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Simulation of industrial robots for laser welding of load bearing construction

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1. Introduction

Welding, as a standard method of joining is constantly being improved and perfected. Laser welding is one method that is more and more widely used. This kind of joining has found its application especially in the automotive industry, where the character of the industry allows for the maximum use of the advantages of laser welding. Most important advantages of laser welding are high flexibility, lack of deformations and high joint quality [1].

A disadvantage of this technology are high implementation cost, due to highly sophisticated technology required. However large investment cost can be offset by maximizing its advantages, especially in the automotive industry, which requires high quality welds, short cooling times, and little or no deformation of crystalline structure in the weld area.

Since very little heat is transferred on the welded piece, and due to high power of laser welding, weld cooling does not require any specific technology. Therefore short cooling times by laser welding causes high hardness in the weld area. Laser welding compared to conventional welding methods significantly improves joint quality. Standard quality weld for construction steel is reached with 0.22% of Carbon, which corresponds to the hardness of HV 350. Laser welding on the other hand, enables us to get welds without cracks by carbon content of some 0.6%, and thus the hardness can be as high as HV 700 [2, 3].

2. Laser welding

There are two general types of lasers being used for welding process which are CO_2 and the Nd: YAG. Both laser types operate in infrared electromagnetic spectrum. It is important to note that these lasers have different wavelengths.

Protective gas used in laser welding should provide the protection of weld in the welding area from external factors, shape the weld and protect laser optics from metal fumes. In order to increase energy output as well as to enable faster welding, argon based gas mixtures with addition of carbon dioxide and – or oxygen are used. Beside the type of gas used, the way of gas input plays an important role in the welding process; it can be either coaxial or sidewise input through one or more gas input hoses (Fig. 1) [2].

For every laser welding application it is important to optimize the gas flow input and the type of gas used. It is highly important to synchronize these parameters; if air flow is too low oxides and discoloration are formed on the weld surface which causes low weld quality.

The principal of laser operation can be described as following: laser beam which was produced in resonator can be transmitted through a system of lenses and mirrors, or through fiber optic cable, straight to the weld piece. The transmitted laser beam is focused by optics based in weld head. Weld head is attached to the robot arm which welds on a prearranged trajectory Fig. 2 [3].

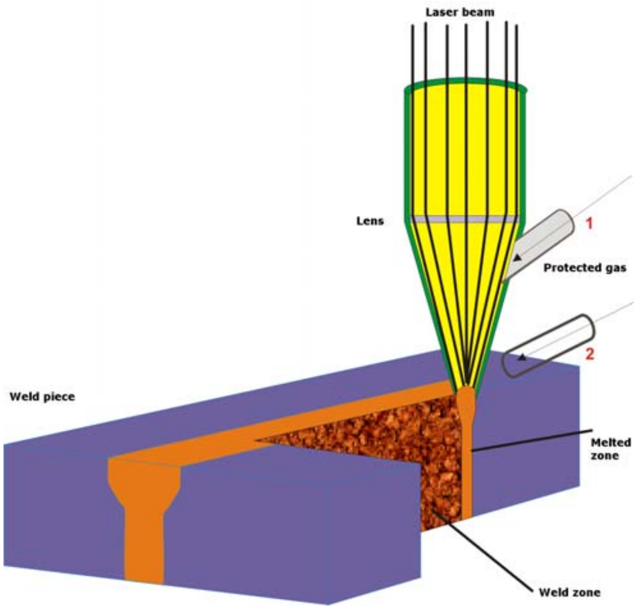

Fig. 1 Laser welding processes: *1* - protection gas is coaxial, *2* - protection gas is sidewise

Fig. 2 Laser welding in automotive industry

The diameter of laser beam on the weld piece surface is in the range of 0.2 to 1 mm; this highly focused beam is required in order to achieve required power density. Focal length determines the diameter of focused beam in focused area [2].

These two values are directly proportional. Power density on weld q (W/cm^2) is equal to laser power P divided by the surface area of the laser beam As (m^2) and it is the most important parameter in the welding process. The largest power density is thus reached in focus area since the diameter of the beam is the smallest Fig. 3 [3].

