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Multi Objective Optimization of Welding Process on Dissimilar Material by using Hybrid Techniques

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Abstract: ***Improving the ability to join dissimilar materials for welding process with engineered properties are enabling new methodologies to light-weighting, improving methods for vitality production, creating next generation medical products and consumer devices, and many other manufacturing and industrial uses. The main objectives of present work to optimize the welding process parameters on dissimilar plate (mild steel and stainless steel). In this case variation of voltage, welding speed and welding current for analysis of Tensile is testing and Impact testing (responses). Using hammer excitation Total full factorial design (27 set of experiment) is used to conduct the experiment. Analyses of variance are premeditated for significant parameter affects weld performance of weld joint on base. These two contradicting requirements have been simultaneously satisfied by selecting an optimal process environment (optimum parameter setting) by using hybrid method that is grey based fuzzy logic model.***

Keywords: Dissimilar welding; Universal Testing; Impact Testing; Grey relation analysis; Fuzzy logic method; Hybrid method

1. Introduction

In the recent years, fuzzy-logic-based multi-criteria decision making approaches have become very popular in optimization of all conventional and nonconventional machining and other manufacturing processes. Increasing the productivity and the quality of the machined parts are the main challenges of manufacturing industries [1].

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 designs of experiment (DOE) techniques that allows the analysis of experiments with the minimum number [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. 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.

Optimized the multiple performances like recast layer thickness and surface roughness using fuzzy-logic method with the design of Taguchi L18 mixed- orthogonal array. It was observed that application of this optimization technique significantly improved multiple responses. The same technique was also used to predict material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR) in ultrasonic-assisted EDM (US/EDM) process [15]. Different other manufacturing processes were also optimzed using similar type of optimization technique [16-18].

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. Different Work-Piece Material

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. Work piece welding and Provision

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 Figure 1.

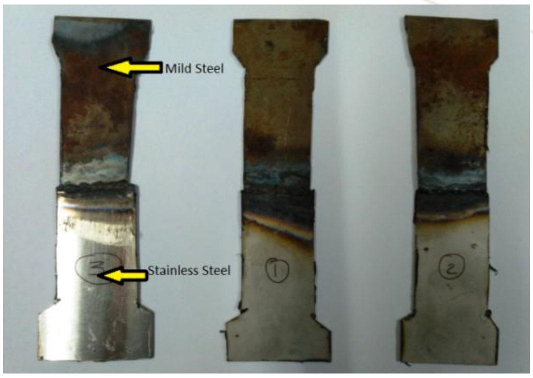

Figure 1: Specimen of Weld joints for tensile test

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 3: 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. Measurement of Responses (tensile Strength and Impact test)

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, 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.

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. 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. Methodology for optimization

6.1 Grey Relation Analysis

Grey Relational Analysis is an effective method in which analysis being done among the sequence groups requires that all sequences satisfy comparability conditions, for instance, non-dimension, scaling, and polarization attributes. Normally, two different types of comparability equations are used for generating the comparable sequence as follows:

(1) Higher the better: (Higher objective value is better)

$$x_i^*(k) = \frac{x_i(k) - \min x_i(k)}{\max x_i - \min x_i(k)} \quad (1)$$

(2) Lower the better: (Lower objective value is better)

$$x_i^*(k) = \frac{\max x_i(k) - x_i(k)}{\max x_i - \min x_i(k)} \quad (2)$$

Where $x_i^*(k)$ and $x_i(k)$ the normalised data and observed data, respectively, for i[th] experiment using k[th] response. And also the Grey relation coefficient can be calculated by using Equation 3.

$$\zeta_i(k) = \frac{\Delta_{min} + \zeta\Delta_{max}}{\Delta_i(k) + \zeta\Delta_{max}} \quad (3)$$

Where $\Delta_i(k)$ is the k[th] value in Δ_i different data series, Δ_{max} and Δ_{min} are the global maximum and global minimum values in the different data series, respectively. The distinguishing coefficient ζ lies between 0 and 1, which is to expand or compress the range of GRC.

6.2. Fuzzy Logic System

Fuzzy logic is a mathematical theory of inexact reasoning that allows modeling of the reasoning process of human in linguistic terms. The fuzzy logic control allows the existence of uncertainty in handling parameter values. Fuzzy logic system (Mamdani system) comprises of a fuzzifier, membership functions, a fuzzy rule base, an inference engine, and defuzzifier. Next, the inference engine (Mamdani fuzzy inference system) performs fuzzy reasoning on fuzzy rules to generate a fuzzy value. Finally, the defuzzifier converts fuzzy predicted value into a single equivalent Multi Performance Characteristics Index.

