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Study on Erosion Corrosion behaviour of Gas Tungsten Arc Welded Duplex Stainless Steel using Taguchi Technique.

R.Sasidharan[1*], S.Rajendra Boopathy[2], S.R. Koteswara Rao[1], B.Ganesamoorthi[2]

[1*]Department of Mechanical Engineering, Tagore Engineering College, Chennai, India.

[2]Department of Mechanical Engineering, Anna university, Chennai, India.

* Corresponding Author (sasienggdes@gmail.com)

Abstract

In this study, the parameters for obtaining maximum erosion corrosion behaviour(weight loss) of the Gas tungsten arc (GTAW or TIG) welded duplex stainless steel were delivered. Essentially, the erosion corrosion behaviour is determined by several quality characteristics, for instance, the pH value, % mixture of sand in water (slurry) and slurry flow rate in Liters per minute (LPM). To look at these material removal rate(weight loss) in the selection of process parameters, the Taguchi method was adopted to evaluate the effect of each erosion corrosion parameter and then to define the process parameters for the maximum erosion corrosion behaviour. Experimental results were offered to establish the proposed approach.

Keywords: Liters per minute, Erosion corrosion, Tungsten inert gas welding, Taguchi method

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Introduction

Tungsten inert gas (TIG) welding is an important welding process, which uses a non consumable tungsten electrode coupled with inert gas for arc shielding. It is most frequently used for welding hard-to-weld metals such as stainless steel [1]. Basically, solid particle combined with liquid droplet erosion are surface removal processes caused by encroachment of solid particles carried in moving fluid stream in opposition to the airfoil. Unremarkably, the desired erosion corrosion process parameters are set based on experience or from a handbook. Corrosion is an omnipresent form of surface degradation, occurring in both natural systems and fabricated products. In machinery and materials handling equipment for industrial applications most component damage is induced by the impact of small solid particles entrained in a gasoline or liquid stream [2]. Such erosion of material surfaces occurs by a high strain rate extrusion, forging fracture mechanism that differs from other cases of wear processes such as abrasive wear and sliding wear [2,3]. The complexity of the erosion–corrosion phenomena is not just limited to the interaction between the various parameters affecting erosion corrosion. In order to see the total wear rate caused by the mixed consequence of erosion and corrosion, various rigs have been planned to evaluate this result. Amongst these rigs are slurry pot erosion tester[4–9],], Coriolis erosion tester [10–12] and rotating cylinder apparatus [13–15].

Nevertheless, this does not assure that the selected erosion corrosion process parameters can generate the optimal or close to optimal weight loss for that particular erosion corrosion machine and environment. In this report, the role of the Taguchi method to limit the erosion corrosion process parameters with the optimal weight loss is accounted. Taguchi method [16,17] is an organized application of design and analysis of experiments for the purpose of planning and improving product quality. In recent years,[18] the Taguchi method has become a potent instrument for improving output during research and evolution so that high quality products can be grown

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rapidly at low cost. Basically, the erosion corrosion behaviour of the weld pool has been influenced by weight loss of the weld pool. However, the original Taguchi method has been projected to optimize a single quality characteristic. Therefore, Taguchi method is embraced in this paper to examine the outcome of each parameter on the erosion weight loss along the weld metal, and then to learn the parameters with the optimal erosion corrosion behaviour.

Experimental results are also provided to illustrate the proposed approach. In the pursuit, the Taguchi method for optimizing individual quality characteristics of the erosion corrosion behaviour using TIG welding process is described in detail. In the end, the report concludes with a detailed summary of this work.

Experimental Procedure

The Taguchi method

Optimization of process parameters is the foremost measure in the Taguchi method to attain high quality without increasing cost. This is because optimization of process parameters can increase quality characteristics and the optimal process parameters obtained from the Taguchi method are insensitive to the variation of environmental conditions and other noise factors. Commonly, the number of experimentations that have to be carried out becomes higher when the number of the process parameters increases. To carry out this undertaking, the Taguchi method uses a particular design of orthogonal arrays to examine the entire process parameter with a lower number of experiments only. In this study, Irrespective of the category of the quality characteristic, a larger S/N ratio corresponds to a better quality characteristic.

Taguchi recommends the exercise of the loss function to evaluate the difference of the quality characteristic from the desired value. Overall loss function calculated for the corresponding weight loss. The value of the overall loss function is further translated into a signal-to-noise (S/N) ratio. The S/N ratio for each degree of process parameters

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is calculated based on the S/N ratio analysis. Furthermore, a statistical analysis of variation (ANOVA) is performed to determine which process parameters are statistically significant. Finally, a confirmation experiment is performed to support the optimal process parameters obtained from the process parameter design.

