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RESEARCHES ON TRUE PULSE LASER MICRO-WELDING

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ABSTRACT: Microwelding represents an important machining method that, theoretically, requires special technological equipment. Also, the involved „working" parameters must be set to their appropiate values, depending on material's type, workpiece's thickness, welding's required characteristics etc. Some preliminary research results on Nd: YAG laser microwelding are going to be presented above, for some specific type materials (alluminium alloy, stainless steel, copper-zinc alloy), while the technological equipment is a „combination" of two already existing ones: Trumf laser and Isel CNC machine.
KEYWORDS: microwelding, preliminary research results

INTRODUCTION

Laser Beam Machining (LBM) is highly used in top industrial fields (aerospace, nuclear), because of, both, tough characteristics of the involved materials and required machining complexity (high geometrical precision, such as x100 or, x 10 μm).

The applicability of this machining method is due to laser beam's specific properties, such as: one direction; intensity; monochromatics; amplifying when passing through different environments, coherent light and high energy density.

Laser beam represents an „universal tool" used in micromachinig (welding, drilling, cutting, engraving, deposition, etc.) one of its important characteristics being the lack of direct physical contact tool – workpiece. As consequence, there are no machining forces on the workpiece and no wear of the tool [1]

When laser micromachinig ther is no absolute request for void equipment, thermal influenced zones can be neglected and thermal deformations are very small, while the machined materials can be tough, extra-tough or, fragile ones.

Microwelding represents an important machining method that, theoretically, requires special technological equipment. Also, the involved „working" parameters must be set to their appropiate values, depending on material's type, workpiece's thickness, welding's required characteristics, etc. [2]. Some preliminary research results on Nd: YAG laser microwelding are going to be presented above, for some specific type materials (alluminium alloy, stainless steel, copper-zinc alloy), while the technological equipment is a „combination" of two already existing ones: Trumf laser and Isel CNC machine.

METHOD AND EQUIPMENT

When laser machinig, there has to be defined two important parameters [1]:
- spot diameter obtained in lens focus:

$$d_0 = \frac{\frac{4}{\pi} f\lambda}{D} \quad [\mu m] \qquad (1)$$

where: f is lens focal distance [mm]; D - lens opening [mm]; λ - wave length of emitted radiation [μm].
- power maximum density in lens focus.

$$W_P = \frac{P}{10^2 \lambda^2} \quad [W/cm^2] \qquad (2)$$

where: P represents the power emitted by laser radiation [W].

There are also some other laser beam specific parameters that do influence the machining process, meaning:
- power – determines the penetration depth;
- power density / intensity – is dependent on cross section of the laser beam;

- energy – determines the volume of molten material and can be calculated by:
- the product of power and laser – material interaction time, or
- the product of power and pulse duration.

Laser (micro) machining is based on two main phenomena: material's melting and vaporization when the laser beam impacts the work-piece surface by spot focusing. Each material has a specific value of density power when vaporization starts, for example: aluminum – W_{PS}=2Ý10^5W/cm^2, iron / steel – W_{PS}=1,2Ý 10^5 W/cm^2 etc.

So, radiation penetration depth can be determined by:

$$h = v \cdot t_i \text{ [mm]} \quad (3)$$

where: v - represents prelevation speed; t_i - pulse duration

This paper presents experimental results in laser microwelding, the equipment used being made of the following ones.

A. Laser central unit TruePulse 62 – see figure 1.

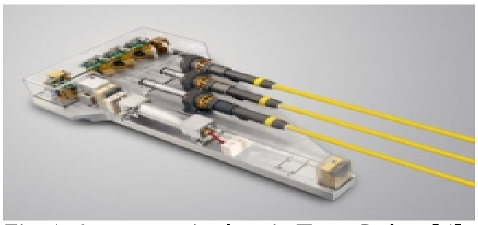


Fig.1. Laser optical unit True Pulse [4]

This is a Nd: YAG laser type, that generates intense invisible radiations, with wavelength „close to" infrared radiations. Some of its technical charactersitics, as mentioned by the producer, are presented in table 1. Laser lenses can be used for radiation wavelength values from 1030 nm to 1064 nm.

Tabel 1 [4]

Characteristics	Values
- Rradiation wave length	1064 nm
- Medium power	65 W
- Pulse minimum power	250 W
- Pulse maximum power	5000 W
- Pulse minimum duration	0,2 ms
- Pulse maximum duration	50 ms
- Pulse maximum energy	50 J
- Maximum frequency of pulse repetition	900 Hz
- Laser beam quality	8 mm mrad

B. Isel-automation machining systems [5] - systems made of three main components: isy CAM software, ProNC software and Flatbed or Euromod basic units. An image of its basic unit – used in experiments can be seen in fig. 2.

