Conference Paper

Benefits and Prospects of Laser Welding Application in Vacuum

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Abstract

In the recent years laser beam welding has been more and more broadly used in the industry for the production of details of significant appointment. One of the perspective directions of laser technologies for the production of significant products of big thickness is the welding by the concentrated laser beam in vacuum that allows producing faultless welded seams with the high relation of seam depth to its width. The conducted researches confirm results of theoretical modeling of processes at laser beam welding.

Keywords: laser beam welding; laser beam in vacuum; depth of pro-melting; physical models processes

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1. Introduction

Laser beam welding is becoming more and more attractive in the industry for the production of the parts of significant appointment. Due to high concentration of thermal impact, high growth rates, and reduction of temperature in a handling zone as well as a possibility of fast formation of a welded bathtub, we can effectively apply laser light for welding process. The great interest to laser beam welding is caused by a number of benefits that profitably distinguish it from other welding methods. However, nowadays laser beam welding is generally applied for the welding of products of small thickness.

One of the perspective directions of laser technologies (i.e., production of significant products of big thickness) is welding by the concentrated laser beam in vacuum. By such method we can obtain faultless welded seams with the high relation of seam depth to its width. Based on the data from foreign references, we can argue that the scientific society makes only first efforts in studying the physical processes proceeding during laser beam welding in vacuum, which is necessary for the efficiency increase of welding technologies.

During laser beam welding in vacuum, the depth of pro-melting can be increased by 2-3 times as compared with laser beam welding in the atmosphere. Until now, the use of this method was not considered expedient because of high cost of laser equipment and its low energy characteristics. The electron beam welding is applied instead. At the same time, the use of laser beam has a number of advantages.

First, the laser beam interacts weakly with atoms of residual gases and metal vapors from a handling zone; thus we can conduct the process in a low vacuum. Electron beam welding requires the residual vapor pressure in the camera of about 10^{-1}-10^{-2} Pa. The laser beam welding demonstrates the benefits already at the pressure of about 1 kPa and 100 Pa. The obtained results do not differ practically from the outcome in case of 10^{-1} Pa. Due to this advantage we can abandon the molecular pumps and thus increase considerably technological effectiveness of the process. Besides, it considerably simplifies the creation of mobile local forvacuum systems, which can be applied for welding of large-size products.

Second crucial advantage is the lack of sensitivity of a laser beam to magnetic fields. The application of laser beam (i.e., in order to receive deep pro-melting) gives essentially new opportunities for the management of hydrodynamics of a welding bathtub via constant and variable magnetic fields.

At electron beam welding it is difficult to reproduce the mode of focusing. Laser systems have much more stable parameters of focusing in comparison with electron beam systems. The deviations of parameters are small in this case and can be caused only by the change of optical properties of a focusing lens under heating. Moreover, the focusing parameter is less significant at laser beam welding due to higher re-reflections intensity of a laser beam in the pro-melting channel.

The fact that the atoms of residual gases and metal vapors from a processing zone exert less influence on a laser beam causes more stable formation of a welded seam. So, the problem of root defects at laser beam welding is particularly less significant in comparison with electron beam welding. Note also the lack of x-ray radiation and possible arising of nonmetallic products, which is an additional advantage of laser beam welding.

2. Methods

Further studies of laser beam welding process in vacuum [1-5] have caused the emergence of laser beam welding technology in vacuum for practical use especially for products of big dimensions.

The elimination of root defects is very important at laser beam welding of big thickness in vacuum. The experts in the area of laser beam welding are generally familiar with the specified defects. We should stress out that by conducting the process in vacuum their size is increased. In order to overcome the obstacle, we can apply the methods widely used in technologies of electron beam welding eliminating root defects. These methods are: periodic impacts on a beam [6-7], the choice of optimum focusing [8-10], etc.

The additional factor that blocks the development of laser beam welding technologies in vacuum is the lack of physical models of the accompanying processes. The mechanism of pro-melting depth increase (the decrease of external pressure is still the debatable issue) and the complexity of the occurring phenomena require most up-to-date numerical experiments. The method for the determination of a steam-gas channel form based on the calculation of energy balance by step-by-step approach has been proposed in work [11]. In the work [12] the authors has described the application of this technique for electron beam welding. In the works [13, 14] you can find theoretical fundamentals of numerical modeling of stationary pro-melting provided by a laser beam, and in the work [15] the fundamental part of studies is greatly emphasized. The found analytical solutions and the use of numerical simulations (for simplified statements) contributed to the development of the applied LaserCad software product designed for the use in production in order to forecast laser beam welding results.

3. Results

The first attempts of conducting laser beam welding process in vacuum come back to the second half of the 80-s [1,2]. The works of descriptive character note the increase in pro-melting depth and change of a seam form.