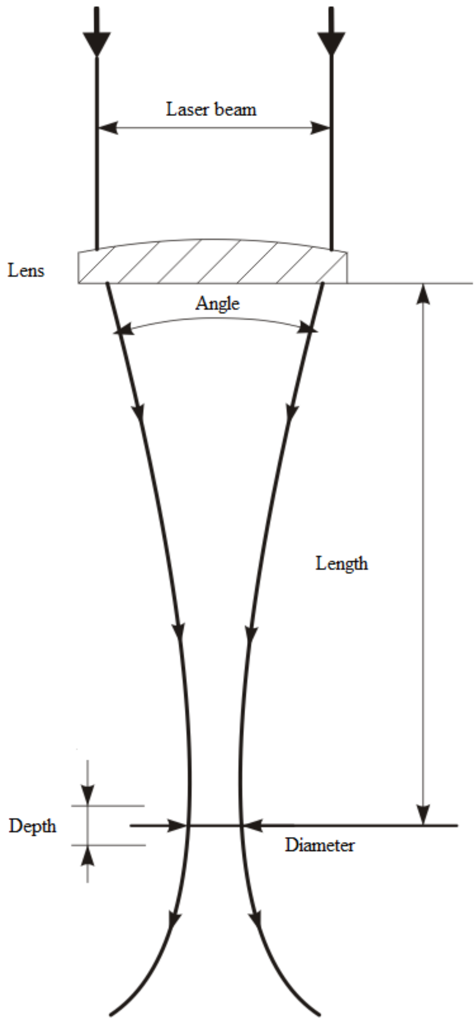

Fig. 3 Laser beam characteristics

Interaction of the laser beam has three forms Fig. 4:

- laser beam reflection;
- laser beam absorption;
- laser beam penetration.

Intensity of these interactions depends on type of material and laser beam power density. Some materials

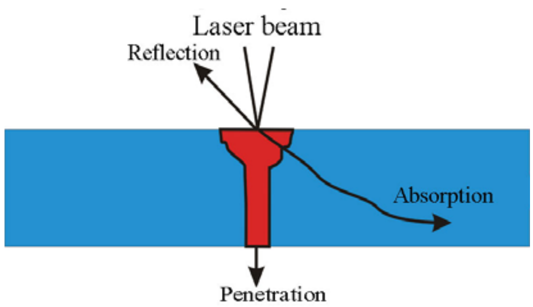

Fig. 4 Interaction of weld piece and laser beam

such as aluminum or copper which are highly reflective are rarely welded by laser.

3. Load bearing construction welding

There are two laser welding techniques determined by laser beam power density:

- laser welding by melting;
- laser welding by melt-trough process.

Laser welding by melting happens when power density of the beam is relatively small. Every material has a threshold value of power density; above witch melt-trough process begins.

When we want to achieve welding with melt-trough it is necessary to heat up weld pieces to very high temperatures in the weld area. After such prepared surface is treated with laser beam, a crater is formed, and a part of material evaporates. Due to relative weld piece motion, the crater is filled with material, and immediate cooling causes a weld to be formed.

Reflective material property is a ratio of reflected and total energy, and depends on the type of material, temperature wavelength and laser beam power density. Metal reflective property at a room temperature is high, more than 90%, which means the maximum of 10% laser beam energy is absorbed [2].

Basic laser welding parameters are:

- laser power P, W;
- welding velocity v ,cm/min;
- protective gas, (type, flow, input – coaxial or sidewise);
- lens focal length f, mm;
- lens focal diameter d_F, mm;
- focal position relative to the weld piece surface z, mm [4].

Sensors play an important role in laser welding process [5]. We use them for focal point control and laser beam guidance. These two parameters directly a influence the weld quality since small tolerance can have detrimental effect on weld piece quality. Chemical composition and a shape of the weld can be controlled by addition of supplemental material [3].

Laser weld joints require constructional adjustments, and thus pose new challenges for the engineers when perfecting load bearing constructions. On the other hand, this technology introduces special preparation of the welds as well as their positioning during the welding process. Since weld quality depends on the positioning of the weld pieces, the use of robots for this work is unavoidable.

The distances between work pieces depend on focal diameter, the type and kind of the weld. There is different information in the literature regarding allowable tolerances. Thin metal sheets (up to 2 mm), distances between 2 to 10% of the thickness can have detrimental consequences [3, 6, 7].

