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EXPERIMENTAL EXAMINATION OF WELDING PROCESS PARAMETER ON DISSIMILAR MATERIAL BY USING FULL FACTORIAL DESIGN

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ABSTRACT

Design engineers are gradually faced with the need to join dissimilar materials as they are seeking creative new structures or parts with engineered properties. Sometimes a part needs high-temperature resistance in one area, good corrosion resistance in another. Improving the ability to join dissimilar materials with engineered properties are enabling new approaches to light-weighting automotive structures, improving methods for energy production, creating next generation medical products and consumer devices, and many other manufacturing and industrial uses. The main objective is to analyses the effect of welding on dissimilar plate of alloy steel and mild plate. In this case variation of voltage, welding speed and welding current (machining parameters) will give the strength variation. Tensile testing and Impact testing (responses) using hammer excitation Total full factorial design is selected for 27 numbers of experiments is conducted. ANOVA table are calculated for significant parameter affects weld performance of weld joint on base.

KEYWORDS: Dissimilar welding; Universal Testing; Impact Testing; ANOVA; Welding Strength; Full factorial design.

1. Introduction

The integration of efficient quality welding technologies for dissimilar metals will be a key component in the successful weld quality for transportation and power plant systems.

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Welding of dissimilar metals with melting one of the metals is efficient if the welding conditions that determine the duration of the interaction between the solid and liquid metal are strictly controlled. The properties of the welded joints and the feasibility of the welding processes are influenced by many factors: for example, carbon migration from the low-alloy side, and the microstructure gradient and residual stress situations across different regions of the weld metal.

Due to welding process parameters directly affecting the quality of the weld joints, it is necessary to work in the suitable range. However, defining the suitable parameters to obtain the required quality welded joints is a time-consuming process. Several optimization methods are utilized in order to solve this problem. The Taguchi method is one of the most common design of experiment (DOE) techniques that allows the analysis of experiments with the minimum number [1-2]. In the literature, several researchers have used DOE methods to optimize quality characteristics in welding parameters.

Benyounis and Olabi [3] have presented a review of the application of optimization techniques in several welding processes. Anawa and Olabi [4] used the Taguchi method for the purpose of increasing the productivity and decreasing the operation cost of laser welding ferritic-austenitic steel sheets. Another study of the authors [5] analyzed the optimized shape of dissimilar laser welded joints and fusion zone area depending the process parameters. The Taguchi method and desirability function analysis relate the parameters to the weld bead dimension and the tensile strength of the joints with various shielding gasses is given by various researchers [6-8].

In addition to these studies, several researchers used other DOE methods to investigate the effect of laser parameters on the mechanical properties and bead geometries of laser welded joints. Benyounis et al. [8] examined the influence of process parameters on the weld bead geometry. They stated that weld bead dimensions were affected by the level of heat input. Ruggiero et al. [10] and Olabi et al. [11] showed the effects of the process parameters on the weld geometry and operating cost for austenitic steel and low carbon steel. The authors developed models and stated that, in terms of weld bead dimensions, the most influential parameter was welding speed. Reisgen et al. [12] optimize the parameters of the laser welded DP and TRIP steels to obtain the highest mechanical strength and minimum operation costs. Zhao et al. [13] investigated the effects of prescribed gap and laser welding parameters on the weld bead profile of galvanized steel sheets in a lap joint format and developed regression models.

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Benyounis et al. [14] reported the multi-response optimization of laser welded austenitic stainless steel. They developed mathematical models and established relationships between process parameters and responses, such as cost, tensile and impact strength.

The aim of this work is to optimize welding process of a selected important dissimilar material stainless steel and mild steel materials. Further, full factorial design parameter design can optimize the performance through the settings of design parameters. It can also reduce the fluctuation of system performance to allow the source of variation to be identified. The tensile strength and impact failure test, discussed as responses of dissimilar welding processes.