In our research, we confirmed these regularities. We installed welded points on a flat sample on laser beam welding machine of the model ALFA – 300T in order to imitate laser beam welding process. The experiment was carried out in the open atmosphere and in a low vacuum. All points were subjected to the identical welding modes. Several welding points were produced in order to get accurate statistical data.

Visual studies have revealed that regardless of the environment the welding points have the comparable sizes of 0,8-1,2 mm with the deepening at the center of points. In some cases, the bottom has been visible in this deepening. Hence, we can determine the closing speed of the steam-gas channel. There are no visible cracks and no visible pores on the melted-off metal and in the heat-affected zone. As for visual distinctions, it is necessary to allocate the presence of temper colors: surface color of the points executed in the open atmosphere processes caused by oxidation.

The results of the metallographic studies of the most characteristic points are presented in Fig. 2. The formation of welding points executed in the open atmosphere has the form of an asymmetrical "mushroom". Pro-melting depth makes up 0,73-0,88 mm. The formation of welding points executed in vacuum has a more symmetric form of "mushroom" (with mainly dagger pro-melting). The depth of pro-melting makes up 1,12-1,17 mm. In both cases we observe dense metal of points without pores and cracks, with pure weld-fusion line and faultless heat-affected zone. The structure of both metal rows of points is of cellular and dendritic nature. The points created in the open atmosphere demonstrate dendrites of smaller sizes. This fact can be explained by the speed of crystallization processes at laser beam welding.

4. Conclusion

Nowadays, we should direct more attention not just to the processes that determine the dependence of pro-melting depth (taking into account the values of environment external pressure), but much more to the processes that proceed in the steam-gas channel at welding. Therefore, we could design mathematical models of processes. The studies of plasma torch emerging at laser beam welding will enable us to estimate

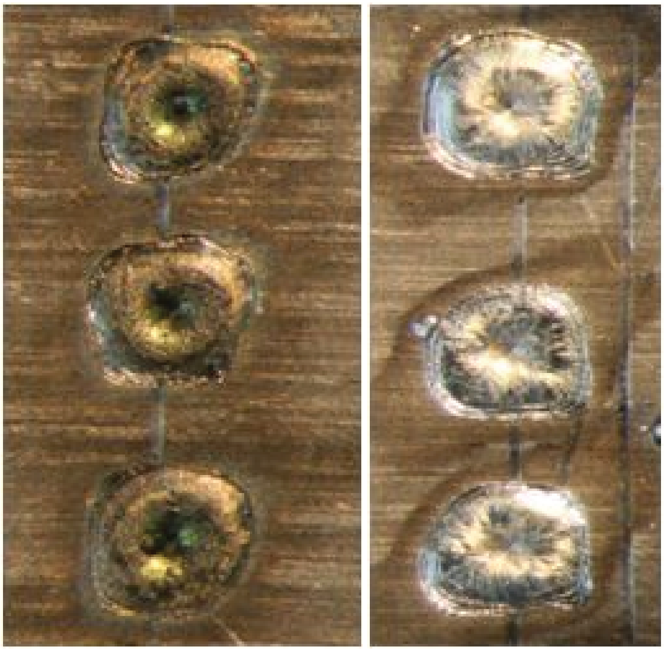

Figure 1: Configuration of welding points: welding is executed in the open atmosphere (a), welding is executed in a low vacuum (b).

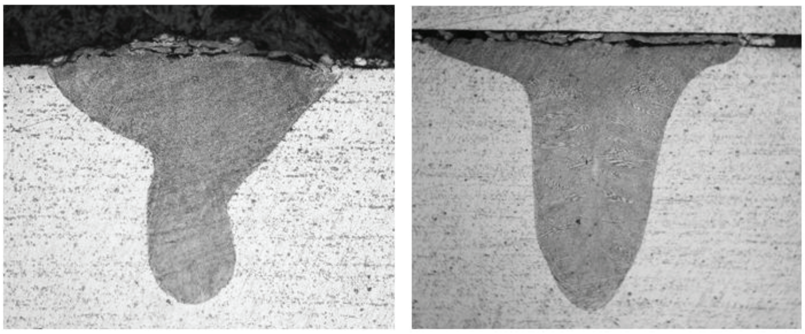

Figure 2: Microstructure of welded points, x50: welding is executed in the open atmosphere (a), welding is executed in a low vacuum (b).

the power characteristics of a welding process. The control and management system of laser beam welding process is based on these characteristics.

Thus, the study of processes that proceed during laser beam welding in the atmosphere and in vacuum is an actual task. It is important for development of highly effective technologies of laser beam welding of products of significant appointment.

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