Building of CNC cutting laser and its use in educational activities at the Department of Manufacturing Technology

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Abstract

Laser technologies are very important manufacturing technology widely used in the industry. With the aim of educating laser technologies on high level, construction of modular cutting laser was done as teaching aid. This cutting modular laser uses 1 W blue laser diode, CNC XYZ programmable table, controlling PC, safety covering. Use of this laser is planned for practices of subjects as Technology 1, Technology of Welding and Cutting of Materials and Special welding technologies, where students are instructed about laser principles, laser safety and to programme and cut complex trajectory in paper.

Keywords

Laser diode, Cutting, Teaching aid

1. Background

Use of lasers in industrial manufacturing is very dynamically evolving area that deserves attention of every industrial engineer. Lasers are used in cutting of steel plates for ships, for welding car bodies, for rapid prototyping, for scanning and measuring, medical surgeries etc. Obviously laser principles, trends and practical use should be educated to university students of Mechanical Engineering Faculty. To enhance and improve education of laser technologies we decided to build simple CNC cutting diode laser as teaching aid and to use this laser in practices with students of Department of Manufacturing Technologies. In the last year the FRVŠ grant supported this project of improvement of education of laser technologies so the project started.

2. Concept of cutting laser

To successfully and easily accomplish the aim of the project, to build the educational aid, the laser should be done as simple as possible. Using modular construction from widely available components would be the easiest. Concept taken from hobby CNC milling machines was applied and exchanging the milling tool for laser was exchanged by laser. From the laser we demanded these:

1. Possibility to cut thin organic material – paper. Paper in A4 is simply available processing material. The result could look like at fig. 1.
2. Create complex cutting trajectory – lasers are used to do simple as well as complex cutting trajectories.
3. Enable safety operation due to full covering – safety first always.

Fig.1. *Example of laser cutting*

These 3 demands lead to modular concept of the machine from 4 main groups: 1. Laser diode, 2. CNC table, 3. CAD/CAM controlling PC, 4. Full safety covering.

1. The simplest laser beam source is laser diode. Laser diode with power 1 W and frequency 445 nm were selected because of its good availability. The laser diode power is regulated from 0-1 W by changing current from current source. The current source is controlled by TTL chip and pulse width modulation.
   Control of focus size is done by simple spherical lens in front of the laser diode. By axial movement of the diode the focal size can be changed. At present moment the size of focus is 0,1x0,4 mm is used for cutting.

2. Possibility to create complex trajectory is enabled by CNC programmable table known from small milling machines and routers. For our case, milling spindle was exchanged by laser module. As basic CNC table with step motors and thread screws programmable in X, Y, Z with movement 400x300x80 mm was purchased. The movement is done by electric impulses sent to step motors.

3. To enable the digital control PC together with other special hardware were used. The cutting trajectory, movement of cutting head, switching laser on and off is complex operation realized by several steps. CAD data are loaded into CAM program, G codes is generated by NC postprocessing and these interpreted as electric to step motors.
   As CAD program ProgeCAD is used. Any program creating curves is suitable. CAM program is Sheetcam. It is reading the curves and enables programming of offsets, cutting trajectories and generates G code readable by machine. The CNC table is controlled by Mach3, which interprets G code and creates controlling pulses for step motors.
   PC needed to be equipped with smoothstepper, TTL circuit and signal isolator to ensure perfect communication of PC with CNC table and laser power source.

4. Lasers can present very big danger for humans and countermeasures needs to be taken. Full covering of laser to fully prevent escaping laser beam is necessary to protect anyone from eye or skin damage. Structure is created from Al profiles with filling panels, as at fig. 2.

Fig. 2. *Safety covering*

3 Machine assembly and testing

From all major parts the machine was wired uncovered, then tested using safety goggles. After the tests the machine was covered. It is at fig. 3.
The paper of density 200 g/m^2 was used to test the cutting abilities of the machine. First the laser focal point, most suitable for cutting was found. Array of circles with certain movement in Z axis with movement from circle to circle were designed and cut. This way the ideal focus was found.
More complex trajectory was designed in dxf file format, and then transformed to G code. G code M3 starts the laser and M5 code ends, interrupts the laser beam. Full laser power and cutting speed of 400 mm/min were used. The results of such cut are shown at fig. 4.

Fig. 3. *Laser covered*

Fig. 4. *Cut samples*

4 Use of the machine for education

The use of the machine is being planned for several practices with students in of Technology I, TSDM (Technology of Welding and Cutting of Materials), SMSs (Special welding technologies).

In the practice of subject TSDM the theoretical introduction and practical part would be present. Both these parts are to be done by the students with the help of the academic staff. In theoretical part questions about lasers are given to the students. Practical tasks are to be done next.

Theoretical questions:

1. What is laser?
2. Describe properties of laser light?
3. What use can laser have industry?
4. What safety precautions need to be taken?
5. What are the main parts of laser generator?

Practical tasks for students:

1. Laser safety

Using the safety values for eye and skin exposure from the governmental safety regulations calculate if a) laser pointer, b) our 1 W cutting laser is dangerous for eyes in direct viewing and after diffusion reflection. What precautions do we need to safely operate the laser?

2. Measuring laser divergence

For a) laser pointer, b) our 1 W cutting laser diode measure spot size and calculate divergence in fast and slow axes.