Fig.2. Isel Flatbed unit [5]

❖ EXPERIMENTS

There are many factors that do influence laser micro-welding process, some being: material's type, laser beam power density, pulse duration and shape, shielding gas etc.

Even the process is rather complex, it has many advantages, the main ones dealing with: welding materials with different physical – chemical properties; welding in hard accessible zones and positions – by laser beam focusing with lenses; or, by allowing its pass through medium that are transparent with respect to laser radiation wavelength, etc.

Mainly, there are two micro-welding principles, one is *conduction* (the heat source generated by laser beam absorption is localised on work-piece surface, where melting starts - see fig. 3) and the other is *penetration* (melting temperature is above evaporation value and so, into the metal it is generated an absorbent cavity full of ionized metallic gas - see fig. 4).

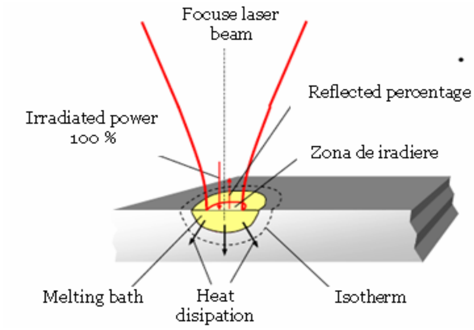


Fig. 3. Micro-welding by thermal conduction

The exepriments used penetration micro-welding so, high depth and very narrow welding belt could be obtained. The Nd:YAG laser was used in CW mode CW (continuous wave). Images taken while micro-welding experiments are presented in fig. 5, 6 and 7 – there can be noticed both values of the laser beam parameters, and images of the welding belt of the work-piece.

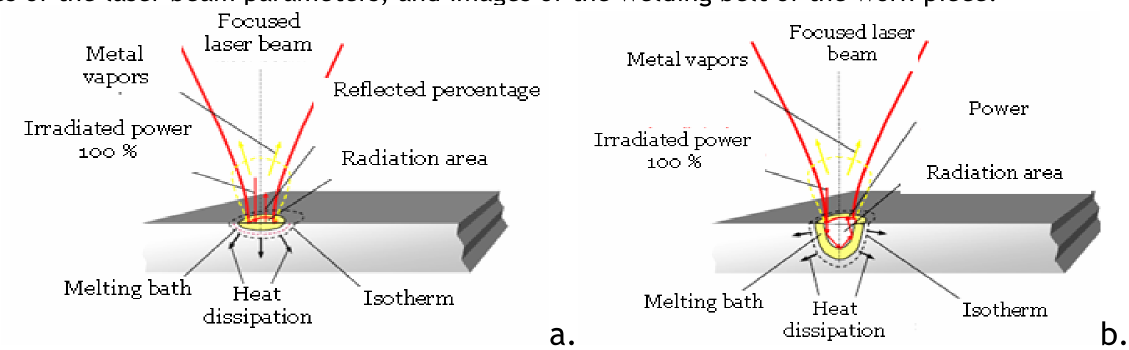


Fig. 4. Micro-welding by penetration

It has to be pointed out the fact that even some orientative values of laser beam parametrs in micro-welding are presented in specific references, if considering them exactly, no good results are obtained. So, it was necessary to make experiments with specific materials and existing equipment – and the results to be further used in industrial application.

The laser head (on TruePulse 62) is the one generating radiation (for micro-), and the CNC machine (Isel Flatbed) allows computer aided welding - on various complex trajectories and high precision (1 μm) [3].

Images of microscope checking on the welding belts width (that points out the micro-charactersitic) are presented in figure 8.

