Laser Cutting Machine with a Single Galvanometric Head for Cutting of Technical Textile Materials

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Efficient cutting of technical textile materials is currently a significant challenge in industrial solutions. Traditional laser cutting machines, due to the large mass of the laser head support system, exhibit high inertia and low cutting speeds for complex geometric shapes. For this reason, a laser cutting machine with a single galvanometer head was designed and constructed, where the displacement of the laser spot over the working area surface is achieved solely by changing the angle of the mirrors and the focal length of the optical system. The main objectives of the designed device were speed, accuracy, repeatability, and the quality of laser cutting for the processed materials. The control systems of the constructed device are based on programmable logic controllers (PLC). The device is operated through a communication graphical user interface (HMI). The entire software used to handle the machine's additional functions is proprietary and optimized for accessibility, providing visual representation of the machine's status and the ongoing process, particularly for individuals with disabilities. One of the additional functionalities of the device is the marking on the fly (MOTF) feature, which compensates for the cutting while the object is in motion, based on the read speed of the object passing under the laser head. In the constructed device, special emphasis was placed on user safety. To achieve this, light curtains were implemented to protect the working area from accidental intrusion by hands or other potentially dangerous objects. The device bases on the components from renowned European manufacturers, such as Raylase, Luxinar, and Siemens. A comparison between the project and the constructed device is presented in Figure 1

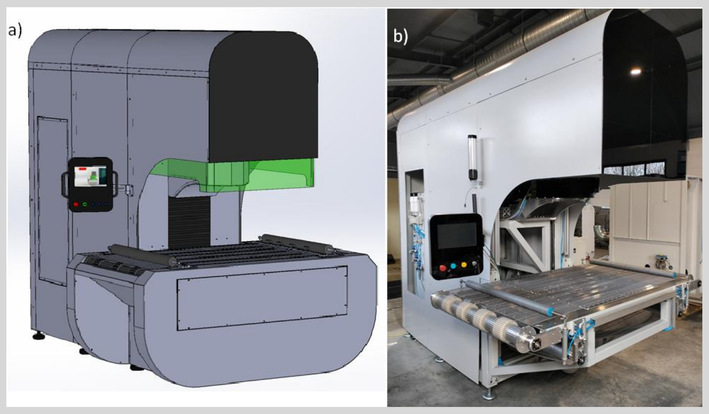
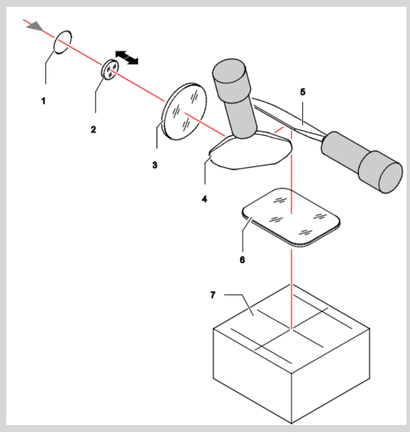


FIG. 1: Laser cutting machine with a single galvanometer head: a) computer design, b) constructed device.

The main execution element of the designed machine is the galvanometer head, which, thanks to its unique design, enables rapid path changes and high precision beam positioning, unlike standard laser plotters. These plotters have high inertia due to the heavy gantries that allow head movement, making them incapable of performing quick vector velocity changes. The constructed device incorporates an advanced galvanometer head, which, in addition to a very fast beam steering system using moving mirrors, also enables beam control in the Z-axis.

This functionality, achieved through the movement of a ZnSe lens, allows for focal length adjustment without changing the height of the entire head. Such a solution enables material processing at various heights of the machined planes, even during the execution of a single three-dimensional cutting project. Additionally, with the automatic beam adjustment in the Z-axis, which is active even during cutting on a single plane, the head continuously compensates for focal length changes related to spot movement, maintaining a consistent laser spot size across the entire 1000 x 1000 mm working area. This solution completely eliminates the effect of varying cutting quality depending on the distance between the head and the spot within the working area. The operational diagram of the employed galvanometer head is presented in Figure 2.



1 - Laser beam input
2 - Moving ZnSe lens for beam control in the Z-axis
3 - ZnSe lens
4, 5 - Galvanometer motors with mounted mirrors for beam control in the X and Y axes
6 - ZnSe glass cover protecting the optical system from contamination
7 - Working area

FIG. 2: Schematic diagram of the internal structure of the galvanometer head (source: manufacturer's head manual - Manual_3_Axis_AS-50-DIGITAL II_v1.0.4 p. 13)

The internal structure of the employed galvanometer head, along with the calibration and adjustment points marked in red, is presented in Figure 3.

