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EXPERIMENTAL STUDY ON THE INFLUENCE OF LBW PROCESS PARAMETERS ON MECHANICAL PROPERTIES OF AISI 4130 &AISI 304 DISSIMILAR METAL JOINTS

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Abstract: Laser beam welding is a fusion welding process in which work piece is welded due to high temperature generated by concentrated beam of laser light. In this paper a full depth butt welding of stainless steel AISI 304 and Alloy steel AISI 4130 sheets of 2 mm thickness by using CO2 laser welding machine. L_{25} is done by using Taguchi method i.e. level 5 by considering process parameters i.e. power intensity, welding speed, beam angle, focal point position and focal length. The experimental output results that are measured for the mechanical properties like Tensile Strength and Impact Strength. The Analysis of Variance (ANOVA) is carried out to obtain the influence of the process parameters and statistical evolution of the results. The Genetic Algorithm is used to determine the best combination of the process parameters of the LBW.

Keywords—Laser Beam Welding, Analysis of Variance, Genetic Algorithm.

I. INTRODUCTION

Laser melting of plate metals offers considerable advantages over the conventional techniques. Some of these advantages include precision of operation, local processing, fast processing time, and low cost. The proper selection of welding parameters is necessary for defect-free welded joints. In addition, high temperature gradients developed in the welded section result in high stress fields in this region, which can limit the practical applications of the welded products. The model study gives physical insight into the welding process, which provides useful information on the process control and stress levels in the welding sections.

With the materials, the need for welding of complex shape with various applications is on strong demand in the industry. Laser Beam Welding is used extensively due to its small and narrow welding zone. Due to narrow focusing zone of the laser beam, a very low heat input is produced in the weld bead which in turn creates no Heat affected Zone (HAZ) or a very narrow HAZ. Moreover, less residual stress is produced in the weld metal and no deformation is produced in the weld joint.

In order to laser beam weld two dissimilar materials with two different metallurgical and mechanical properties, the selection of proper welding variables is very important variations in the material properties of dissimilar materials, such as laser beam attractions, melting points and heat conductions can influence the quality of the joint. In this study, two steel materials are being welded. One of the materials is made of AISI 4130 alloy steel and the other material is made of AISI 304 steel.

II. LITERATURE SURVEY

In any welding process of dissimilar metals, it is important to analysis the parameters performance which can be obtained by Weld joints results. Quite a good number of published papers show the usability of metallurgical investigation of both non-fusion and fusion weldings including LBW of different materials. A brief literature is presented in the following:

Jaiteerth, et al., [1] have studied microstructural and mechanical behavior of fiber laser beam and tungsten inert gas dissimilar ultra-high strength steel welds. In this comparative study Laser beam weld joints have shown higher weld joint strength has improved the joint efficiency from 62% to 97% in terms of ultimate tensile strength with rapid heating and cooling experienced by the HAZ efficiencies as compared to pulsed current TIG weld joints. Mahmoud et al., [2] have investigated that the welding speed influences the hardness and corrosion resistance of similar (304) and dissimilar Stainless Steels (304) / Carbon Steel Alloys (A36) welding by LBW.

Arivarasu et al., [3] have conducted experiments on metallurgical and mechanical properties of CO2 LBW joints of Alloy 825 (intermetallics TiN and Al4C3) for Vickers micro hardness, tensile and impact tests. The tensile test at 180° root bend of weld joints ascertains the soundness by SEM / EDS analysis and shown to have improved the weld metal strength and hardness.

Nikhil Kumar, et al., [4] have investigated the effect of incident angle on the weld pool geometry, microstructure and tensile property of the welded joints by welding of Austenitic stainless steel 304 with varying incident angle of pulsed Laser Beam.

Mechanical behavior joints of AISI 4130 Steel obtained by TIG and LBW are studied by comparing each other process. It is shown that the LBW is more suitable for mechanical characterization Souza Netoa et al., [5].

