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SOME CONSIDERATION ABOUT LASER WELDING AUTOMATION

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ABSTRACT
The article presents some methods about the automation for overlap welding with a laser device, HL54P Trumpf. In some cases the edge of the metal sheet is not linear, it can take different shapes: circular, elliptic, and other shapes more complex. The solution found by the authors was to determine the position of the edge and a path which the processing optics to follow. The controller read the edge with two focus infrared phototransistor sensors, memorized the position of edge, or identifies the shape edge in a 1:1 scale image, captured with a video camera, and generate the path for processing. These methods are necessary in the case of non-CNC (Computer Numerical Control) machine or the CAD (Computer Aided Design) files and CAM (Computer Aided Manufacturing) software for CNC programming are missing.
Keywords: laser, Nd:YAG , automation, welding

1. INTRODUCTION
The goal of the team was the automation of the HL54P laser device for the overlap welding, in the case of non-CNC (Computer Numerical Control) machine or in the case of missing CAD (Computer Aided Design) file and CAM (Computer Aided Manufacturing) software for CNC programming. In our case the laser device had the laser beam generator, the processing optics, which focuses the laser light onto the surface of the work piece and optical cable, which guides the laser light from the laser device to the processing optics. The team had to obtain a positioning system in order to use the laser device in machining.
The HL54P was obtained after an international collaboration program with University of Stuttgart. It is a solid-state laser with an Nd: YAG rod (Neodymium-doped Yttrium Aluminum Granat).
The laser beam as a thermal device is a relatively new practice in finishing technologies. In order to process raw materials, one can use the following procedures: cutting, welding, local hardening and drilling.
The advantages of laser beam machining compared to other methods are: greater precision, increasing work speed, allowing the point-like processing of the piece - this is a process that does not imply touching the piece with an instrument (beam).
The use of this procedure reduces the heating of the working area because the energy is introduced faster and on a small surface – this is why large power densities can be reached. Other advantages are flexibility and accessibility.
Nd:YAG lasers emit light in the near infrared range, at a wavelength of 1.06µm. This means that the light emitted by Nd:YAG lasers is almost in the visible range. The laser light of an Nd: YAG laser can be routed through glass optics and optical fibers.
In processing, the laser power absorbed by the material causes the latter to heat up rapidly and - if the intensity is sufficiently high - results in melting or even vaporization of the material. As better a

material can absorb the wavelength of a laser, then greater the amount of energy that can be introduced into the material. This means that the efficiency of the laser beam increases proportionately with the capacity of the material to absorb the laser wavelength.
The following question is therefore especially important in material processing: how well do different materials absorb the wavelength of Nd: YAG lasers (figure 1).

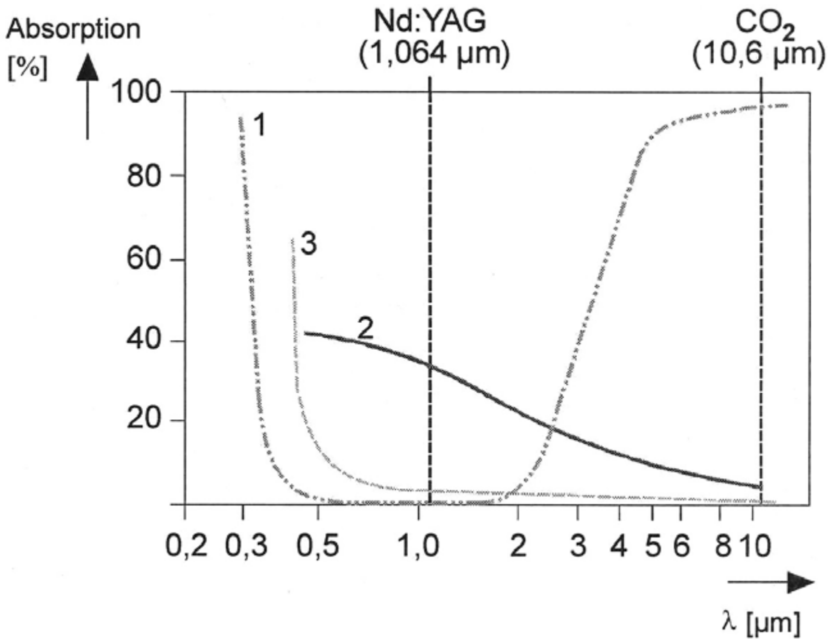

Figure 1. Absorption capacity for: 1-glass; 2-transition metals (iron, nickel); 3-other metals (copper, aluminium, silver, gold) [4].

2. GENERAL ASPECTS

The laser radiation is released in form of pulses with a wavelength of 1064 nm. The pulse power of the laser is determined by the power of the flash lamp which irradiates the laser rod. A higher lamp power leads to a higher pulse power. The laser light is generated by optical pumping. Other parameters of the laser are presented in Table 1. The laser light is fed into one light cable via the optical arrangement. The optical arrangement contains beam switches, shutters and input coupling.

Table 1. Parameters of the laser HL54P[4].

Parameter	HL54P laser
Average laser power [W]	50
Maximum laser power [W]	65
Minimum pulse power [W]	300
Maximum pulse power [W]	5000
Pulse energy [J]	0.1 … 50
Pulse duration [ms]	0.3 … 20
Maximum pulse duration frequency [Hz]	100
Beam quality [mm·mrad]	16

The laser emits light with a single wavelength and it lies between ultraviolet and far infrared.
The positioning system has the following configuration: two axes for moving the working table in xOy plane and one axe for moving the processing optics Oz axe in order to focus the laser beam on the work piece.