For thicker weld pieces distance between the weld pieces can be up to 0.3 mm, or up to 70% of the diameter of focused laser beam. Frontal welding however, requires special preparation [2, 3, 6].

The Fig. 5 and Fig. 6 show different position of weld piece during the laser welding process, depending on the type of construction, technology, and required stress resistance.

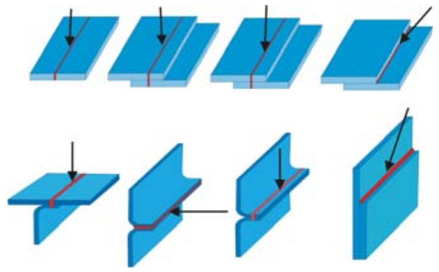

Fig. 5 Weld piece position during laser welding process

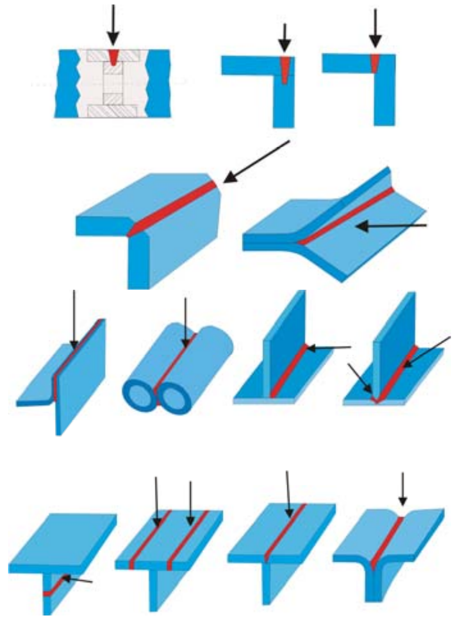

Fig. 6 Weld piece position during laser welding process

4. Laser welding simulation

Laser welding simulation is required for optimization process parameters before the introduction on the manufacturing line. There are several parameters that have to be determined in order to achieve the most efficient process.

Laser welding process parameters can be divided into two separate groups:

- constant parameters;
- variable parameters.

Constant parameters are determined by the equipment we posses, that is by the equipment supplier; they are focal length, the system of introducing laser beam on the work piece, introduction of protective gas as well as the robot system attached to the welding equipment.

Variable parameters influence the efficiency of production process and they are the subject of this paper. Simulation of these variable parameters help us to determine optimum production environment and thus the best quality and price ratio.

Parameters that influence the control of metal fumes and thus success of welding are: gas hose diameter, distance from the gas hose to the weld piece, gas type, gas flow, kind and thickness of weld pieces, laser power and welding speed.

Most of the above mentioned parameters are interdependent. Higher penetration can be achieved with smaller hose diameter and smaller distance from the weld piece, however weld quality and speed of welding is going to decline.

We simulated the following parameters for this paper:

- focal position relative to the weld piece;
- welding speed.

4.1. Focal position relative to the weld piece

Focal length of the laser lens is a primary determinant of focal position relative to the weld piece. There are several methods for determining focal position, as laid out in the literature overview.

Focal position directly influences penetration, and it is necessary to aim for the optimum position value. Regression analysis has been carried out over the experimental results, and parameter optimization has been carried out.

The following diagram (Fig. 7) presents interdependence of penetration and relative focus position on the weld piece [3].

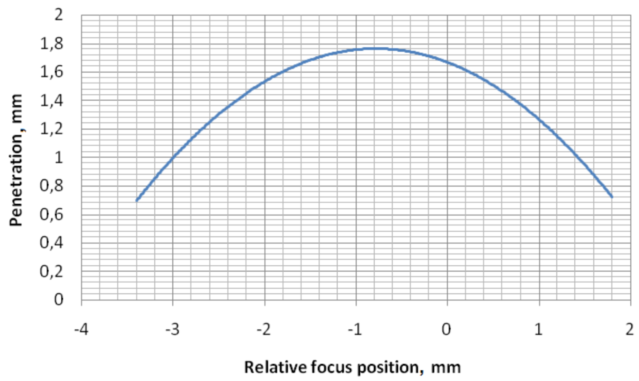

Fig. 7 Simulation of relative focus position

Optimum penetration has been achieved when focus position is at 0.1-0.4 δ, where δ is the thickness of the weld piece.