6.3 Optimization of multiple quality characteristics with Grey-Fuzzy logic

Grey-Fuzzy logic is used to convert multiple responses into a single characteristic index known as Grey-Fuzzy Reasoning Grade (GFRG) for optimisation. Grey-fuzzy logic method is generated and applied. It precedes fuzzy rules approach rather than making a traditional GRG estimation for grey relational analysis. At first, the experimental values of tensile test and impact test are normalised in the range of 0 to 1 for all the experimental run by using Equation 1 and 2 respectively. Here the weightage of all three responses are considered relatively equal. Then, the Grey Relational Coefficient (GRC) of each response is calculated by using Equation 3.

In fuzzy logic system, the fuzzifier uses the membership functions to fuzzify GRC of each performance characteristic. In this paper two inputs (responses) and one output fuzzy logic system are shown in Figure 2 (steps for GFRG). The inference engine (Mamdani fuzzy inference system) performs fuzzy reasoning with fuzzy rules to generate a fuzzy value. These fuzzy rules are presented in the form of if-then control rule. For each rule, the three inputs are assigned in the fuzzy subsets of Small, Medium and Large and the corresponding membership functions, μx_1, μx_2 and μx_3, respectively. The output is assigned to any of the five fuzzy subset (Very small, Small, Medium, large, Very large) membership functions µY.

The number of rules yielded from the present study is eight and the membership function of the input and output are indicated in Figure 3 and 4. Fuzzy rules are directly derived based on the fact that larger-the-better characteristic that is shown in Figure 5. By tracking maximum-minimum compositional operation, the fuzzy reasoning of these rules yields a fuzzy output. Finally, the defuzzifier converts fuzzy predicted value into a GFRG. This GFRG values are shown in Table5.

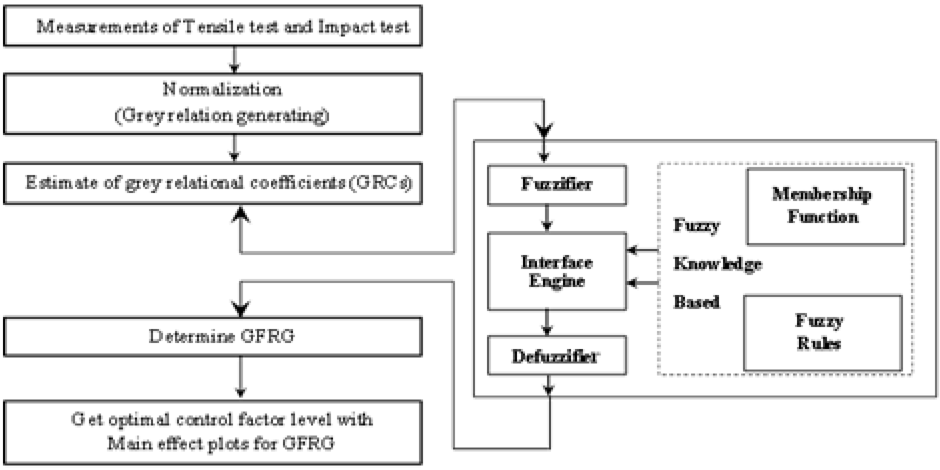

Figure 2: Steps for grey-fuzzy logic method

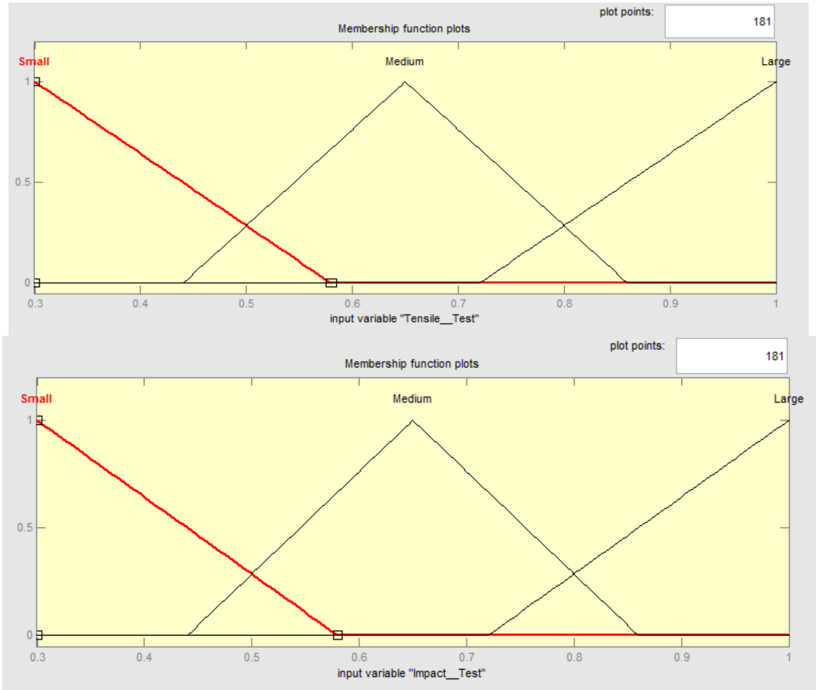

Figure 3: Membership function for input (Impact test and tensile test)

