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Spot Welding of Dissimilar Metals Using an Automated Nd:YAG Laser System

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Abstract: An assembled pulsed Nd:YAG laser-robot system for spot welding similar and dissimilar metals is presented in this paper. The study evaluates the performance of this system through investigating the possibility and accuracy of executing laser spot welding of 0.2 mm in thickness stainless steel grade AISI302 to 0.5 mm in thickness low carbon steel grade AISI1008. The influence of laser beam parameters (peak power, pulse energy, pulse duration, repetition rate, and focal plane position on the final gained best results are evaluated. Enhancement of the experimental results was carried by a computational simulation using ANSYS FLUENT 6.3 package code.

Introduction

Laser-robot welding processes have potential advantages over conventional materials processing methods. The advantages vary greatly depending on applications and results from the high flexibility of laser-robot systems, the non-contact nature of the processes as well as the capability of achieving consistent quality. Most of the laser-robot systems that are currently being used for welding employ CO2 laser-robot systems. The easy availability of high power CO2 lasers makes CO2 laser robot welding more popular than Nd:YAG laser-robot welding. In many instances, however, the Nd:YAG laser-robot systems may be more suitable for sheet metal processes than the CO2 laser-robot systems for the following reasons:

The solution of transmitting the Nd:YAG laser beam by an optical fiber provides high flexibility, accessibility and ease of maintenance, especially in three-dimensional process. This gives advantages over the CO_2 laser-robot systems [1]. The short wavelength of the Nd:YAG laser beam (1.06µm) means that metals such as aluminum or its alloys have higher beam absorption for the Nd:YAG laser beam than for the CO_2 laser beam [2]. In spite of the executed tasks in this work were of stationary heat source, the role of the robot is to be of great importance for the most sophisticated geometry of welding and for the tortuous welding tasks that require high maneuvering. Several Nd:YAG laser-robot systems are commercially available for wide range of applications that indicate potential advantages in production [3,4] With the development of high kW power Nd:YAG laser technology and the improvement of laser beam fiber optics, as well as the better performance of articulated robots, those researching and applying Nd:YAG laser-robot systems are turning their attention to sheet metal welding, especially in the automotive industry [5,6] Laser welding, fiber optics, robot performance for beam handling and pulsed Nd:YAG laser behavior are four important components of the Nd:YAG laser-robot system for material processing.

Over the last ten years, laser welding (spot and seam) has become a widely acceptable joining method for its several advantages compared to other welding techniques (low heat input, small HAZ, low thermal distortion of the workpiece, less risk of deformations, high welding speeds, deep and narrow weld shape, easy automation, no filler materials, welding complex joint configurations and different materials) as soon as it is a good choice when classical joining methods are not suitable. Laser welding is a keyhole fusion welding method which is obtained by a high power density, laser power is often in the range of 0.3-3 kW for Nd:YAG laser, and 5-10 kW for CO_2 laser, achieved with focusing a laser light beam to a very small spot. Due to this small spot, the energy is very concentrated, with a focused power density at the weld surface in order of 10^6 W/cm^2, which is one of the highest among the different welding processes available [7].

Integrated Nd:YAG laser-robot system

The pulsed Nd:YAG laser-robot system employed for the benefit of this article is constructed from the following components; Class four pulsed Nd:YAG 1.064 μm wavelength laser apparatus PB80, maximum output power of 80 W, peak power of 8 kW, and a single pulse capability up to 70J/10ms. The pulse duration is variable between 0.1 to 50 ms, and the repetition rate is 1-100Hz. The pulsed Nd:YAG laser has adjustable pulse shapes which offers high flexibility in optimizing the weld parameters to achieve defect free joints. That means the waveform can be divided into fourteen segments. This apparatus is equipped with a class 2 CW He:Ne laser of 0.5mW maximum output power for alignment purposes.

A manipulator model Motoman-HP6, type YR-HP6-A00, controlled six controlled axes, 6kg Payload, 1378 mm maximum reach, and repeatability of ±0.08mm. For a flexible maneuvering transmission of the laser beam from the laser apparatus to the manipulator an optical fiber of 0.4mm in diameter and 10m long is coupled to the laser output at one end and to the beam focusing head mounted on the manipulator at the other end. Figure 1 shows the employed Nd:YAG laser-robot system.