4.2. Weld speed and penetration simulation

Optimum weld speed is a demanding parameter, as the consistency of the weld has to be absolute. Penetration is a function of weld speed. Regression analysis has been carried out over experimental results, and a model for process optimization has been developed. The following diagram Fig. 8 presents results [3].

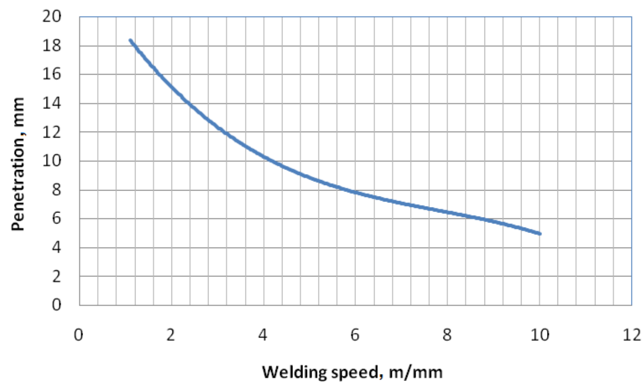

Fig. 8 Weld speed and penetration

4.3. Robot welding simulation

Virtual robot environment has been optimized in such a manner that the welding process is uninterrupted and welded pieces are removed and new pieces placed on the work surface.

Work bench consists of two pieces, which have several characteristics that enable easy and efficient transport of weld pieces. Basic work bench characteristics are as following [8] (Table).

Table

Characteristic of robot bench

Desc.	Value
Weight (without OS)	19 kg
Dimension lxwxh	769.5x159x415.7 mm
C	250 A

The robot is equipped with standard and additional devices in order to enable laser welding of load bearing construction. Robot layout is presented in the following (Fig. 9) [8].

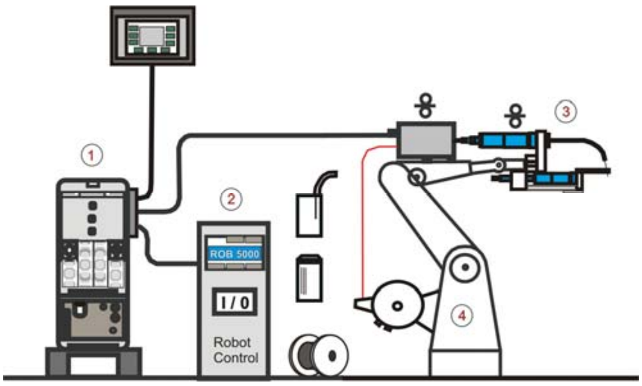

Fig. 9 Robot with integrated laser welding equipment layout

As shown in the figure, the robot consists of the following components:

- power source (1);
- robot interface (2);
- integral laser head (3);
- the robot itself with the attached welding system (4).

Robot arm consists of the integrated laser welding system, which is depicted in the Figs. 10 and 11.

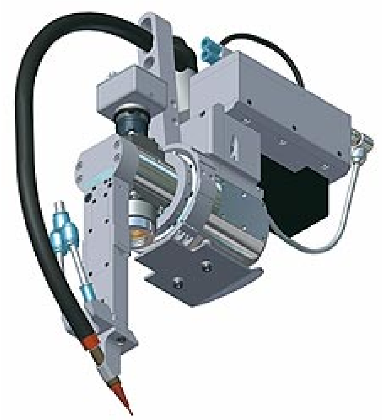

Fig. 10 Integral laser head [9]

Fig. 11 Laser welding in automotive industry [10]

5. Conclusions

Laser welding is finding wider application in industry, especially automotive. It is conceivable that in the foreseeable future, laser welding will entirely replace classical welding process wherever it is possible.

When we consider implementation of laser welding together with a robot system in manufacturing process, we can conclude that the weld quality achieved, weld joint properties and speed of welding justifies the expense incurred when implementing this technology. This technology will therefore enable us to offer a product on the market with a competitive edge in terms of both quality as well as product costs.

Calculation of penetration in laser welding process play important role, this paper indentifies that penetration as a function of 2 main parameters: relative focus position and weld speed.

Classical methods largely depend on manual welding which is detrimental to weld trajectory precision and accuracy. Laser welding as a technological process is always used in conjunction with robot production.