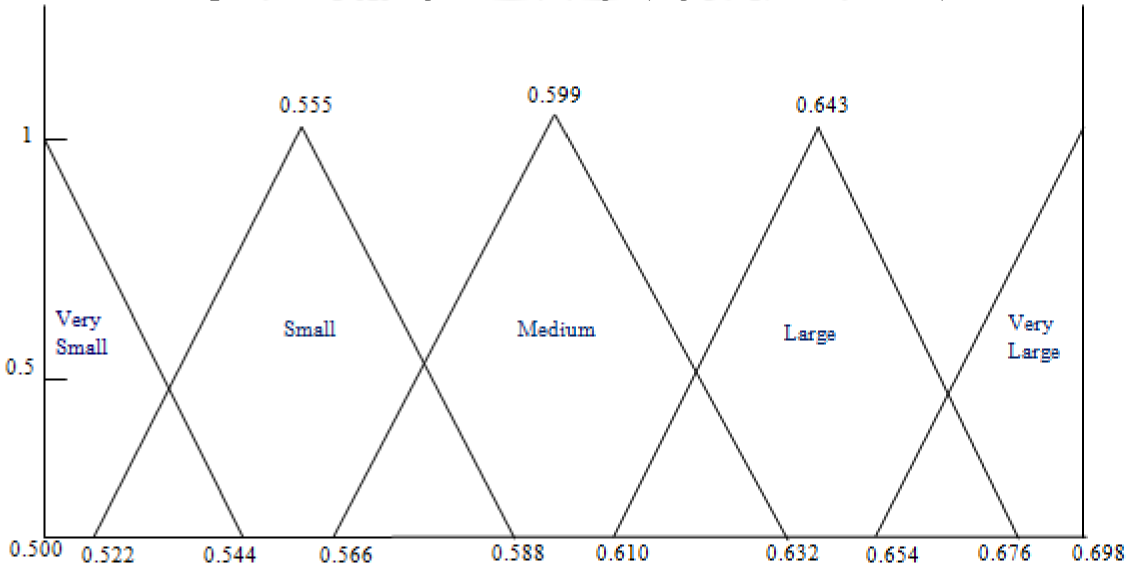

Figure 4: Membership function for output (GFRG)