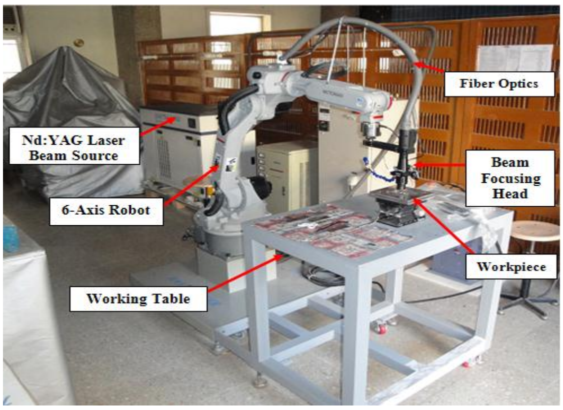


Fig.(1): Nd: YAG laser-robot system for material processing.

Materials

Power generation, structural, chemical, petrochemical and nuclear industries typically uses AISI 1008 steel [8,9]. Stainless steel AISI 302 is widely employed for heat exchangers industries, chemical and food processing [10]. Both materials were employed for the benefit of this evaluation using two overlapped workpieces with 20mm overlapping distance. The upper workpiece is stainless steel AISI 302 sheet of (100mm×10mm×0.2mm) facing the laser source while the carbon steel AISI 1008 sheet of (100mm×10mm×0.5mm) is the lower one. A clamping device is designed to compress both workpieces together during the welding task in order to ensure better contact between the welded sheets and overcome any gap may occur in between that may negatively affect the quality of the joint. For having guaranteed results the workpieces followed several preparation steps in order to suppress the effect of any existing defects in the welding region. Pure alcohol was used for acquiring the workpieces clean surfaces. Several grads of abrasive silicon carbide papers of rang (400, 1000, and 1200) grain / cm^2 were used for removing the oxide layers from the surfaces of the welded regions. Finally, HCL solution 50% concentration was used in order to get very clean surfaces followed by washing with distilled water [11].

By using a universal testing strength machine the base metal tensile strength for both stainless steel and low carbon steel was checked. The welded workpieces were tested for obtaining the tensile shear strength of the spot welded zone that compared finally with the base metal tensile strength for the evaluation of the joint quality.

Laser process parameters

Several workpieces that were already prepared for this purpose are welded using laser pulse peak powers of 2, 4, and 6 kW versus pulse duration of 1.5, 2.5, 5 and 8 ms. In addition, 3.8 mm standoff distance was chosen and 0.65 mm laser spot diameter focused on the workpiece surface. The welded workpieces then went through tensile shear strength test for determining the most successful working parameters that led the workpiece of the highest shear strength.

Results and Discussion

1. Experimental Results

Tensile shear test is achieved for the evaluation of the workpieces spot welding quality. The welding zone strength of the joined workpieces increased as the pulse energy increased as well as enlarging the pulse duration while decreasing the repetition rate. Several workpieces were welded choosing values of peak power ranging from 5-7kW with 0.5kW increment while fixing the pulse energy at 48J and the repetition rate at 2Hz in order to estimate the peak power effect.

Workpieces that were welded at 5.5kW of peak power show the highest quality of their welding zone (300N of shear strength). These working parameters that led to the highest strength of joining zone were employed for welding another workpieces with different values of pulse duration (5, 6, 6.5 and 7ms) for estimating its effect on the quality. Workpieces welded at 6.5ms of pulse duration show the highest shear strength in this group that is 244N. Hence, working parameters of 5.5kW, 2Hz, 48J, and 8.7ms were the most successful to be intended for the evaluation. Figure 2 shows the cross section of the spot welding zone that belongs to the most successful joined workpieces.

