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Comparative Study and Optimization of Process Parameters of Dissimilar metal Weld Joints by GTAW Process

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ABSTRACT

Industries are focusing on various cost reduction initiatives by choosing alternative material without compromising quality. The main aim of this paper is to identify such an alternate material for Duplex Stainless Steel/Duplex Stainless Steel (DSS/DSS) similar metal weld joint. Similar and various dissimilar metal weld joints like DSS/DSS, DSS/Corten-A, DSS/Cold Rolled Steel and DSS/Hot Rolled Steel were assessed in this paper and the results have been compared to find out the superior dissimilar metal in terms of Tensile strength. Objective of this work is to optimize the process parameters for the best superior dissimilar metal weld joint by using Taguchi method. Voltage, Current and filler feed rate were chosen as a control factors considering the impact on the input variables. Ultimate tensile strength has been taken as response variable to calculate the signal-to-noise ratio. Analysis of variance (Anova) was used in order to identify the percentage contribution for all the factors as well as high significant factor which is contributing for the optimum result

Keywords: Comparative study, Process Optimization, Dissimilar Welding, Corten-A, Gas Tungsten Arc Welding.

INTRODUCTION

Gas Tungsten Arc Welding(GTAW),gives good quality for welding a variety of metals and alloys to make sure weld joints are free from any defects since the electrode, molten metal and arc are confined by argon as shielding gas [1]. GTAW is extensively being used since it has ability of welding complicated shapes with large sequence of dimensions, aesthetics and low cost [2].

GTAW method is widely being used for joining thin materials in manufacturing sectors and has got its restrictions of lesser joint diffusion and incapability to welding wide materials [3]. Duplex stainless steel consists of both high strength of ferritic steels and the corrosion-resistance of austenitic steels. These steels are used in corrosive environment applications where reliability of the weldment is significant, mainly in offshore and petrochemical plants. The duplex stainless steel has the huge benefit of contributing a grouping of high strength and outstanding corrosion resistance which allows plate thickness to be reduced by as much as 30% [4].

Corten-A steel belongs to the family of high strength low alloy steel (HSLA) and is also known as weathering steel. These steels can provide corrosion protection without any additional protective coating. The increase in the percentage of copper content as the alloying elements, acts as an arresting mechanism to atmospheric corrosion in the material itself with the help of a rust (oxide) layer. Corten-A steel is superior to low carbon steel especially in strength and corrosion resistance aspects [5].

Cold reduced steel(CRS) sheets offers a variety of outstanding properties including easy formability, clean, smooth surface and mainly used for manufacturing automobile parts. Superior workability and dimensional accuracy is one of the key characteristics of CR steel [6].

Hot rolled steels (HRS) can be used to produce parts containing simple bends as well as drawn parts. HRS is used especially in high strength applications and good formability is required. Some of the

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structural applications exist by using HRS in automotive industries which include frame components, Panels, brackets, brake components, wheels, clutch plates, construction, industrial machinery and agricultural equipment's.

Quality of dissimilar metal weld joint is very significant for the functioning of whole unit. In general dissimilar metal weld joining requires more attention than that of similar metals since it differs in physical, mechanical and metallurgical properties of the base metals to be joined.

Experiment procedure:

The work piece sheets were made from 2205 duplex stainless steel and dissimilar metal of Corten-A,CRS and HRS sheets of thickness 2mm. Test specimens of both DSS and dissimilar metal sheets were cut in to the size of 2mmx150mmx250mm and welded with GTAW process. 309L filler rod was used as the welding materials in all the experiments.

In this experiment, TRIDENT 4009 make GTAW machine was used. During welding, welding gun was controlled manually and the filler rod was fed manually into the welding area [7].

2mmx150mmx250mm sizes of both similar and dissimilar metal plates were kept together separately with 1.2 mm root gap and the plates were tack welded followed by run weld. Clamps were used to align and hold the plates together in order to avoid misalignment and distortion. Welding was carried out by means of GTAW with argon as shielding gas. After welding, specimens were cooled in the air. 10 samples were made on each similar and dissimilar metal welds and finally 2 samples on each method selected based on the visual inspection parameters like uniform bead width and weld appearance [8]. Process parameters used for similar and all dissimilar metals are given in Table 1. Welded joints were then cut in to sections of required size, using band saw for making tensile test specimens

Table 1: Process Parameters

Thickness of specimen	Joint Design	Flow rate	Welding position	Current	Voltage	Filler feed rate
2.0mm	Butt Joint	7 Lts/minute	Down hand	55 Amp	16V	0.5mm/sec

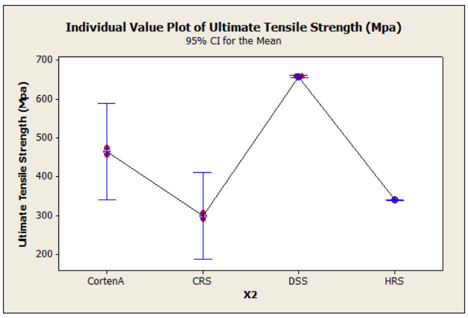
Comparison of Mechanical properties of DSS/DSS, DSS/Corten-A, DSS/CRS, DSS/HRS:

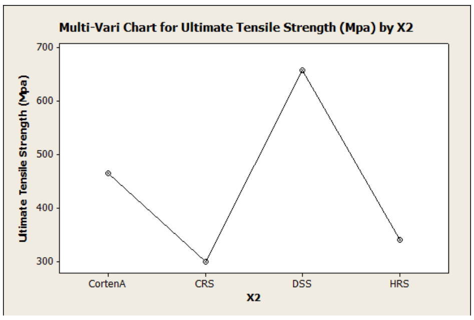
In this paper mechanical properties of each of the joints mentioned above have been compared to choose the superior metal among the dissimilar group. Average values of results of tensile test performed from the similar and dissimilar metal joints have been tabulated in table 2.

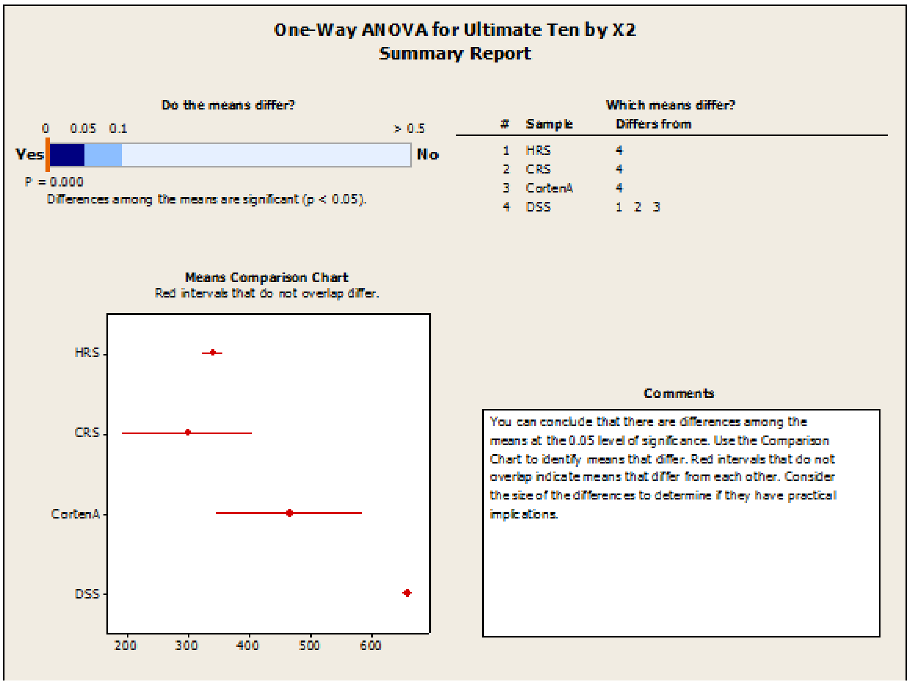
Table 2: Mechanical Properties comparison for Similar and Dissimilar weld joints.

Sl No	Mechanical Properties	DSS/DSS	DSS/Corten-A	DSS/CRS	DSS/HRS	Ranking in high order
1	Ultimate tensile strength in Mpa	659	466	299	340	1.DSS/DSS 2.DSS/Corten-A 3.DSS/HRS 4.DSS/CRS
2	Yield strength in Mpa	596	365	217	240	1.DSS/DSS 2.DSS/Corten-A 3.DSS/HRS 4.DSS/CRS

Based on the ranking of mechanical properties tabulated above, inference is DSS/DSS is superior metal in terms of mechanical properties and DSS/Corten-A is next superior metal among the dissimilar metal group based on the tensile test values. Different amount of variation in the values of Tensile strength were observed for all the joints in which DSS/CRS having the maximum variation followed by DSS/Corten-A and DSS/HRS. DSS/Corten-A has been chosen for process optimization since the tensile strength is high compared to other dissimilar metal weld joint. Individual value plot of Ultimate Tensile strength based on 95% Confident interval for the mean and multi vari chart for Ultimate tensile strength have been plotted for identifying the next superior dissimilar metal which is DSS/Corten-A.







One way Anova for Ultimate tensile strength summary report derived from Minitab conclude that there is difference among the means at the 0.5 level of significance. Red intervals that do not overlap indicate that differ from each other shown below.

Optimization of process parameter by using Taguchi method for DSS/Corten-A metal weld joints by GTAW process:

Taguchi method is a very successful tool for process optimization under limited number of experimental runs. Optimization of process parameters is the important step in the Taguchi method for achieving high quality without cost increase. Optimization of process parameters can improve quality characteristics and the optimal process parameters obtained from the Taguchi method are insensitive to the variation of environmental conditions and other significant factors. Mainly, standard process constraint design is complex and cumbersome to apply. Number of experiments will be increased when the number of factors and levels increases. In order to overcome this task, the Taguchi technique uses a special design of orthogonal arrays to study the entire process parameter space with a small number of experiments [9].Impact factors with 3 level proposals have been mentioned in Table.3

Table 3: Factors and Levels

Factors	Code	Level 1	Level 2	Level 3
Voltage (V)	A	16	15	13
Current (Amp)	B	55	65	80
Filler Feed rate(mm/sec)	C	0.5	0.4	0.7