Tungsten Inert Gas Welding (TIG)

The Material selected for the studies were Duplex Stainless steel plates (UNS32205) of thickness 6mm plates. The plates were roughly polished with silicon carbide paper and cleaned with acetone. Welds were made using Autogenous Gas Tungsten Arc Welding using Argon as shielding gas. A standard non-consumable thorated tungsten electrode was used for welding. The parameters used for producing the Tig weld are given in Table 1. In the above cases, complete penetration bead on weld joint were produced by single pass.

Mechanical and Corrosion Testing

The Erosion corrosion test is held away in the typical Erosion testing machine. The test specimen is prepared in flat side perpendicular to the focal point of the discharge nozzle as shown in Fig. 3. Slurry is prepared using mixing up of water and abrasive mixture (50-70 mesh). The abrasive mixture contains the chemical composition of SiO_2-99.76%, Al_2O_3-0.5%, Fe_2o_3, Potash and soda. slurry is prepared in the ratio of mixing water and abrasive sand by (i) 1liter of water : 0.1kg of abrasive sand = 10, (i) 1liter of water : 0.2kg of abrasive sand = 20, (i) 1liter of water : 0.3kg of abrasive sand = 30 (water : abrasive mixture). Each erosion corrosion test is carried out with a time span 6hr per test.

Weld metal Ferrite content was measured using Fisher Ferritoscope, taking an average value of 10-15 measurements from different positions according to ASTM E1019 standards. Studies were done to reveal the microstructure in base and weld metal of DSS. To study the pitting corrosion resistance of 2205 DSS plates, potentiodynamic

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polarization tests were served using a Software based PAR Basic electrochemical system. Saturated calomel electrode (SCE) and carbon electrode were used as reference and auxiliary electrodes respectively. The experiments were led in 0.5 Mole H2SO4 (49ml in one litter) + 0.5 Mole NaCl (17gm in one litter) solutions with pH adjusted to 4. The potential scan was performed out at 0.166 mV/sec with the initial potential of –0.25V (OC) SCE to final potential of pitting. The touch region for these experiments was 1 cm^2. The Potential at which current increases considerably was considered as critical pitting potential (E_{pit}). Specimens exhibiting comparatively more positive potential, (or less negative potentials) were regarded as those with better pitting corrosion resistance.

Optimal selection of process parameters

In this section, the use of the Taguchi method to find out the process parameters in the Erosion Corrosion behaviour of TIG welds(DSS) is reported step-by-step. Erosion corrosion behaviour with the best(maximum erosion) process parameters are determined and verified.

Orthogonal array experiment

In the present study, three three-level process parameters, i.e. Ph value, flow rate, and Slurry percentage of silica sand, are considered. The value of the erosion corrosion process parameter were listed in Table 2(a). There are thus 6 degrees of freedom owing to the three sets of three level erosion corrosion process parameters. The degrees of freedom for the orthogonal array should be greater than or at least equal to the process parameters.

In this study, an L_9 (3^3) orthogonal array which has 6 degrees of freedom was used. Nine experiments are required to learn the entire erosion corrosion parameter space when the L_9 orthogonal array is used. The experimental design for the erosion corrosion process parameters using the L_9 orthogonal array is shown in Table 3 and the experimental results for the erosion corrosion behaviour using the L_9 orthogonal array are shown in Table 2(b).

Overall loss function and its S/N ratio

In this study, quality of erosion corrosion behaviour of weight loss belongs to the higher the-better quality characteristic. The loss function of the larger-the-better quality characteristic can be expressed as

$$Lij = \frac{1}{n}\sum_{1}^{n}\frac{1}{{Y_{ij}}^{2}} \qquad (1)$$

where L_{ij} is the loss function of the i^{th} quality characteristic in the j^{th} experiment, and y_{ij} the experimental value of the i^{th} quality characteristic in the j^{th} experiment . As a outcome, quality characteristics corresponding to Ph value, flow rate and percentage of silica sand of the weight loss are obtained using Eq. (1). The overall loss function is further transformed into the S/N ratio. In the Taguchi method, the S/N ratio is used to find out the deviation of the quality characteristic from the desired value. The S/N ratio in the jth experiment can be expressed as

$$\frac{S}{N}\, ratio = -10\log\left[L_{ij}\right] \qquad (2)$$

The S/N ratio corresponding to the overall loss function is shown in Table 4. The effect of each erosion corrosion process parameter on the S/N ratio at different levels can be separated out because the experimental design is orthogonal shown in Table 5. & Fig. 1 shows the S/N ratio graph the larger is the S/N ratio, the better is the superiority(maximum erosion) characteristics for erosion corrosion behaviour