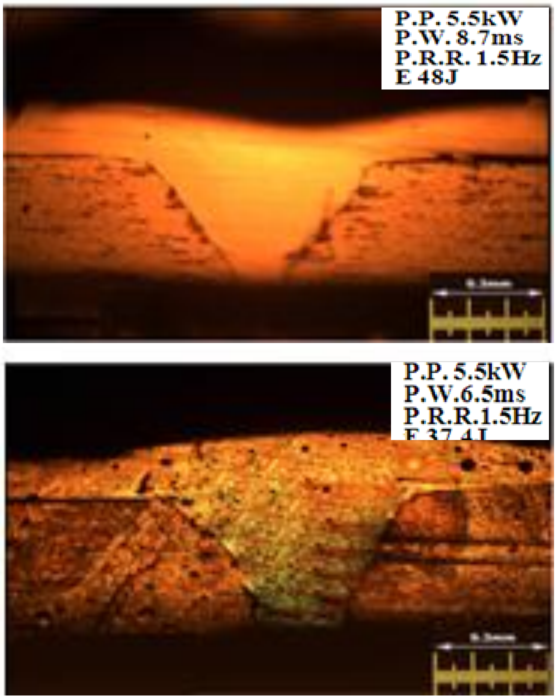


Fig. (2): Spot welding zone cross section view of the highest strength joined workpieces.

Computational Results

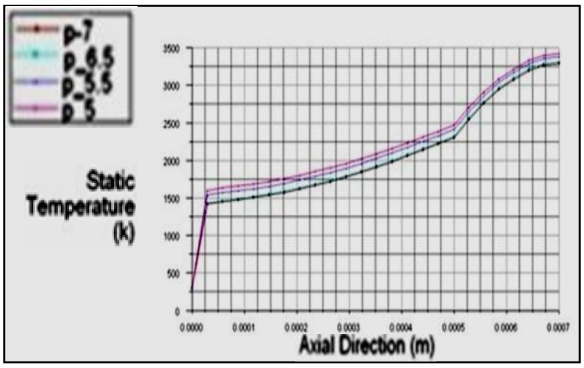
The following assumptions were taken into consideration for simplification:

−Temperature independency of material's physical properties.

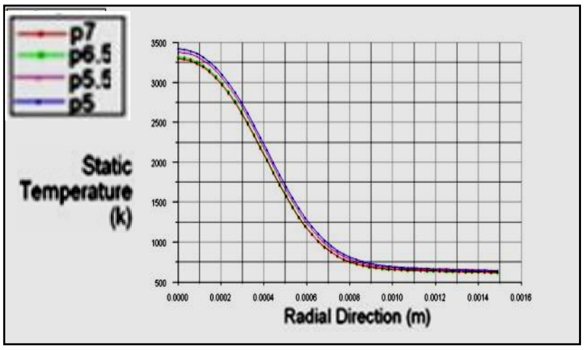
−Neglected internal generation.

−Homogenous and isotropy material of workpiece.

The analyzed section of the workpiece is meshed into a division of 0.03mm along thickness and width directions. The computational temperature distribution that results by varying the peak power (7, 6.5, 5.5, and 5kW) at a fixed pulse energy of 48 J and repetition rate of 2Hz is shown in Figure 3 along (a) the axial direction x and (b) the radial direction y.



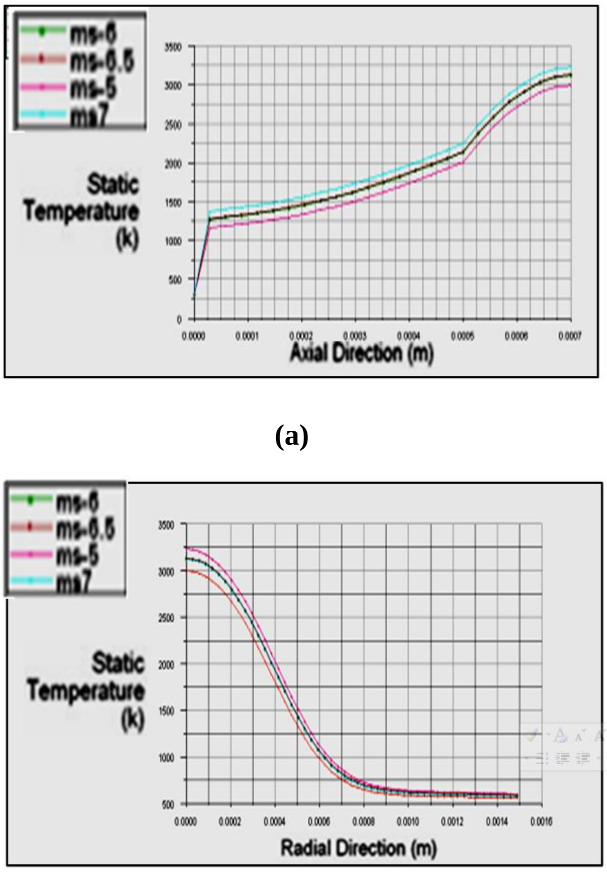
(a)



(b)

Fig.(3): The computational temperature distribution for different values of peak power along (a) the axial direction x and (b) the radial direction y.