Fig. 5. Alluminum alloy micro-welding

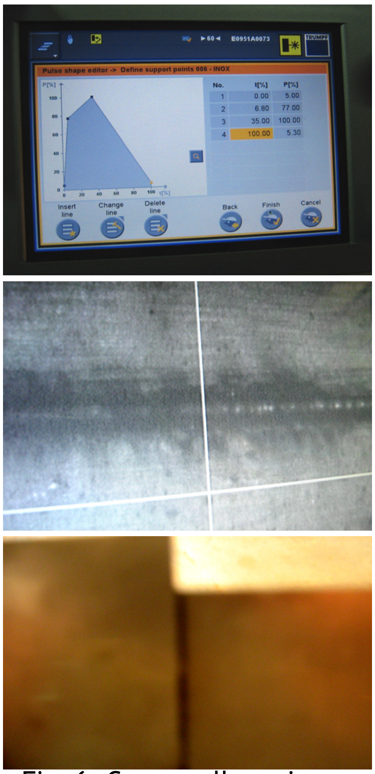


Fig. 6. Copper alloy micro-welding

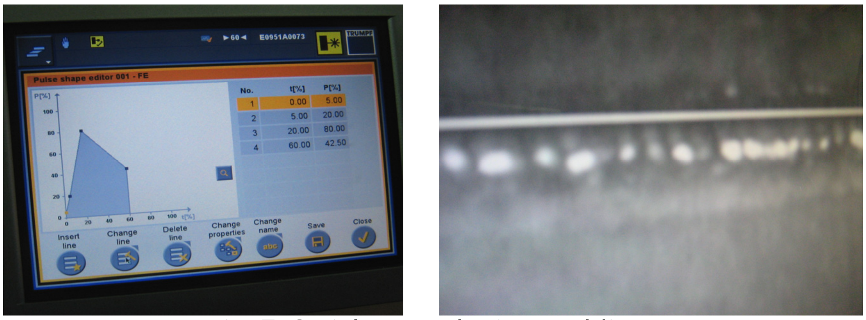
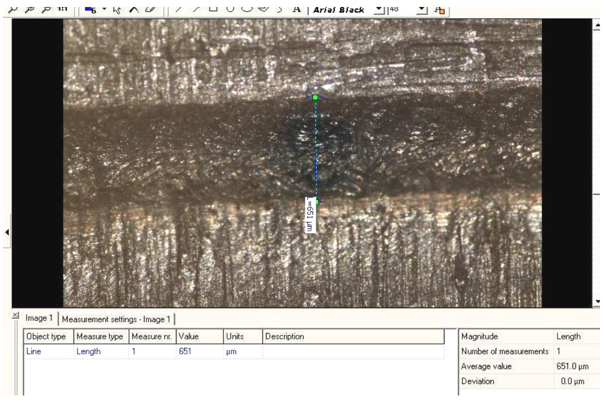
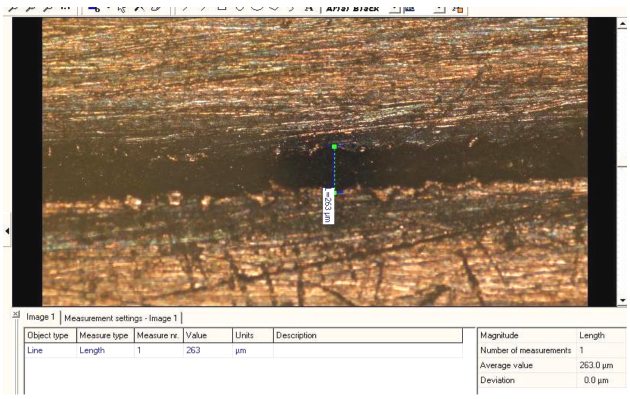


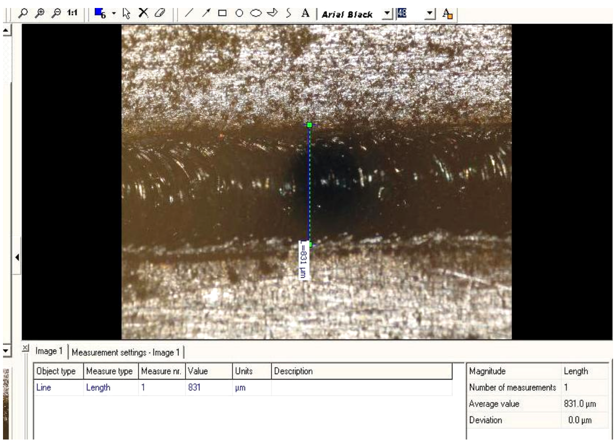
Fig. 7. Stainless-steel micro-welding



Alluminum alloy welding belt width: 651 μm



Copper alloy welding belt width: 263 μm



Stainless steel welding belt width: 831 μm

Fig. 8. Microscope images of the welding belts

❖ CONCLUSIONS

Laser Beam Machining is highly used in top industrial fields. When machining the materials, welding is an important method.

Some orientative values of laser beam parameters in micro-welding are presented in specific references, but, no good results are really obtained, if considering.

It was necessary to make experiments with specific materials and existing equipment – and the results are further used in industrial application. The materials tested were: aluminum alloy, copper alloy and stainless steel.

Further research must be developed - based on design of experiments and specific software so that, if possible, regression models of micro-welding parameters and welding belt's characteristics, to be obtained.

❖ ACKNOWLEDGMENT

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