Anova

The aim of the ANOVA is to investigate which erosion corrosion process parameters significantly affect the quality characteristic. This is achieved by dividing the total variability of the S/N ratios, which is assessed by the total of the squared deviations

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from the total mean of the S/N ratio, in contributions by each erosion corrosion process parameter and the error. The percentage contribution by each of the process parameter in the total sum of the squared deviations can be employed to assess the importance of the process parameter change on the quality characteristics. In summation, the F test named after Fisher [19] can also be applied to determine which welding process parameters have a substantial consequence on the quality characteristics. Usually, the alteration of the erosion corrosion process parameter has a substantial force on the quality characteristic when the F value is great

Results of ANOVA (Table 6 & Fig. 2) indicate that Ph value, flow rate and percentage of silica sand are the significant erosion corrosion process parameters affecting the material removal(weight loss). The percentage contributions due to these process parameters are shown in Table 6. Based on the above discussion, the process parameters with the optimal erosion corrosion behaviour are Ph value at level 3, flow rate at level 3 and percentage of silica sand at level 3. Minitab 16 used for optimization of process parameter and perform ANOVA.

Confirmation Test

The final step is to verify the improvement of the material removal(weight loss) using the optimal level of the erosion corrosion process parameters. In order to verify the experimental conclusion, confirmation test was performed. The confirmation test was performed by setting the optimum condition of the three factors such as 10ph for ph value, 18l/min for flow rate and 30% of silica sand. The weight loss was found to be 0.51g in the confirmation test. The confirmation test results features the erosion corrosion behaviour are greatly improved through this study.

Microstructure, hardness and Pitting corrosion tests

The microstructures of Base metal and weld metal of Duplex Stainless steel are shown in Fig. 4(a&b). Duplex stainless steel (DSS) normally contains equal proportions of body-centered cubic ferrite (α) and face-centered cubic austenite (γ). The ferrite contents of the Base metal and weld metals, measured magnetically are given in Table 7. Vickers microhardness test survey were conducted across the weld using 0.5kg load.. The results are pictorially shown in Fig. 7. The weld center showed higher hardness compared to the base material. Dynamic polarization curves of base material and TIG weld is shown in Fig. 5 & 6. The pitting potential values point out the potential at which the onset of pitting takes place, and the greater values indicate better pitting corrosion resistance.

Conclusion

In this paper, the selection of the process parameters for erosion corrosion behaviour of duplex stainless steel TIG welding with the higher weight loss has been reported. The Taguchi method is adopted to find out the larger-the-better quality characteristics (higher weight loss). Experimental results have shown that effect of the ph value, % mixture of sand in water (slurry) and slurry flow rate in Liters per minute(LPM) on weight loss due to erosion corrosion behaviour of TIG welded duplex stainless steel, are identified using this approach.

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JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 17, Preprint 23 submitted 23 April 2014

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Table 1 Parameters For Tig Welding

S.no	Parameter	Tig welding
1	Material grade	Duplex 2205
2	Material thickness	6mm
3	Electrode size(non consumable tungsten electrode)	3.4 mm dia
4	Current	250 amps
5	Welding machine type	Tig welding

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 17, Preprint 23 submitted 23 April 2014

Table 2(a) Process parameters (Erosion corrosion) and their levels

Symbol	Process parameter	Unit	Level 1	Level 2	Level 3
A	Ph value	Ph	4	7	10
B	Flow rate	l/min	12	15	18
C	Percentage of silica sand	%	10	20	30

Table 2(b) Experimental layout using an L_9 orthogonal array

EXPERIMENT	PH VALUE	FLOW RATE	% OF SILICA SAND
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 3 Experimental result for the erosion corrosion behaviour

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 17, Preprint 23 submitted 23 April 2014

EXPERIMENT	PH VALUE	FLOW RATE	% OF SILICA SAND	WEIGHT LOSS
1	4	12	10	0.0039
2	4	15	20	0.1096
3	4	18	30	0.5068
4	7	12	20	0.0039
5	7	15	30	0.1746
6	7	18	10	0.2673
7	10	12	30	0.0708
8	10	15	10	0.0294
9	10	18	20	0.3086