L_9-3^3 Level Taguchi Orthogonal Array:

Experiments Experiment	Control Factors		
	A	B	C
1	L1	L1	L1
2	L1	L2	L2
3	L1	L3	L3
4	L2	L1	L2
5	L2	L2	L3
6	L2	L3	L1
7	L3	L1	L3
8	L3	L2	L1
9	L3	L3	L2

Experimental Design and the Response Values:

Run	Voltage(Volt)	Current(Amp)	Filler feed rate(mm/sec)	Ultimate tensile strength in Mpa
1	16	55	0.5	466
2	16	65	0.4	470
3	16	80	0.7	451

4	15	55	0.4	467
5	15	65	0.7	445
6	15	80	0.5	452
7	13	55	0.7	448
8	13	65	0.5	463
9	13	80	0.4	454

In order to study the significant process parameters which affects the quality characteristics, ANOVA method was used. The purpose of ANOVA is to investigate which welding process parameters significantly affect the quality performance. The percentage contribution by each of the welding process parameters in the total sum of the squared deviations can be used to evaluate the importance of the process parameter change on the quality characteristic.

Anova Table:

Factor	DOF	Sum of squares	Mean squares	F ratio	Contribution %
A	2	0.040390516	0.020195258	2.476413	16.49
B	2	0.040297679	0.020148839	2.47072	16.46
C	2	0.147880323	0.073940161	9.066799	60.39
Error	2	0.016310092	0.008155046		6.66
Total	8	0.24487861			100.00

Result of the ANOVA indicates that the Filler feed rate (60.39 % contribution) is the most effective parameter on the responses under the multi criteria optimization (higher tensile load). The percentage contributions of other parameters are Voltage (16.49 %), Current (16.46 %) and the error factor (6.66 %)

Signal to Noise (S/N) Ratio:

Analysing the response variation using the signal-to-noise ratio is important as per Taguchi method which helps to identify the effect of quality characteristic variation due to uncontrollable parameter [10].3 Signal-to-Noise ratios is being used as a common interest for optimization

(I) Smaller-The-Better:

n = -10 Log10 [mean of sum of squares of measured data]

(II) Larger-The-Better:

n = -10 Log10 [mean of sum squares of reciprocal of measured data]

(III) Nominal-The-Best:

n = 10 Log10 (square of mean)/ Variance [11]

The signal-to-noise ratio measures how the response varies relative to the nominal or target value under different noise conditions. We can choose from different signal-to-noise ratios, depending on the goal of our experiment.

The term 'signal' indicates the required value (mean) for the output characteristic and the term 'noise' indicates the undesirable value (standard Deviation) for the output characteristic as per Taguchi Method.

To obtain optimal welding condition, higher-the improved quality characteristic for Tensile strength have to be taken. The Mean S/N ratios have been tabulated below from which the higher value needs to be taken from all the factors against the 3 levels.

Mean S/N ratio:

Level	Factor A	Factor B	Factor C
1	0.097774	0.059910239	0.060740447
2	-0.04786	0.04029723	0.123175439
3	-0.04053	-0.090822973	-0.174531391

Optimum Process Parameters:

SL No	Factors	Code	Level 1	Level 2	Level 3	Optimum Parameters
1	Voltage	A	16	15	13	16 V
2	Current	B	55	65	80	55 Amp
3	Filler Feed rate	C	0.5	0.4	0.7	0.4mm/sec

Optimum combination levels:

A1	B1	C2

Confirmatory Test:

Confirmatory Test has been conducted by following optimum combination levels and found higher tensile strength 475Mpa as mentioned below.

Run	Voltage(Volt)	Current(Amp)	Filler feed rate(mm/sec)	Ultimate tensile strength in Mpa
1	16	55	0.4	473

Conclusion:

Experimental results have shown that the tensile load, in the GTAW of Dissimilar metal DSS/Corten-A steel are greatly improved by using Taguchi method. Variation in Filler feed rate resulted in significant changes in the mechanical properties of the weld.

- Results show that higher Filler feed rate resulted in lower tensile strength and high current also resulted in reduced tensile strength. A lower value of filler feed rate 0.4mm/sec gave the highest tensile strength.
- Filler feed rate is the factor that significantly contributed to a higher percentage and has greater influence on the tensile strength followed by contributions from current and voltage.
- The optimum range includes current of 55 amperes, Voltage of 16volt and Filler feed rate 0.4mm/sec.
- DSS/Corten-A metal joint shows tensile strength (466Mpa) before process optimization and shows results of tensile strength (473Mpa) after process optimization witnessed during confirmatory test.
- DSS/CRS dissimilar metal weld joint shows lower tensile (299Mpa) and yield strength (217Mpa) compared with DSS/Corten-A and DSS/HRS dissimilar metal weld joint.
- Higher tensile strength (470Mpa) obtained after Process optimization of DSS/Corten-A dissimilar metal weld joint experiment.
- Process optimization results indicates that DSS/Corten-A dissimilar metal can be a best option in place of DSS/DSS considering the cost impact and without compromising quality.

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