3. Spot size

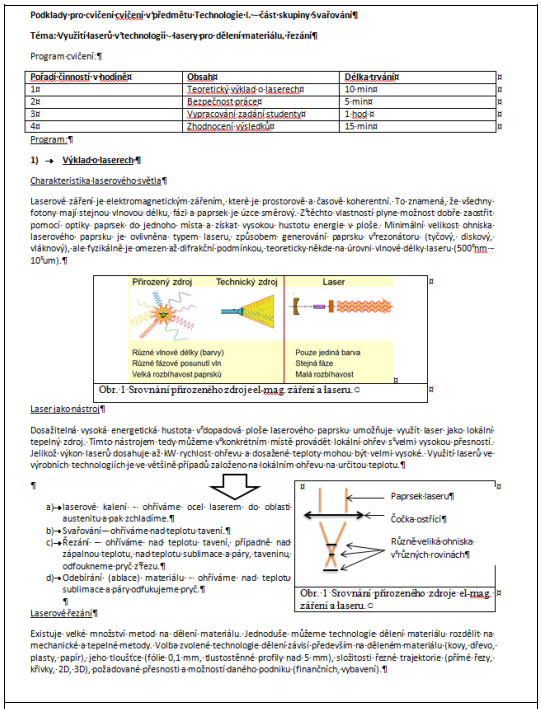
What will be the minimum spot size of blue cutting laser? How can we practically find optimum position of laser for laser operation?

4. Finding optimum spot

Running program in Mach3, load file Ohnisko and run it. Insert paper before cutting. This program will cut series of circles changing focal position in Z. Comparing different circles and select which position creates the best cut.

5. Cutting sample

Design a cutting trajectory or select from offered list of drawings. Make the necessary step to transfer this drawing to G codes by CAM program. Set laser in right Z position (focal plane) and run series of cutting lines with different cutting speed to check if material is processable. Check if all the safety measures are taken and cut the trajectory. Check the results of you work.



Podklady pro cvičení cvičení v předmětu Technologie I. – část skupiny Svařování

Téma: Využití laserů v technologii - lasery pro dělení materiálu, řezání

Program cvičení:

Pořadí činností v hodině	Obsah	Délka trvání
1	Teoretický výklad o laserech	10 minut
2	Bezpečnost práce	5 minut
3	Vypracování zadání studenty	1 hod
4	Zhodnocení výsledků	15 minut

Program:

1) → Výklad o laserech

Charakteristika laserového světla

Laserové záření je elektromagnetickým zářením, které je prostorově a časově koherentní. To znamená, že všechny fotony mají stejnou vlnovou délku, fázi a paprsek je úzce směrový. Z těchto vlastností plyne možnost dobře zaostřit pomocí optiky paprsek do jednoho místa a získat vysokou hustotu energie v ploše. Minimální velikost ohniska laserového paprsku je ovlivněna typem laseru, způsobem generování paprsku v rezonátoru (tyčový, diskový, vláknový), ale fyzikálně je omezen až difrakční podmínkou, teoreticky někde na úrovni vlnové délky laseru (500 nm – 10 um).

Obr. 1 Srovnání přirozeného zdroje el.mag. záření a laseru.

Laser jako nástroj

Dosažitelná vysoká energetická hustota v dopadové ploše laserového paprsku umožňuje využít laser jako lokální tepelný zdroj. Tímto nástrojem tedy můžeme v konkrétním místě provádět lokální ohřev s velmi vysokou přesností. Jelikož výkon laserů dosahuje až kW rychlost ohřevu a dosažené teploty mohou být velmi vysoké. Využití laserů ve výrobních technologiích je ve většině případů založeno na lokálním ohřevu na určitou teplotu.

a) → laserové kalení – ohříváme ocel laserem do oblasti austenitu a pak zchladíme.
b) → Svařování – ohříváme nad teplotu tavení.
c) → Řezání – ohříváme nad teplotu tavení, případně nad zápalnou teplotu, nad teplotu sublimace a páry, taveninu, odfoukneme pryč z řezu.
d) → Odebírání (ablace) materiálu – ohříváme nad teplotu sublimace a páry odfukujeme pryč.

Obr. 1 Srovnání přirozeného zdroje el.mag. záření a laseru.

Laserové řezání

Existuje velké množství metod na dělení materiálu. Jednoduše můžeme technologie dělení materiálu rozdělit na mechanické a tepelné metody. Volba zvolené technologie dělení závisí především na děleném materiálu (kovy, dřevo, plasty, papír), jeho tloušťce (fólie 0,1 mm, tlustostěnné profily nad 5 mm), složitosti řezné trajektorie (přímé řezy, křivky, 2D, 3D), požadované přesnosti a možností daného podniku (finančních, vybavení).

Fig. 5. *Written explanation of tasks*

During all the cutting the laser covering needs to be closed and the academic staff will be at the place to help students and to check safety measures. Written explanations are prepared for the practices as at fig. 5. End of the practice with students is finished with short discussion of results.

5 Conclusions

CNC cutting laser using 1 W laser diode was built as educational aid to help education of laser technologies. For this machine modular concept was used to enable future changes and improvements. These improvements involve using stronger laser diode, which actually is being prepared for the machine. In short future 10 W diode will be installed on the machine.

The machine itself is starting to be used in education of the practices teached at the department of Manufacturing Technology. In this paper the concept how the laser would be used in practice as planned for subject TSDM (Technology of Welding and Cutting of Materials) is shown in detail.

Laser technologies are important manufacturing technologies and we want to put increasing effort to their education, which is demonstrated by this educational aid.

Literature

The literatures used for this project were mainly manuals of used software as Mach3, Sheetcam TNG etc. that are available online.

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