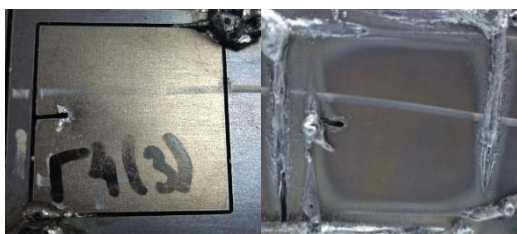
**Figure 11.** Sample 31 from the upper and bottom sides as well as the cut surface of the upper separated layer and the cut surface of the merged middle and bottom layers

Figure 12 shows sample number 32 from the top and bottom side. Three layers of material were cut with the recommended traverse speed (100%). As in the previous case, all three layers were cut, but there was also a merging of the second and third layers, which could not be separated.



**Figure 12.** Sample 32 from the upper and bottom sides as well as the cut surface of the upper separated layer and the cut surface of the merged middle and bottom layers

Figure 13 shows sample number 34 from the top and bottom side. Three layers were cut at the same time with a traverse speed of 120% of the recommended value. At this traverse speed, not a single layer was cut. The cutting is partially done, but not completely. Due to the high traverse speed, the working gas did not successfully carry away the molten material, instead, it cooled quickly and remained trapped and deposited between the layers. No layer could be removed.



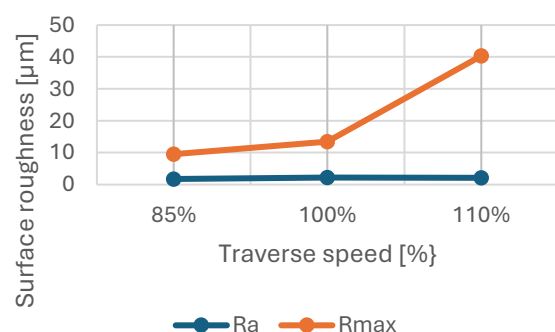
**Figure 13.** Sample 34 from the upper and bottom side

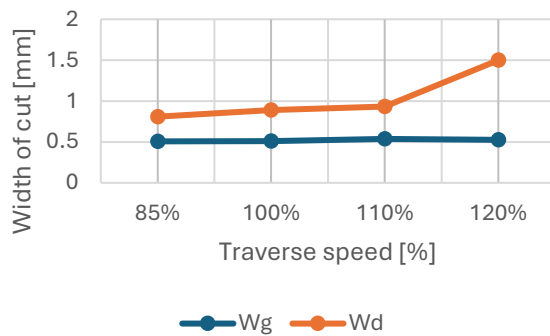
The width of the cut of the samples was measured from the upper side of the upper layer and the lower side of the lower layer. The

measurement was performed on a tool microscope. The surface roughness was measured using the device ISR - C002, INSIZE. The measuring device is placed on the base of the Talisurf-6 measuring system. The surface roughness parameters were measured at a distance of 1 mm from the upper surface. Table 3 shows the measurement results.

**Table 3.** The width of the cut and the roughness of the machined surface

| Sample No | Width of cut  |                | Roughness |           |
|-----------|---------------|----------------|-----------|-----------|
|           | Upper side mm | Bottom side Mm | Ra (μm)   | Rmax (μm) |
| 11        | 0.507         | 0.809          | 1.757     | 9.533     |
| 12        | 0.511         | 0.891          | 2.207     | 13.435    |
| 13        | 0.537         | 0.931          | 2.148     | 40.304    |
| 14        | 0.524         | 1.499          | -         | -         |
| 21        | 1.128         | 0.808          | 2.943     | 17.485    |
|           | 0.045         | 0.08           | 2.298     | 18.176    |
| 22        | 0.016         | 0.495          | 1.060     | 7.458     |
|           | 0.405         | 0.636          | 2.592     | 19.016    |
| 23        | 0.708         | 0.722          | 4.555     | 19.164    |
|           | 0.44          | -              | -         | -         |
| 24        | 0.143         | -              | -         | -         |
|           | -             | -              | -         | -         |
| 31        | 0.798         | 0.81           | 10.718    | 67.173    |
|           | 0.131         | 0.407          | -         | -         |
| 32        | 0.61          | 0.74           | 6.925     | 43.218    |
|           | 1.668         | 1.011          | 7.165     | 35.562    |
| 33        | 0.911         | 0.801          | 6.925     | 43.218    |
|           | 0.789         | -              | -         | -         |
| 34        | -             | -              | -         | -         |





**Figure 14.** Diagrams of the roughness of the machined surface and the width of the cut depending on the traverse speed

Based on the results shown in table 3, the diagrams of the change in the roughness of the machined surface and the width of the cut depending on the traverse speed are shown, figure 14. The diagrams are given only for cutting one layer of material.

