Optimization of Laser Welding Parameters: A Review

Amey K. Tilekar[1], Nitin K. Kamble[2]

[1]*M.E-Final Year, Dept. of Production Engineering, D. Y. Patil College of Engineering, Pune, India*
[2]*Professor, Dept. of Production Engineering, D.Y. Patil College of Engineering, Pune, India*

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Abstract - *Now-a-days it is of great importance to select a proper welding process to obtain optimal weld geometry. Laser welding is a non-conventional joining process which is used to weld various types of ferrous and non-ferrous materials and their alloys. An intense laser light is used to heat the material to form a weld. Various input parameters of laser welding, viz., laser power, weld speed, focal length, fiber diameter, shielding gas etc. are reviewed in this paper. The effect of these input parameters on different material and response parameters like weld width, weld penetration, characteristics of heat affected zone, tensile strength of weld etc. are revised from different aspects.*

Key words: Laser power, weld speed, focal length, weld width, heat affected zone.

1. INTRODUCTION

Automobile industry is constantly coping with continuous research and development in the field of joining technology to get efficient and high quality of weld. In conventional welding processes the strength and toughness of the weld joint produces is very poor. In traditional CO_2 welding process, large amount of heat is involved during the process, affecting the microstructure of the base metal. Owing to these difficulties while manufacturing a weld, laser welding was found out to be more efficient than other conventional machining process. Laser welding is a advance welding process which has characteristics like high efficiency and power, low maintenance cost, flexible beam delivery and has a compact size as compared to other welding technologies. Laser welding process produces the coalescence of the materials by application of concentrate coherent light beam impinging upon the surface of the material to be joined. Laser stands for Light Amplification by Stimulated Emission of Radiation. Optical systems like focusing elements or lenses are used to direct the beam on materials to be joined. It is a non contact type of welding process where pressure is not required and can join less thickness materials easily. Generally shielding gas is used to avoid the oxidation of the weld pool and filler metal is used occasionally depending upon the application. Firstly, CO_2 type of laser welding were used, but recent advantages in Nd:YAG laser, which are capable of producing high powers of 2 kW or more through use of fiber optic cable.

Laser welding process consist of various input parameters , viz., laser power , weld speed, focal length, fiber diameter, shielding gas are major of them. Each input parameter has significant amount of contribution to get desired weld for given material. So, it is really important to validate whether a good quality of weld is produced with given set of input parameters. In these review paper a summary of research done by various authors in laser welding technology is being highlighted. A brief summary of input parameters, materials and methodology used, output responses observed are discussed from different perspective.

2. LITERATURE REVIEW

M. M. A. Khan, L. Ramoli, M. Fiaschi, G. Dini, F. Sarri [2010][1]: Their research is based on optimization of laser welding process parameters for martensitic AISI 416 and AISI 440 FSe stainless steels. Constrained overlap configuration of weld was used for thickness of 0.55mm. Full factorial DOE is prepared in Design Expert V7 software which consist of 18 experiments having 3 levels of laser power and welding speed respectively and 2 levels for fiber diameter. The response parameters considered are weld width , weld penetration, resistance width and shearing force. ANOVA is used to find out the most significant factor among the process parameters. It is concluded that laser power and welding speed is most important factors affecting weld bead geometry as well as shear force of weld. Laser power in range of 800-840W, weld speed 4.75-5.37m/min and fiber diameter of 300μm are optimal setting of welding parameter for given material.

J. Ahn, L. Chen, C. M. Davies, J. P. Dear [2016][2]: In this work full penetration laser weld of Ti-6Al-4V is evaluated considering laser power, welding speed and beam focal position as input process parameters. Microstructural change, weld defects, characteristics of heat affected zone and weld metal are taken as response parameters. Traditional method is used in this research where two process parameters were varied keeping one constant. It is concluded that weld width of work piece is increased with increase in laser power and focal length and less laser speed. Incomplete penetration was observed at low speed and undercut was observed at high speed. Spatter was observed at bottom of work piece with high welding speed.

Yuewei Ai, Ping Jiang, Xinyu Shao, Chunming Wang, Peigen Li, et. al. [2015][3]:They studied the process parameters effects on the responses. The research insights the optimization method that is defect reducing which considers the geometric effect of bead of weld as evaluation indexes of weld defects. Laser power, weld speed, focal position and gap between two work piece are taken as process parameters whereas left and right front width, back width and bead height are taken as output parameters. DOE is created by Taguchi with 5 factor levels of each process parameter. A non-linear mathematical model is formed by using particle swarm optimization and back propagation neural network (PSO-BPNN) and genetic algorithm (GA) is adopted to solve the model. It is concluded that the predicted results from PSO-BPNN are reasonable accurate. The welding process parameters have been optimized by GA for the desired weld bead and minimum defects. The optimal results demonstrate good agreement with the experimental results.

Zhongmei Gao, Xinyu Shao, Ping Jiang, Longchao Cao, et. al., [2016] [4]: They investigated the significance of suitable welding parameters of a hybrid laser arc welding to obtain optimal weld geometry of AISI 316L austenitic steels. Welding current, laser power, travelling speed and distance between laser and arc are taken as input parameters and bead width, penetration depth and bead reinforcement are taken as output parameters. A five level four factor L_{25} Taguchi matrix is designed considering the process parameters. A Kriging model opted to proximate the relationship between input parameters and response parameters. The model was then used for optimization of parameters by using genetic algorithm (GA). It was found out that laser power, welding current, and weld speed are main effects analysis on penetration depth, bead width and bead reinforcement. Microstructure of optimized weld is more uniform than un-optimized weld. The microstructure analysis showed that micro hardness decreases towards the center of weld zone, while it is highest in the base metal.