In automotive industry, weld point diameter is in the range of 0.5-1 mm. Narrow weld area in laser welding process makes this technique especially suitable for thin metal sheet welding. These facts open up new horizons in terms of quality, construction stability, weld integrity and new design possibilities.

Although laser welding infrastructure is expensive, it has found significant application in the automotive industry, especially in the segment of load bearing car chassis elements, for high speed cars.

Other industries that require precision of weld joint will find this technology attractive, so we can anticipate increased use of laser welding in a wide variety of applications in the future. Precision of this technology is derived from two characteristics: laser beam accuracy as well as robotization of the process.

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PRAMONINIŲ ROBOTŲ, SKIRTŲ APKRAUNAMŲ KONSTRUKCIJŲ LAZERINIAM SUVIRINIMUI MODELIAVIMAS

R e z i u m ė

Lazerinis suvirinimas automobilių pramonėje – neatsiejama technologinio proceso dalis. Palyginus su tipiniais suvirinimo technologiniais procesais, tokiais kaip MIG/MAG tipo ir taškiniu suvirinimu, lazerinis suvirinimas yra žymiai pranašesnis dėl mažų įtempių, didelio suvirimo greičio, suvirinimo kokybės ir lankstumo.

Šie pranašumai yra lemiami šiuolaikinėje automobilių pramonėje, dėl kokybės, nepriekaištingo tikslumo, garantuoja apkraunamų konstrukcijų saugumą, tuo pačiu užbaigto gaminio konkurencingumą. Aukštas suvirimo greitis ir trumpas suvirinimo siūlės atvėsimo laikas papildomai didina produktyvumą.

Šiame straipsnyje aprašomas pramoninio roboto, skirto apkraunamų konstrukcijų lazeriniam suvirinimui automatizuotame gamybos procese, modeliavimas. 3D darbo modeliavimas yra svarbus veiksnys, vystant robotų techniką. Šiandien mes galime modeliuoti kiekvieną gamybos proceso dalį naudodami IT priemones. Šis modeliavimas leidžia vystyti naujai kuriamus gamybos procesus esant minimalioms išlaidoms.

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SIMULATION OF INDUSTRIAL ROBOTS FOR LASER WELDING OF LOAD BEARING CONSTRUCTION

S u m m a r y

Laser welding is becoming an essential procedure in Automobile industry. Compared to standard welding processes such as MIG/MAG and point welding, laser welding has distinct advantages, such as small strains, higher speed of welding, quality welds as well as high flexibility.

These advantages are crucial in modern automobile industry since the quality and flawless accuracy of load bearing welds ensures safety and thus competitiveness of the final product. High welding speed and short cooling periods of the weld additionally increase productivity

This paper is a presentation of a simulation industrial robot laser welding of load bearing construction in automated production process. 3D simulation play very important role in robotics development. Today we can simulate every production process segment by using IT tools. This simulation process enables to develop new production processes with minimal costs.

И. Карабегович, Б. Грнйица

МОДЕЛИРОВАНИЕ ПРОМЫШЛЕННЫХ РОБОТОВ ПРЕДНАЗНАЧЕННЫХ ДЛЯ ЛАЗЕРНОЙ СВАРКИ ЗАГРУЖЕННЫХ КОНСТРУКЦИЙ

Р е з ю м е

В автомобильной промышленности лазерная сварка стала неотъемлемой частью технологического процесса. По сравнению с известными технологическими процессами сварки, такими как MIG/MAG, точечная сварка, лазерная сварка значительно превосходит упомянутые из-за незначительных напряжений, высокой скорости сварки, качества, и гибкости.

Эти превосходства являются определяющими в современной автомобильной промышленности, из-за хорошего качества, безупречной точности, гарантируют безопасность напряженных конструкций и конкурентоспособность завершенного изделия в целом. Высокая скорость сварки и короткий промежуток времени необходимый для охлаждения шва сварки, дополнительно увеличивало продуктивность.

В статье описано моделирование производственного робота, предназначенного для лазерной сварки загруженных конструкций и работающего в условиях автоматизированного производства. 3D моделирование его работы является важным фактором при усовершенствовании робототехники. Сегодня мы можем моделировать каждый этап производственного процесса при помощи IT технологий. Упомянутое моделирование позволяет усовершенствовать любые создаваемые процессы производства с минимальными затратами.

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