The computational temperature distribution that results by varying the pulse duration (7, 6.5, 6, and 5ms) and fixing the peak power at 5.5kW and repetition rate of 2Hz is shown in Figure 4 along (a) the axial direction x and (b) the radial direction y.



(a)

(b)

Fig. (4): The computational temperature distribution for different values of pulse duration along (a) the axial direction x and (b) the radial direction y.

Conclusion

Laser performance for material processing can be evaluated by the beam quality and the fluctuation of beam power. The effective focus range, beam orientation angle and path deviation tolerance can be used to evaluate robot performance for different tasks of laser material processing.

References

1. Walker, R. W., The Role of Fiber Optics in Laser Material Processing. SAE-The Eng. Society for Advancing Mobility Land Sea Air and Space, Aerospace Technology Conf. and Exposition, Anaheim, California, 1989, pp. 77—85.

2. Bagger, C., Investigations in on-line process control of the laser welding process. Dissertation, Technical University of Denmark, January 1991, Publication no. AP 91-02/PI.91.1-A.

3. Hanicke, L., YAG/fiber-robot system for laser cutting in carbon steel. Lasers in Manufacturing Conf. LIM-5. IFS Ltd, Stuttgart, September 1988.

4. Belforte, D. A. & Levitt, M. R., Annual technology, industry, and market review and outlook. In The Industrial Laser Annual Handbook, Vol. 1241 ed. D. Belforte. Pennwell Books, Oklahoma, USA, 1990.

5. Shibata, K., Laser processing in the Japanese automotive industry. Laser Applications in the Automotive Industries, Symposium on Automotive Technology and Automation, 25th ISA TA ed. J. E. Soliman. Automotive Automation Ltd, Croydon, UK, 1992, pp. 431—7.

6. Tonshoff, H. K. & Beske, E. U., 3-D laser material processing by KW Nd:YAG lasers, optical fiber and robotics. In Proceedings of 23rd ISATA- 90, Vol. 1, ed. J. E. Soliman. Automotive Automation Ltd, Croydon, UK, 1990.

7. Alberto J. P. F., Mechanical properties of Hybrid laser-MIG welding and spot welding on lap joint, Luleå University of Technology Department of Applied Physics and Mechanical Engineering Division of Manufacturing Systems Engineering, Luleå, June 2008.

8. Perrie W., Rushton A., Gill M., Fox P. and O'Neill W. "Femtosecond laser microstructuring of alumina ceramic". Applied Surface Science, 248, 213–217, 2005.

9. Vikulin V., Kelina I., Shatalin A., Rusanova L. ''Advanced Ceramic Structural Materials,'' Refractories Ind. Ceram, 45, 383–386, 2004.

10. Elijah K. - Asibu, Jr., "Principles of Laser Materials Processing", John Wiley & Sons, Inc., USA, 2009.

11. J. D. Farren, J. N. Dupont and F.F. Noecker, "Fabrication of Carbon Steel-to-Stainless Steel Transition Joint Using Direct Laser Deposition : A Feasibility Study", Welding Journal, March, 555-616, 2003

لحام نقطي لمعادن غير متماثلة باستخدام منظومة مؤتمتة لليزر النديميوم:ياك النقطي

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الخلاصة تم في هذه الدراسة تقييم أداء المنظومة المشار إليها من خلال التحقق من أمكانية ودقة تنفيذ لحام نقطي باستخدام هذا الليزر لمعدن فولاذ مقاوم للصدأ نوع AIS302 بسمك 0.2 ملم مع معدن فولاذ ذو محتوى كربون واطئ نوع AISI1008 بسمك 0.5. هذه الدراسة تقيم تأثير معاملات الليزر (القدرة العظمى، طاقة النبضة، زمن النبضة، معدل التكرار، وموقع مستوي البؤرة) على النتائج النهائية التي يتم الحصول عليها. تم تعزيز النتائج العملية بمحاكاة حاسوبية باستخدام البرنامج الحاسوبي التطبيقي ANSYS FLUENT 6.3