Table 4 S/N ratio for the erosion corrosion behaviour

EXPERIMENT	S/N ratio
1	-48.1787
2	-19.2038
3	-5.9033
4	-48.1787
5	-15.1591
6	-11.4600
7	-22.9993
8	-30.6331
9	-10.2121

Table 5 S/N ratio response table for the erosion corrosion behaviour

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 17, Preprint 23 submitted 23 April 2014

Symbol	Process parameter	Level 1	Level 2	Level 3
A	Ph value	-24.429	-24.933	**-21.281**
B	Flow rate	-39.786	-21.665	**-9.192**
C	Percentage of silica	-30.091	-25.865	**-14.687**

(The optimum level of the factors are given in bold the highest value in the column)

Table 6 Results of ANOVA for the erosion corrosion behaviour

Symbol	Process parameter	Degrees of freedom	Sum of square	Mean square	F	Percentage of contribution
A	Ph value	2	0.008506	0.004253	5.93	3.69
B	Flow rate	2	0.183884	0.091942	128.30	79.86
C	Percentage of silica sand	2	0.036408	0.018204	25.40	15.83
Error		2	0.001433	0.000717		0.62
total		8	0.230231			

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Table 7 % Ferrite & Pitting Corrosion properties of Base metal & DSS welds.

Specimen Designation	% Ferrite	Pitting Potential E(pitt) mV
Base metal	51	940
Tig weld	57	925

List of Figures

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 17, Preprint 23 submitted 23 April 2014