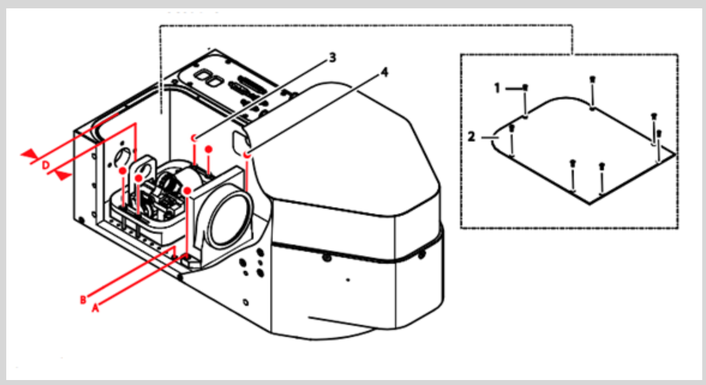


FIG. 3: Regulatory and calibration points of the employed galvanometer head.

A beam expander, placed between the laser source and the galvanometer head, is used to increase the effective beam diameter after proper adjustment. The operation diagram of the beam expander is shown in Figure 4. The laser source itself has a power of approximately 420 W and a wavelength of 10.6 µm.

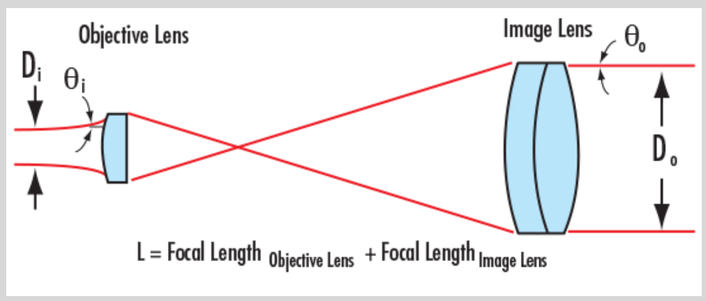


FIG. 4 Schematic diagram of the beam expander used to enlarge the diameter of the laser beam entering the head (source: https://www.htpow.com/blog/bid-47.html access date: 01.12.2022).

The simplified block diagram of the electrical connections enabling power supply and control of individual modules of the constructed device is presented in Figure 5.

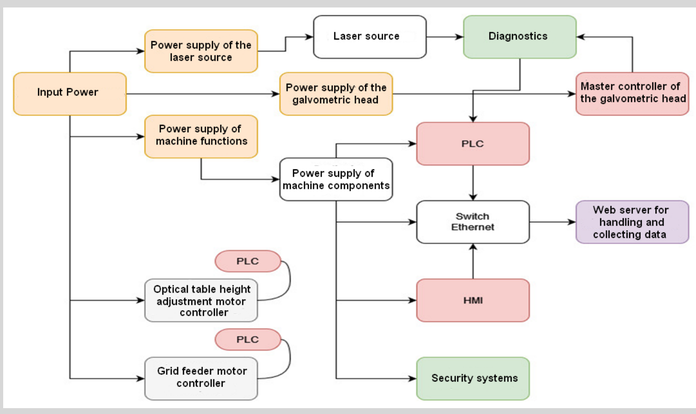


FIG. 5: Simplified diagram of the connections between systems of the constructed device

As part of determining the capabilities of the constructed laser cutter with a single galvanometer head, tests were conducted on cutting selected textile materials. Seven textile materials used in the most progressive industrial sectors, such as the defense and automotive industries, were chosen for testing. The selection of test materials aimed for maximum diversity in laser cutting properties, considering factors such as thickness, fabric weave density, composition, and structure. In order to obtain objective results, the cutting tests were conducted on six different industrial laser plotters, with different laser source power, head motion systems, and varying market prices. The comparative tests were performed on the following plotters: Eurolaser L-1200 200 W, Eurolaser M-1200 200 W, Eurolaser M-800 100 W, CadCam Contour Cut Vision 150 W, Tombit SL 1060 130 W, and the LMC 150 DOT 150 W engraver equipped with a galvanometer head. Subsequently, identical tests were conducted on the constructed prototype of the laser cutter with a single galvanometer head. To ensure an objective comparison between the prototype and market-available devices, a sample of high and low complexity was designed, designated as V_1 and V_2, respectively. For the V_1 sample, the total cutting line length was 10,000 mm, total idle travel length was 8,576.25 mm, consisting of 444 cutting paths and 1,770 nodal points. In the case of the V_2 sample, the total cutting line length was 10,000 mm, total idle travel length was 28.28 mm, consisting of 3 cutting paths and 89 nodal points. Regarding the cutting time of the V_1 sample for all materials, the prototype proved to be the fastest. Compared to traditional plotters, the prototype was approximately ten times faster in cutting most materials. For the most demanding materials, the prototype cut approximately four times faster. Furthermore, when compared to the LMC 150 DOT, the prototype was approximately three times faster. During the measurement of the cutting time for the V_2 sample, once again the prototype proved to be the fastest. For thin materials, the cutting times on the prototype were nearly three times shorter than on the other tested plotters. The prototype cut thicker materials twice as fast as the other tested plotters. Based on the conducted tests, it can be concluded that the constructed prototype of laser cutting machine with a single galvanometric head is at least twice as fast as other solutions used in the industry, while maintaining the same level of cutting quality and precision.

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