2. SELECTION OF MATERIAL FOR WELDING

Stainless steel is a variation of the 18% chromium 8% nickel austenitic alloy, which is the most familiar and the most frequently used in the stainless steel family. Alloy 302 is a slightly higher carbon version of 304, often found in strip and wire forms. It is a tough, ductile grade that demonstrates comparable corrosion resistance, is non-magnetic, and is not harden able by heat treatment. Alloy 302 is usually used in its annealed condition and has a high ease of fabrication and formability.

Steel is made up of carbon and iron, with much more iron than carbon. In fact, at the most, steel can have about 2.1 percent carbon. Mild steel is one of the most commonly used construction materials. It is very strong and can be made from readily available natural materials. Table 1 and 2 represented the chemical properties of stainless steel and mild steel respectively.

Table 1 Mild Steel Chemical Properties

Mild steel	C	Ma	Si	S	P	Rest Iron
%	0.16-0.18	0.70-0.90	0.40	0.04	0.04	

3. JOINT DESIGN AND PREPARATION

In this study two types of design weld joints have been applied, firstly, the butt joint design was applied for joining ferrous to ferrous dissimilar components, and secondly, the overlap joint design was applied for joining the ferrous dissimilar materials as shown in Fig. 1.

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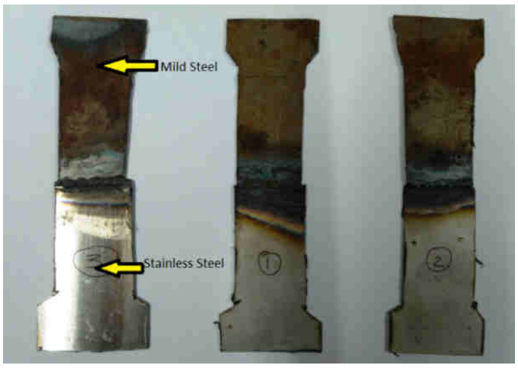

Fig 1 Specimen of Weld joints for tensile test

The above mentioned dissimilar materials were jointed using butt welding jointing design and the welding input parameters were studied. The operating range was determined using pilot experiments. The welding inputs variables and machining parameters and their levels are presented in Table 3. In this study of the dissimilar material joint with the above mentioned thickness, the interactions between the welding parameters are considered.

4. DESIGN OF EXPERIMENT

The three machining parameters are selected for full factorial design Welding speed, voltage and welding current all three parameters as a input parameters. All three parameters are very with three levels. Then the full factorial design was selected for the experiment. Total 27 number of experiment was conduction for this design.

Table 2 Machining parameters and their levels

Parameter/Levels	Level 1	Level 2	Level 3
Welding speed (cm/min)	50	60	70
Voltage (V)	20	25	30
Welding current (A)	110	130	150

5. EXPERIMENTAL SET UP FOR TENSILE STRENGTH AND IMPACT TEST MEASUREMENT

The whole experimental investigation were done using 'FIE' Electronic Universal Testing machine (UTM), model UTS-100 which can be used for conduction test in tension,

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compression and transverse test of metals and other material. Maximum capacity of the machine is of 1000 kN with measuring range between 0 to 1000 kN. Load is sensed by means of precision pressure transducer of strain gauge type loading unit is shown in Fig 2

Fig. 2 Universal testing machine

Toughness of steels is characterized by two parameters; the Charpy Shelf Energy (CSE) and the Impact Transition Temperature, ITT (or ductile-to-brittle transition temperature, DBTT). Charpy impact test is a measure of the toughness of a material and the total energy that is absorbed during the test is shown in Fig.3.

Fig.3 Impact testing machine

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The observation table showed the tensile strength and impact test reading that was calculated by with the help of machines. The full factorial design table shows the tensile test and impact test results are shown in Table 4.

6. INFLUENCE OF WELDING PARAMETERS ON TENSILE STRENGTH

The analysis of variances for the factors is shown in Table 5. which is clearly indicates that the all parameters are important for influencing on tensile strength, welding speed and voltage are the most influencing factors for tensile strength. The F probabilities values are 3636.63, 14.07 and 10.67 respectively, described in same table. The case of tensile strength, it is "Larger is better", so from this table it is clearly definite that welding speed is the most important factor then voltage after that welding speed.