The GTAW method used for investigating the Properties of dissimilar weld joints of AISI 4130 and AISI 316 steels by GTAW are investigated Mostaan et al. [6]. Further, Interface structure is analysed by SEM with EDS.Though the literature shows that the joint properties of the LBW of dissimilar steel joints are affected by Power (W), Speed (m/min) Beam Angle, Focal Point Position (mm) and Focal Length (mm), but they are limited to one or two input parameters. Therefore, experiments are carried-out with various levels of process parameters in the present work.

2. 1 Objective of Present Paper

The literature shows that little investigations on LBW, considering the laser power-A, Speed-B,beam angle-C, focal position-D and focal length-E. Therefore, more research is required for understanding on the effect of different LBW parameters on welding properties of alloy AISI 4130 Steels and AISI 304 Alloy Steel. Hence, a solemn attempt is made in the present work to conduct experimentation with an objective of joining of dissimilar metals and study the effect of input parameters on mechanical properties like, Ultimate Tensile strength (UTS) and Hardness. Then, optimal combination of input process parameters is estimated using Genetic Algorithm so as to achieve good mechanical properties of the welded joints with better surface finish.

III. EXPERIMENTAL PROCESS

Experiments carried out based on Taguchi L25 Orthogonal Array design of experiments for Laser Beam Welding. DOE is shown in the Table 1. The experiments are conducted with a CO2 LBW system of 4kW (Trump Model), keeping the average power constant at 4 KW throughout. The experimental welding process and welded samples of LBW are shown Figure 1. Test Specimens are prepared as per standard UTS of ASTM E 8M-01 and Micro hardness. Then the test results of each joint sample are presented in Table 2 (Columns UTS and Hardness).

Figure 1. Weld joints of the dissimilar metals

Table 1. DOE for the Experimental work with Mechanical Properties.

S.NO	INPUT PROCESS PARAMETERS					OUTPUT RESPONSES	
	A	B	C	D	E	UTS (MPa)	MH HV1
1.	1500	1.2	87	-0.2	16	645.60	548
2	1500	1.4	89	-0.1	17	645.60	530
3.	1500	1.5	90	0	18	542.40	525
4..	1500	1.8	91	0.1	19	296.8	621
5.	1500	2	93	0.2	20	344.80	636
6.	1700	1.2	89	0	19	644.80	484
7.	1700	1.4	90	0.1	20	525.60	539
8.	1700	1.5	91	0.2	16	645.60	528
9.	1700	1.8	93	-0.2	17	232.00	652
10.	1700	2	87	-0.1	18	584.00	482
11.	1800	1.2	90	0.2	17	524.8	541
12.	1800	1.4	91	-0.2	18	668.80	459
13.	1800	1.5	93	-0.1	19	646.40	548
14.	1800	1.8	87	0	20	639.20	536
15.	1800	2	89	0.1	16	672.00	474
16.	2000	1.2	91	-0.1	20	671.20	438
17.	2000	1.4	93	0	16	650.40	454
18.	2000	1.5	87	0.1	17	645.60	529
19.	2000	1.8	89	0.2	18	336.80	518
20.	2000	2	90	-0.2	19	260.00	584
21.	2200	1.2	93	0.1	18	644.80	527
22.	2200	1.4	87	0.2	19	308.00	525
23.	2200	1.5	89	-0.2	20	644.80	520
24.	2200	1.8	90	-0.1	16	672.80	531
25.	2200	2	91	0	17	656.80	452

4 Analysis of Variance and Regression

A Statistical Analysis of Variance (ANOVA) is carried-out on the significant process parameters as shown in Table 4. ANOVA is a particular form of statistical hypothesis testing tool to identify the most significant factors and their percentage (%) of contributions by the control factors for each of machining response and validation. Finally, Confirmation experiments are conducted for verification and validation of the optimal process parameters.

4.1 Results of UTS

The results of ANOVA for IS are shown in Table 2. Input parameters, followed by Degrees of Freedom, Seq SS, adj SS, adj MS,F-Value, P-Value and percentage of contribution (% C) are shown in columns. Similarly, the columns in ANOVA results for MH are shown in Table 3 with same parameters and symbols.