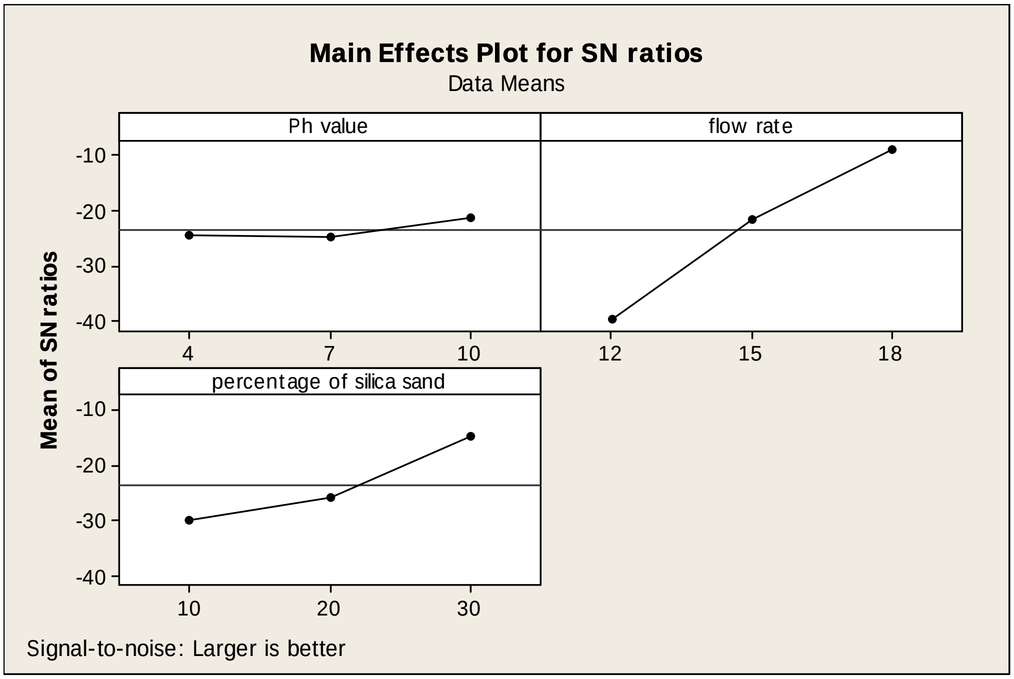

Figure 1

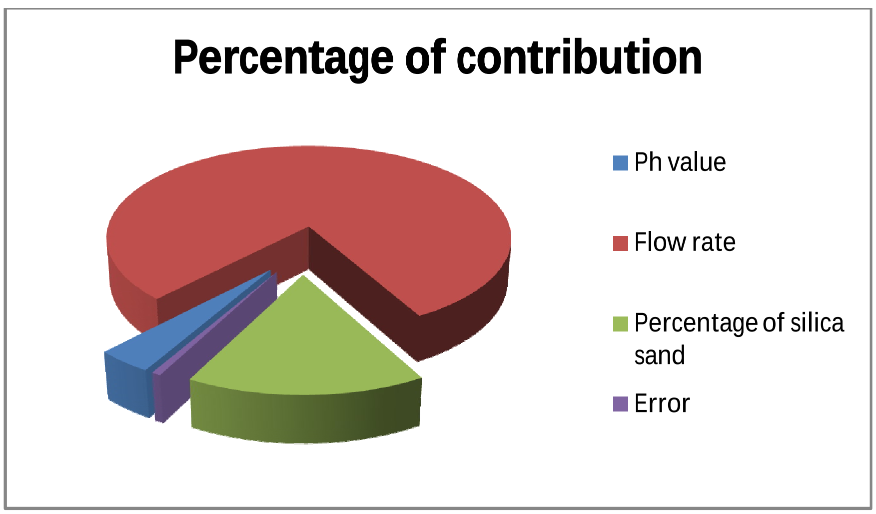

Figure 2

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 17, Preprint 23 submitted 23 April 2014

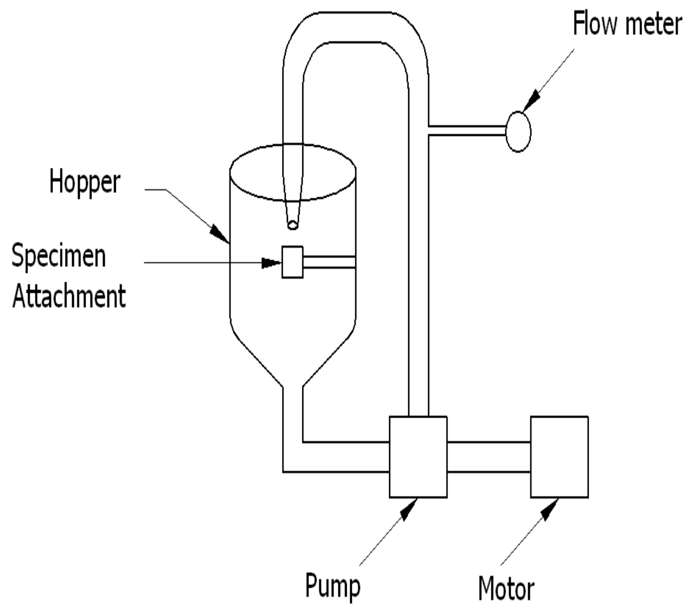

Figure 3

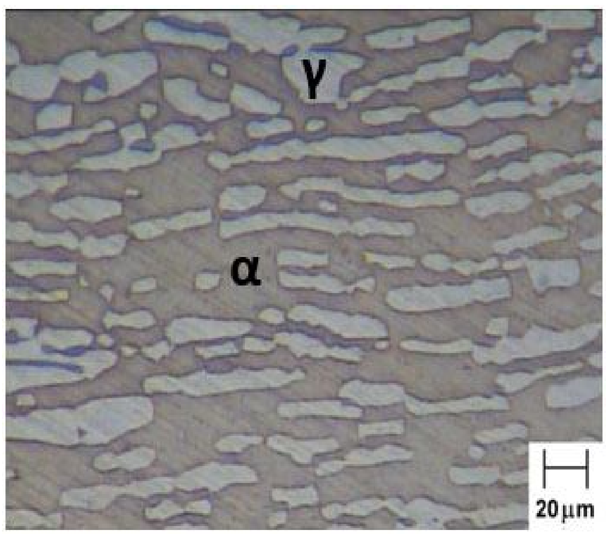

Figure 4(a)

JCSE The Journal of Corrosion Science and Engineering
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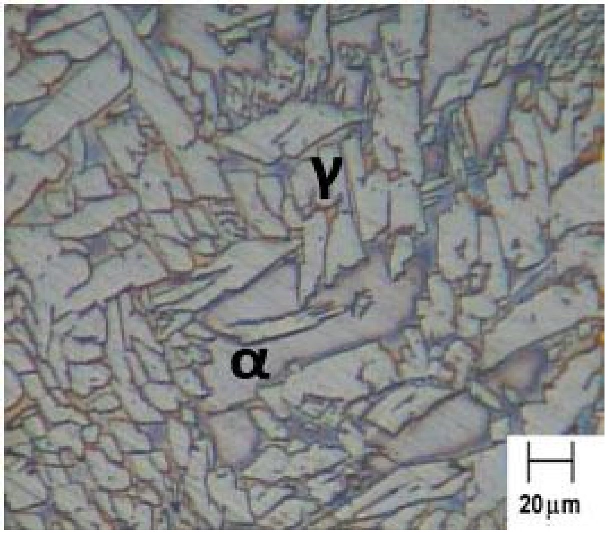