The analysis of variance for tensile strength is shown in Table 5. The parameter R-sq describes the amount of variation observed in tensile strength is explained by the input factors. R-sq = 99.73 % indicate that the model is able to predict the response with high accuracy. Adjusted R-sq is a modified R-sq that has been adjusted for the number of terms in the model. If unnecessary terms are included in the model, R-sq can be artificially high, but adjusted R-sq (=98.65 %.) may get smaller. The standard deviation of errors in the modeling, S= 3.38625. Comparing the p-value to a commonly used α-level = 0.05, it is found that if the p-value is less than or equal to α, it can be concluded that the effect is significant, otherwise it is not significant.

Table 3 Analysis of Variance for Tensile Strength

Source	DF	Seq SS	Adj MS	F	P
Welding speed (cm/min)	2	83400	41700	3636.63	0.000
Voltage (V)	2	323	161	14.07	0.000
Welding current (A)	2	245	122	10.67	0.001
Error	20	229	11		
Total	26	84197			
S = 3.38625 R-Sq = 99.73% R-Sq(adj) = 99.65%					

During the process of welding, the influence of various machining parameter like welding speed, voltage and welding current has significant effect on tensile strength, as shown in main effect plot for tensile strength is shown in Fig 5.

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In this graph clearly shown that the welding speed is directly proportional to tensile strength in the range of 50 to 70 cm/min. This is expected because an increase in speed produces strong spark, which produces the higher temperature, causing more material to melt and dispatch from the work piece. Besides, it is clearly evident that the other factor does not influence much as compared to welding speed. But when the Voltage is increasing the tensile strength is also increasing slightly. And the welding current considerately changes according to graph.

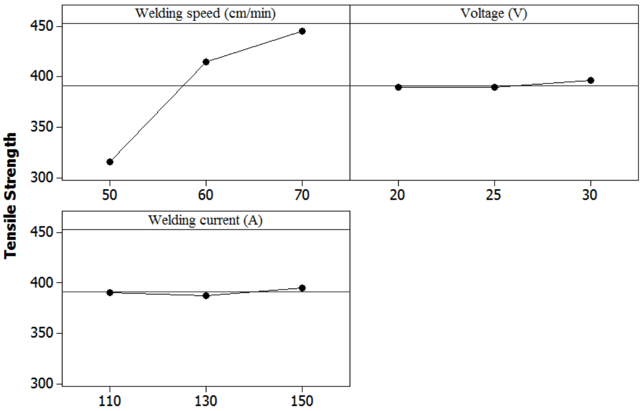

Fig. 4 Main effect plot for Tensile Strength

7. INFLUENCE OF WELDING PARAMETERS ON IMPACT FAILURE TEST

The analysis of variances for the factors is shown in Table 6 which is clearly indicates that the welding speed parameters is important for influencing on impact failure test, welding speed is the most influencing factors for impact test. And Voltage and welding current is not significantly affected the Impact failure test. According to the analysis of variance in this table shows the p value is higher than 0.05 so this two factors are not affected significantly.

The F probabilities values are 136.94, 0.90 and 0.48 for welding speed, voltage and welding current respectively, described in same table. The case of Impact test, it is "Larger is better", so from this table it is clearly definite that welding speed is the most important factor then insignificant factors are voltage after that welding speed.

The analysis of variance for tensile strength is shown in Table 6. The parameter R-sq describes the amount of variation observed in tensile strength is explained by the input factors. R-sq = 91.23 % indicate that the model is able to predict the response with high accuracy. Adjusted R-sq is a modified R-sq that has been adjusted for the number of terms in the model. If unnecessary terms are included in the model, R-sq can be artificially high, but adjusted R-sq

(=91.26 %.) may get smaller. The standard deviation of errors in the modeling, S= 3.61530. Comparing the p-value to a commonly used α-level = 0.05, it is found that if the p-value is less than or equal to α, it can be concluded that the effect is significant; otherwise it is not significant (shown in bolt).