#### 4. CONCLUSION

When cutting one layer of material, samples were cut during laser cutting with values of 85%, 100% and 110% of the recommended traverse speed value. Only when cutting with a traverse speed of 120% of the recommended one, complete cutting of the material did not occur. When cutting two layers of material, both layers were completely cut when cutting with a traverse speed of 85% and 100% of the recommended traverse speed value, for the total thickness of the material. When cutting with 110% of the recommended traverse speed, the upper layer of material is completely cut, but the lower layer is not. High melt retention was observed when cutting at 120% of the recommended traverse speed, so the layers remained uncut. When cutting three layers of material with 85% and 100% of the recommended traverse speed the layers are completely cut, but the bottom two layers remain merged. By cutting three layers with 110% of the recommended traverse speed, only the top layer is completely cut, while when processing with

120% traverse speed, no layer is completely cut.

Based on the conducted experiments, it is observed that when cutting multiple layers with a laser, the traverse speed should be chosen carefully. In the experiment, the recommended traverse speed values were chosen based on the machine manufacturer's literature for the total thickness of the material being cut. When cutting three layers of material during processing with 85% and 100% traverse speed, the middle and bottom layers were merged. It can be concluded that when cutting thicker layers of material, lower traverse speed values should be adopted than those recommended for the total thickness of the material.

The analysis of the effect of traverse speed on the roughness of the machined surface and the width of the cut was done only for cutting one layer of material, because only in this case the material was completely cut for all values of traverse speed. From the diagram, it can be seen that with the increase in traverse speed, the roughness of the machined surface increases and the width of the cut increases. It is necessary to carry out more detailed research on the influence of number and thickness of layers and traverse speed on the width of the cut and the roughness of the machined surface in order to be able to present more detailed conclusions.

#### ACKNOWLEDGEMENT

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#### REFERENCES

- [1] H. El-Hofy: Advanced Machining Processes Nontraditional and Hybrid Machining, Hassan McGraw-Hill, New York, 2005.

- [2] 2D Laser Cutting: Process, Capabilities, & Benefits, available at: <https://www.tdmfabrication.com/blog/2d-laser-cutting>, accessed: 15.08.2025.
- [3] High-Speed Laser Cutting Optimization for Multi-Layered Sheet Metal Assemblies, available at: <https://www.anebon.com/news/high-speed-laser-cutting-optimization-for-multi-layered-sheet-metal-assemblies/>, accessed: 10.08.2025.
- [4] Fibre Lasers – Working Principles, Applications & More, available at: <https://fractory.com/fibre-lasers-explained/0208>, accessed: 02.08.2025.
- [5] Šta su fiber laseri ?, available at: <https://chitech.rs/sta-su-fiber-laseri/>, accessed: 01.08.2025.
- [6] D. Milikić, Nekonvencionalni postupci obrade - priručnik za studije i praksu, Fakultet tehničkih nauka, Novi Sad, 2002.
- [7] M. Madić, Matematičko modeliranje i optimizacija procesa laserskog sečenja primenom metoda veštačke inteligencije, Doktorska disertacija, Univerzitet u Nišu, Mašinski fakultet, Niš, 2013.
- [8] N. Dodd, E. Ballantyne, G. Heron, R. Goodall: Multi-layer laser cutting of electrical steel sheets applied to electric machine laminations, PLoS ONE, Vol. 18, No. 7, (13), 2023.
- [9] M. Alsaadawy, M. Dewidar, A. Said, I. Maher, T. A. Shehabeldeen: A comprehensive review of studying the influence of laser cutting parameters on surface and kerf quality of metals, The International Journal of Advanced Manufacturing Technology, Vol. 130, pp. 1039-1074, 2024.