Table 2: 302 Stainless Steel Chemical Properties

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

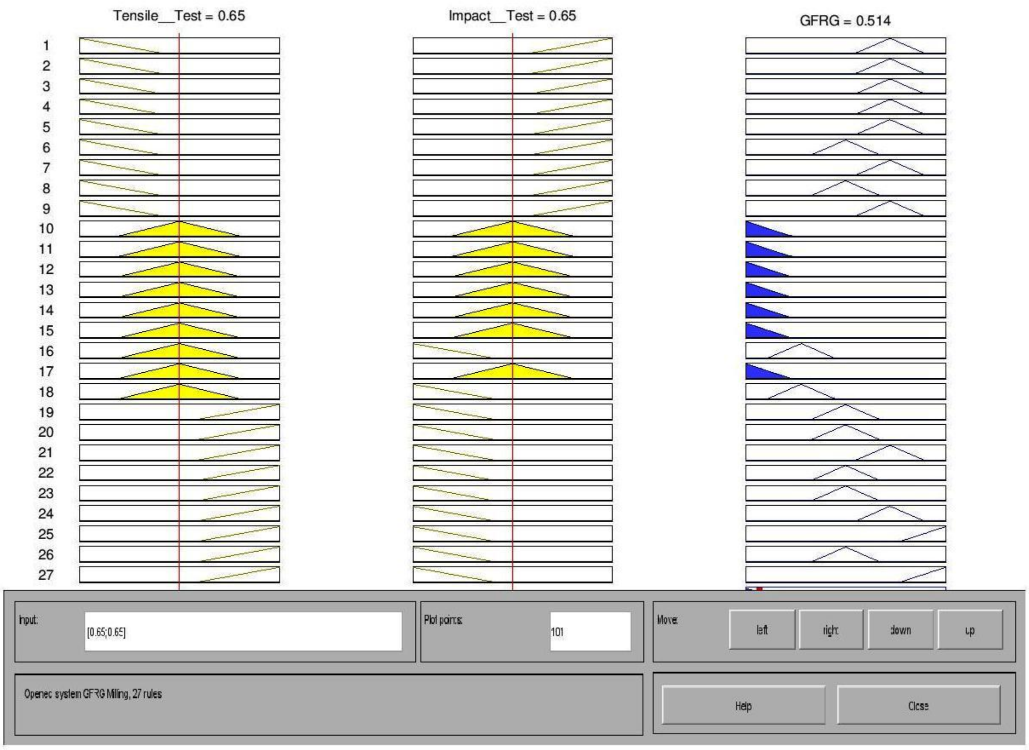

Figure 5: Fuzzy rules

Table 5: Computing GRC and grey fuzzy reasoning grade (GFRG)

Run order	Tensile Strength (MPa)	Impact Test (KN)	N TS	N IT	GRC TS	GRC IT	GRG	GFRG
1	310	286	0.0069	0.4444	0.3349	0.9864	0.6606	5.1568
2	311	280	0.0138	0.2778	0.3364	0.9732	0.6548	5.1573
3	316	285	0.0483	0.4167	0.3444	0.9119	0.6282	5.1598
4	309	285	0.0000	0.4167	0.3333	1.0000	0.6667	5.1563
5	312	280	0.0207	0.2778	0.3380	0.9603	0.6491	5.1578
6	316	275	0.0483	0.1389	0.3444	0.9119	0.6282	5.1598
7	324	280	0.1034	0.2778	0.3580	0.8286	0.5933	5.1642
8	311	285	0.0138	0.4167	0.3364	0.9732	0.6548	5.1573
9	324	280	0.1034	0.2778	0.3580	0.8286	0.5933	5.1642
10	410	306	0.6966	1.0000	0.6223	0.4179	0.5201	5.2744
11	411	300	0.7034	0.8333	0.6277	0.4155	0.5216	5.2772
12	416	305	0.7379	0.9722	0.6561	0.4039	0.5300	5.2924
13	409	305	0.6897	0.9722	0.6170	0.4203	0.5187	5.2717
14	412	300	0.7103	0.8333	0.6332	0.4131	0.5231	5.2801
15	416	295	0.7379	0.6944	0.6561	0.4039	0.5300	5.2924
16	424	300	0.7931	0.8333	0.7073	0.3867	0.5470	5.3214
17	411	305	0.7034	0.9722	0.6277	0.4155	0.5216	5.2772
18	424	300	0.7931	0.8333	0.7073	0.3867	0.5470	5.3214
19	440	276	0.9034	0.1667	0.8382	0.3563	0.5972	5.4068
20	441	270	0.9103	0.0000	0.8480	0.3545	0.6012	5.4139
21	446	275	0.9448	0.1389	0.9006	0.3461	0.6233	5.4537
22	439	275	0.8966	0.1389	0.8286	0.3580	0.5933	5.4
23	442	273	0.9172	0.0833	0.8580	0.3528	0.6054	5.4212
24	446	275	0.9448	0.1389	0.9006	0.3461	0.6233	5.4537
25	454	270	1.0000	0.0000	1.0000	0.3333	0.6667	5.5375
26	441	277	0.9103	0.1944	0.8480	0.3545	0.6012	5.4139
27	454	280	1.0000	0.2778	1.0000	0.3333	0.6667	5.5375

The graphical representation of main effect plot for GFRG is shown in Fig. 5 and this graph presented that the optimal Welding parameter (Welding speed 70 cm/min,, Voltage is 30V and Welding current is 150A) for both responses.

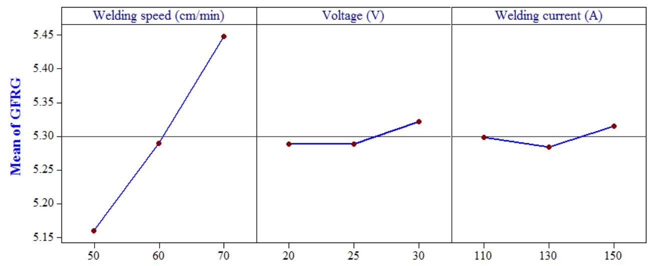

Figure 6: Main effect plot for GFRG

7. 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.

Grey-fuzzy relation analysis was adopted to optimise the welding process with multiple performance characteristics with Tensile test and impact test. The optimal parameter settings were found to be Welding speed 70 cm/min,, Voltage is 30V and Welding current is 150A for optimum Tensile test and impact test, simultaneously.

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