Table 4 Analysis of variance for impact failure load

Source	DF	Seq SS	Adj MS	F	P
Welding speed (cm/min)	2	3579.6	1789.81	136.94	0.000
Voltage (V)	2	23.4	11.70	0.90	**0.424**
Welding current (A)	2	12.5	6.26	0.48	**0.626**
Error	20	261.4	13.07		
Total	26	3876.9			
S = 3.61530 R-Sq = 93.26% R-Sq(adj) = 91.23%					

In the process of impact failure test, the influence of various machining parameter like welding speed, voltage and welding current has significant effect on impact test, as shown in main effect plot for impact failure test in Fig 6. The welding speed is directly proportional to impact test in the range of 50 to 60 cm/min. But, with increase in welding speed from 60 to 70 cm/min the impact failure is decreasing. However, MRR decreases monotonically with the increase in speed. And other factors voltage and welding current is not significantly affected the impact test.

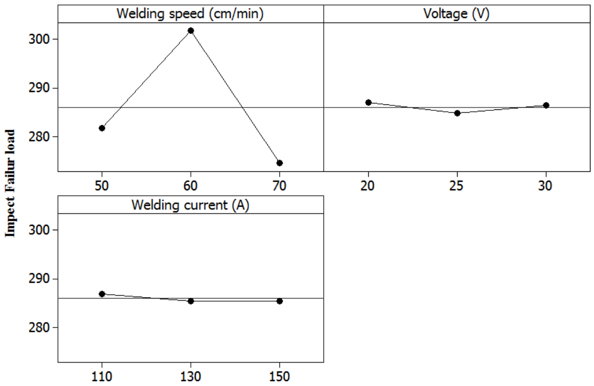

Fig. 5 Main effect plot for Impact test

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CONCLUSIONS

In the present study on the effect of machining responses are tensile strength and impact failure test .The mild steel plates and stainless steel plates using welding with butt weld joint. The experiments were conducted under various parameters setting of different parameters likes welding speed, voltage and welding current this three parameters they are three levels then the total numbers of experiment where conducted on 27 number of experiment, in full factorial design, in Minitab software was used for analysis the results and theses responses were partially validated experimentally.

(1). The analysis of tensile strength the parameter welding speed is most important factor after that voltage and last is welding current is affected the response.

(2). Finding the result of impact failure test the welding speed is most influencing factor and then voltage after that welding current. Impact failure test increased with the welding speed up to 60 cm/min after that they are decease. And the voltage and welding current is not significant effect on impact failure test.

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Table 6 302 Stainless Steel Chemical Properties

302 Stainless Steel	C	Mn	Si	P	S	Cr	Ni	N	Rest Iron
%	Max 0.15	Max 2.0	Max 0.75	Max 0.045	Max 0.03	17-19	8-10	Max 0.10	

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Table 7 Observation table

Run order	Welding Speed (cm/min)	Voltage (V)	Welding Current (A)	Tensile Strength (MPa)	Impact Test (KN)
1	50	20	110	310	286
2	50	20	130	311	280
3	50	20	150	316	285
4	50	25	110	309	285
5	50	25	130	312	280
6	50	25	150	316	275
7	50	30	110	324	280
8	50	30	130	311	285
9	50	30	150	324	280
10	60	20	110	410	306
11	60	20	130	411	300
12	60	20	150	416	305
13	60	25	110	409	305
14	60	25	130	412	300
15	60	25	150	416	295
16	60	30	110	424	300
17	60	30	130	411	305
18	60	30	150	424	300
19	70	20	110	440	276
20	70	20	130	441	270
21	70	20	150	446	275
22	70	25	110	439	275
23	70	25	130	442	273
24	70	25	150	446	275
25	70	30	110	454	270
26	70	30	130	441	277
27	70	30	150	454	280