The precision of the positioning system depends on the accuracy of the axis. In our case we use DGE -25-200-SP for the Oz axe and two DMES-25-200 for the positioning in the xOy plane.
The repeatability for the focusing axe, Oz, is 0.02 mm and for the other axes, Ox and Oy is 0.05 mm. The stepping motor, MTR-ST-57-48S, has the full step angle of 1.8º with a 5% maximum error. It is possible to supply two coils simultaneously with different current share. The result is a 1/2, 1/4, 1/5, 1/8, 1/10, 1/32 of a step, depending on the current share. These allow considerable refinement in the maximum resolution of positions to which a stepping motor can run.
The smallest incremental path (resolution) on a positioning axis is determined by the motor's step angle (number of steps per revolution) and the feed constant of the positioning axis (determined by the diameter of the input pinion or the slope of the spindle).
This can be calculated as follow:

$$n_s = \frac{360°}{\alpha_s} \quad \ldots (1)$$

$$d_r = \frac{d_f \cdot i}{n_s} \quad \ldots (2)$$

In the equations above represents number of steps per revolution, motor angle, resolution, feed constant of the axis, gear multiplication.
For the axis of the work table, in case of the full step, the resolution is 0.012 mm per step and for the focusing axe is a 0.05 mm resolution per step. From this point the position of the work piece can be calculated. Some error can occur if the stepping motors lose steps. This happens only when the load exceeds the maxim load on the axis.

3. RESEARCH COURSE

The connection between positioning system and laser device was made by programming an Atmel microcontroller (Atmel ATMEGA8535). For machining was necessary to control the laser device at the same time with the positioning system. With the help of the PC interface made in Delphi software was possible to synchronize the laser device and the positioning system for machining. The laser pulses were generated when the work piece was in the processing position.
We are using for this attempt two convergent-beam sensors. Most convergent-beam sensors use a lens system that focuses the emitted light on an exact point in front of the sensor and focuses the receiver element on the same point (figure 2). This design produces a small, intense, and well-defined sensing area a fixed distance from the sensor lens.
This is an efficient use of reflective sensing energy. Convergent-beam sensors reliably sense objects with small profiles and materials of low reflectivity that cannot be sensed with diffuse or divergent mode sensors.

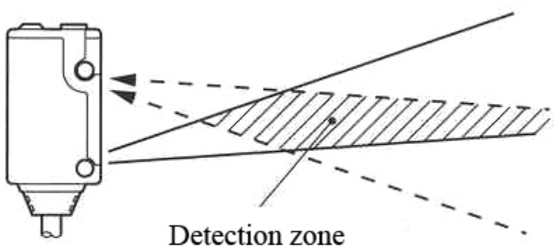

Figure 2. The detection zone is limited to a convergent point.

The range of a convergent-beam sensor is defined as its focus point, which is fixed. This means you must closely control the distance between the sensor and the surface being sensed. These sensors will detect an object of a given reflectivity at its focus point, plus or minus some distance. The sensing

area, centered on the focus point, is called the sensor's depth of field. The size of the depth of field depends on the sensor design and the reflectivity of the object sensed.
The first attempt was to read the edge of the metal sheet with one focus phototransistor sensor. In this case the reading is slow because the positioning system had to move the work piece to find the intersection points between sensor beam and the edge of the metal sheet. To determine a good welding path we need a greater number intersection points depends on the shape of the edge. Complex shapes require a grater number intersection points. More points will slow down the reading process. After reading the intersection points will be process in order to obtain the welding path.
The second attempt was to follow the edge of the metal sheet with two convergent-beam sensors. In this case the path was ease to obtain by keeping the edge of the metal sheet between sensors. The sensors were calibrated to detect the variation of the distance between sensors and the metal sheet. When the positioning system detects any variation of distance, automatically adjust the position of the work piece in xOy plane to keep the edge of the metal sheet between sensors.
With the processing path obtained we can start the welding process by setting the laser parameters. The laser parameters are specific for different types of material, in our case metal sheets. The welding process is after the readings in order to protect the sensor in case of splashing with melt metal.

4. CONCLUSION

The solutions have some advantages or disadvantages. In the first attempt we have a path obtained by connecting a number of points with line. The precision of the path depends on the number of intersection points. A greater number of intersection points we obtain a smooth processing path which follow the edge closely. This solution has a major disadvantage, it stress the positioning system.
In the second attempt the positioning for reading of the processing path is smoother. We can read a greater number of points without stressing the positioning system. For generic geometrical shapes we can use functions to generate parts of the processing path and reduce the number of independent points. Using two sensors we found a problem. When the sensors axe is parallel with the path the intersection point are read with the first method or stopping the reading process and rotate the sensor.
In a future research the team wants to use the monitoring system of the optical head from the laser installation. In this case the welding process will be at the same time with the reading process. Parts of the edge will be identifies in a 1:1 scale image, capture with a video camera, and generate the path for processing.
These methods are necessary in the case of automation of a non-CNC (Computer Numerical Control) machine or the CAD (Computer Aided Design) files and CAM (Computer Aided Manufacturing) software for CNC programming are missing.

5. REFERENCES

[1] Helmut Hügel: Strahlwerkzeug Laser, Teubner Verlag Stuttgart, 1992
[2] Walter Koechner: Solid-State Laser Engineering, 3rd ed., Springer-Verlag,1992
[3] Marcel Sabin Popa: Tehnologii si masini neconventionale, pentru mecanica fina si mecatronica, U.T. Pres Cluj-Napoca, 2005
[4] Trumpf Laser : LCB Laser Devices. Basic Training, Trumpf Laser GmbH+Co.KG,2005