Shanmugarajan B., Rishabh Shrivastava, Sathiya P., Buvanashekaran G. [2016][5] :They optimized the laser welding process for P92 creep strength enhanced ferritic steels (CSEF) which are used in piping, tubing etc. Taguchi based grey relational analysis (GRA) was used to be built up a model with input parameters as laser power, welding speed, focal position and weld width , depth of penetration and heat affected zone width as the output parameters. Most influenced parameter is found with the help ANOVA from the GRA model. From ANOVA, it is concluded that welding speed has the most significant contribution of 74.39%, followed by 014.63% of laser power and 10.97% of focal length. The Taguchi based GRA model gave 3kW of laser power, 1m/min of welding speed and focal position at 4mm as optimized values for given conditions of P92 material.

Mingjun Zhang, Genyu Chen, Yu Zhou, Shenghui Liao [2014][6]: In their research 12 mm thick plate of type 304 stainless steel is laser welded with deep penetration by 10kW high intensity fiber laser. Focus lens, focus size, welding speed, laser power, shielding is considered as a process parameters and cross- section weld penetration, top and bottom weld width for 3 different shielding gases , i.e., Ar , N_2, and He are considered as output parameters. Laser welding is carried out by industry accepted standards, the samples are cut by EDM, polished and etched were observed under metalloscope. Transverse tensile test is conducted on UTM and failed samples are examined by scanning electron microscope (SEM) to identify fracture pattern. After analysis, it is found out that full depth penetration for thick sheets cannot be obtained by proper focal position. Weld speed is directly related to focal position. Weld depth was maximum for helium, followed by nitrogen and argon being the last.

Yangyang Zhao, Yansong Zhang, Wei Hu, Xinmin Lai [2012][7]:They Investigated the effect of laser welding parameters on weld bead geometry of thin-gage galvanized steel of 0.4mm thickness. SAE1004 grade steel with a lap joint configuration has been considered with welding speed, gap, focal position, and laser power as input parameters. Response surface methodology (RSM) is used to develop a model with weld width; weld depth and surface concave as the response parameter are considered. It was found out that there was a negative effect of welding speed on all the response factors, whereas there was a positive effect of laser power on output. To obtain a acceptable joint a prescribed gap is needed to be maintained between the two materials to be joined. RSM has determined the optimal parameters which are follows - welding speed 34.7mm/s, prescribed gap of 0.12mm , defocus amount -0.12mm and laser power of 628W.

U. Reisgen, M. Schleser, O. Mokrov, E. Ahmed [2011][8]: They stated that the quality of laser weld is dominated by setting of input parameter. Dual phase (DP)/Transformation induced plasticity (TRIP) steel sheet is welded with CO_2 laser beam welding process. A model is developed using response surface method based on Box-Behnken design with focal position, laser power and welding speed as the process parameters. Heat input, weld bead penetration, weld bead width, tensile strength and limit dome height are taken as response factor in this study. By choosing desired goals for each factor and its responses, numerical as well as graphical optimization methods are used. It is concluded that a strong, efficient, and low-cost joint can be achieved by using optimal welding conditions. The welding cost is reduced to 11.7% in three comparing criteria and maximum of 14.7% was reached comparing the other values. The welding speed is maximum or near to maximum which increases the production rate.

E.M. Anawa, A.G. Olabi [2008][9]: Studied the joining of a popular dissimilar metals consisting of ferritic/austenitic (F/A) material which is used in many applications. Taguchi approach is used to create a L_{25} matrix of the process factors which consist of focal position, laser power and welding speed. Notched tensile strength and signal to noise ratio is taken as the response factor. Two plates of mild low carbon steel and AISI 316 stainless steel is laser welded in this study. After analysis it is found out that laser power is most significant factor associated with the response, followed by welding speed. Focus point position has no significant effect on the response within the range of parameters applied. The optimal tensile strength value of 656MPa is obtained by the new model developed in Design Expert software. The optimal process factors obtained is 1000mm/min of laser weld speed, laser power of 1.31kW and focal position of -0.67mm respectively.

K.Y. Benyounis, A.G. Olabi, M.S.J. Hashmi [2007][10]: Investigated the laser welded butt joint of AISI304 stainless steel. In order to obtain good welded joint the mechanical properties of the materials should be controlled effectively. Tensile strength, impact strength and joint operating cost of laser welded joint are taken as response factors. To establish the relationship with the response parameters laser power, focal point position and welding speed are taken as the input factors in this study. Response surface methodology is a combination of mathematical and statistical technique which is useful for finding out the optimal response affected by set of input variables. Graphical analysis and ANOVA both are used to in finding the most significant process factor which contributes in obtaining the optimal response. After the analysis, it is concluded that welding speed should be in the range of 35 to 39 cm/min at focal point of -0.2mm and the weld speed should be 60cm/min at focal point of value -0.8mm. Laser power is found out to be optimal in the range of 1.2 to 1.23kW. Quick search of optimal weld setting can be carried out by using graphical optimization technique. 43% cost reduction in weld can be obtained by using the optimal welding conditions for given application.

3. SUMMARY

Studying the above literature it is understood that there is need to optimize the input process parameter in order to get good quality of weld joint. There is different set of input factors associated with different materials, so there is large scope for improvement in laser welding process. Laser power, laser welding speed, focal position and fiber diameter are the main process parameters, which have large influence on responses which are to be mapped. Laser power and weld speed are highly dependent on each other, combination of these two majorly contribute to produce weld joint. Focal position and fiber diameter influence the width of weld and heat affected zones as well as the penetration of the depth, which should be appropriately set to get desired weld joint.

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