Table 2 ANOVA Results for UTS

Source	DF	Seq SS	Adj SS	Adj MS	%C
A	4	63242	63242	15810	11.32
B	4	133773	13377	33443	23.95
C	4	36460	36460	9115	06.50
D	4	161233	161233	40308	28.87
E	4	129793	12979	32448	23.24
Error	4	33916	33916	8479	
Total	2	558417			

The percentage of contribution of each parameter for UTS is shown Table 2. It is clear from the experimentation, that the percentage of contribution of values for Laser power (11.32%), welding speed (23.95%), beam angle (6.5%), focal point position (28.87%) and focal length (23.24%), respectively. It is observed that the focal point position has the greatest influence on UTS. Value of R2 = 93.93% confirms the reliability of experiments. It is also clear from the results that the focal point position is the major factor with (28.87%), is to be selected to get better ultimate strength.

4.2 Results for micro Hardness

Table 3 ANOVA Results for Micro Hardness

Source	DF	Seq SS	Adj SS	Adj MS	% C
A	4	18601	18601	4650.3	22.43
B	4	17355	173555	4338.7	21.00
C	4	15600	15600	3900.1	18.90
D	4	19763	19763	4940.9	23.84
E	4	9538	9538	2384.5	11.50
Error	4	2041	2041	510.2	
Total	24	82899			

It is clear from the experimentation, that the percentage of contribution of for Laser power (22.43%), welding speed (21%), beam angle (18.9%), focal point position (23.84%) and focal length (11.5%). It is observed that the focal point position has the greatest influence on ultimate tensile strength (UTS). R2= 97.54% confirms the reliability of experiment. Thus, it is clear that the maximum contribution with 23.84% focal point position has to be selected to get better ultimate strength.

Regression analysis

Output characteristics pertaining to UTS and MH are formulated as regression equations and as given in the following.

$$UTS = 2057+0.088P-199S-9.1\Theta-204F-29.4L \quad \ldots\ldots (2)$$

$$MH = 85-0.0969P+53.7S+ 4.58\Theta+31.2F+ .72L \quad \ldots (5)$$

Where P, S, Ɵ, F and L represent of Laser power, Welding speed, Beam angle, Focal point position and Focal length respectively.

Optimization

The scheme of experiments to investigate the effect of process parameters on performances measures like UTS and Micro Hardness are conducted and results are analyzed using Genetic Algorithm (GA) technique.

Genetic Algorithms (GAs) are adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. As such they represent an intelligent exploitation of a random search used to solve optimization problems. Although randomized, GAs are by no means random, instead they exploit historical information to direct the search into the region of better performance within the search space. The basic techniques of the GAs are designed to simulate processes in natural systems necessary for evolution; especially those follow the principles first laid down by Charles Darwin of "survival of the fittest".

The various elements of genetic algorithm such as representation of chromosome size of initial population, objective function and fitness function, crossover operator, mutation operator, probability of crossover, probability of mutation and termination criteria are termed as "GA Parameters".

The obtained regression equations are used as fitness functions and are optimized in the MATLAB software via Genetic Algorithm (GA) tool. Table 1.4 shows the optimal process parameters from Genetic Algorithm (GA) tool.

Table 4 Optimized values of laser processed joints.

	Optimal value	P (W)	S (m/min)	θ°	F (mm)	L (mm)
UTS(MPa)	790.50	2200	1.2	87°	-0.2	16
MH(HV1)	613.60	1500	2.0	93°	-0.2	16

CONCLUSIONS

Conclusions based on the experimental results are shown in the following:

- Sound weld is obtained on joining of dissimilar AISI 4130 and AISI 304 steels by LBW.
- LBW is suitable for welding AISI 4130 with AISI 304 steels for industrial applications owing to high welding speed and highest UTS 731.54 MPa and Micro Hardness as obtained for the experimental joints.
- ANOVA results show that the Focal point position(mm) 28.87% is the major influencing process parameter on UTS, whereas Focal point position 23.84% on Hardness.
- Ultimate tensile strength and Micro hardness were found to be 790.5 Mpa and 613.6 HV1 at optimum settings from Genetic Algorithm.

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