Figure 4(b)

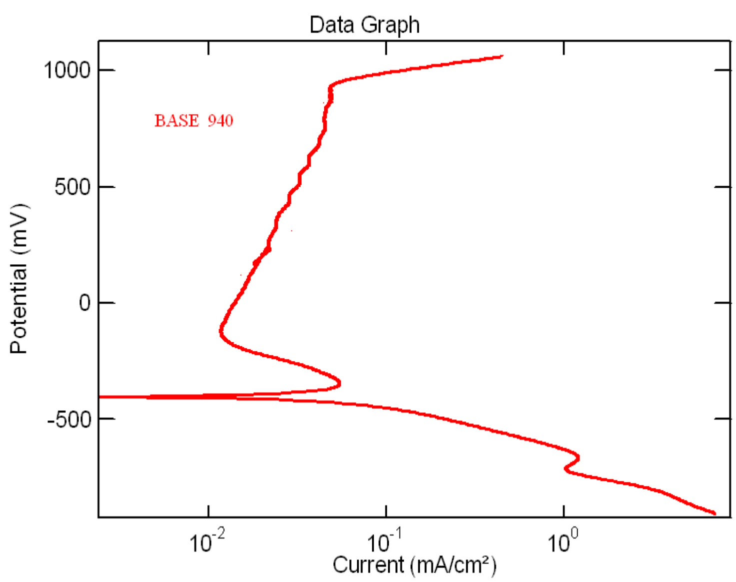

Figure 5

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 17, Preprint 23 submitted 23 April 2014

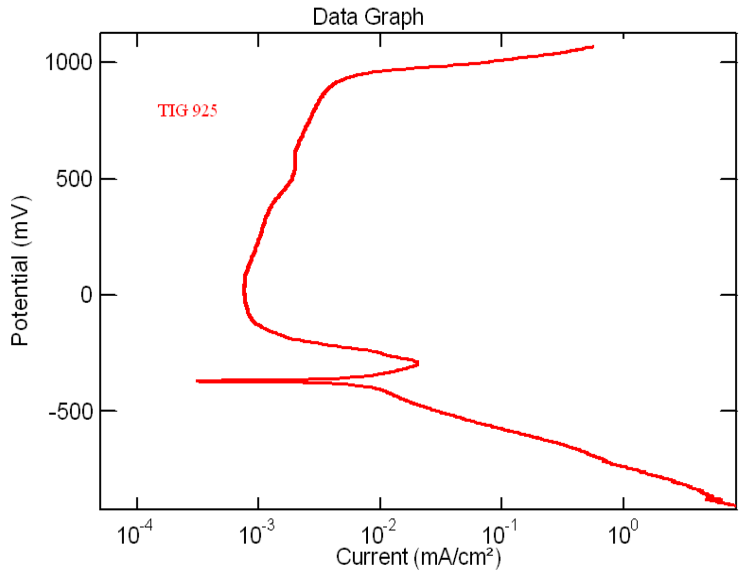

Figure 6

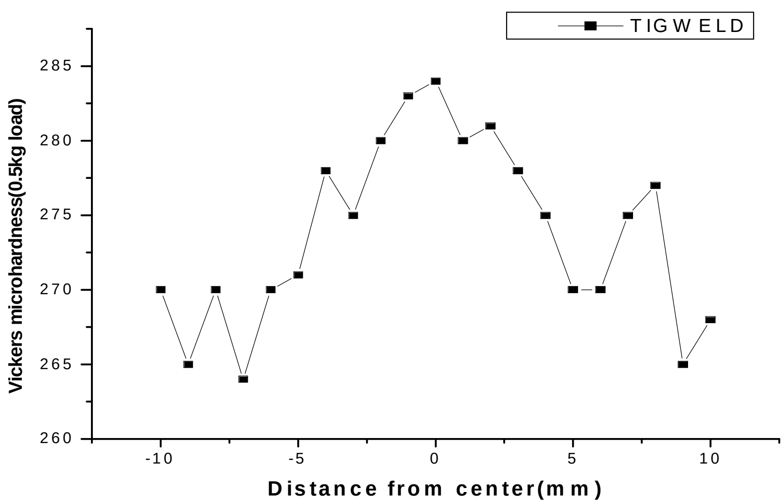

Figure 7