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MULTIPLE OPERATIONS FOR INVESTIGTAION OF CHARACTERIZATION OF MONEL 400 ALLOY AND AISI 304 DISSIMILAR WELDMENTS USING TAGUCHI METHOD

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ABSTRACT
Dissimilar metal welding involving MONEL 400 and AISI 304 finds widespread use in marine and offshore environments for the fabrication of heat exchangers, evaporators, piping and vessels in petrochemical and power generation industries. In this paper, dissimilar weld has been conducted on MONEL 400 and AISI 304 by TIG welding by varying filler materials i.e. E309L and ENiCu-7. For welding dissimilar metal i.e. MONEL 400 and AISI 304 by TIG process with E309L filler material, the optimum welding condition for higher hardness of weld bead width was obtained as 240 (amp) current, 1 mm/s welding speed and 3 mm electrode gap. For welding dissimilar metal i.e. MONEL 400 and AISI 304 by TIG process with E309L, the optimum welding condition for higher fatigue strength was obtained as 240 (amp) current, 1 mm/s welding speed and 5 mm electrode gap. For welding dissimilar metal i.e. MONEL 400 and AISI 304 by TIG process with filler material ENiCu-7, the optimum welding condition for higher hardness of weld bead width was obtained as 240 (amp) current, 1 mm/s welding speed and 3 mm electrode gap. For welding dissimilar metal i.e. MONEL 400 and AISI 304 by TIG process with filler material ENiCu-7, the optimum welding condition for higher fatigue strength was obtained as 240 (amp) current, 1 mm/s welding speed and 3 mm electrode gap.

KEYWORDS:
Dissimilar metal welding, TIG welding, MONEL 400 alloy, AISI 304

INTRODUCTION

Welding of dissimilar metals in general is more challenging than that of similar metals due to the differences in chemical compositions and thermal expansion coefficients. Some weld defects such as segregation, secondary phase formation, dilutions and cracks may generate in the weldment. If the weld metal has lesser corrosion resistance than the base metals, the attack will be concentrated on the weld metal. Formation of inter-metallic compounds that tend to alter the mechanical properties of the weld interface and weld zone associated with the dissimilar weldment.

OBJECTIVES

The objectives of this study were investigating the weldability of dissimilar metal i.e. MONEL 400 and AISI 304 by Gas Tungsten Arc Welding (GTAW) process and carry out the comparative analysis on this weldment for different filler metals such as E309L and ENiCu-7.

METHODOLOGY

Experiments were designed by the Taguchi method using an L9 orthogonal array. This design was selected based on three welding parameters with three levels each. A comparative analysis was carried out on this weldment for different filler metals such as E309L and ENiCu-7. The selected welding parameters for TIG welding are shows as below in Table 1.

Table 1: Welding Parameters and their levels

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Welding Type	Parameters	Unit	Level 1	Level 2	Level 3
TIG Welding	Current	Amp	120	180	240
	Weld Speed	mm/s	1	3	5
	Electrode Gap	mm	3	5	7

The experiments have been conducted using the TIG welding machine available at M/s Vishkarma Engineering, Chandigarh and testing equipment in College Workshop. All the welding work has been done under the supervision of the operator in industry and tests have carried out under the supervision of laboratory technician.

Fig 1: TIG Welding Set-up

Fig 2: Fatigue tested samples

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RESULTS AND DISCUSSION

The experiments have been conducted as per the design matrix by varying the filler material E309L and ENiCu-7 and measuring the output responses i.e. fatigue strength and hardness of welded joint. The effect of TIG Welding parameters i.e. Current (Amp), Welding speed (mm/s) and electrode gap has been evaluated using Taguchi method. After welding the specimens, the hardness of welding beads was measured. After analyzing the experimental data from the test, the data was fed into the Minitab software for finding the optimum value from the parameters being taken in this experimentation. Also, later Signal to Noise ratio (S/N ratio) was evaluated using the Minitab software.

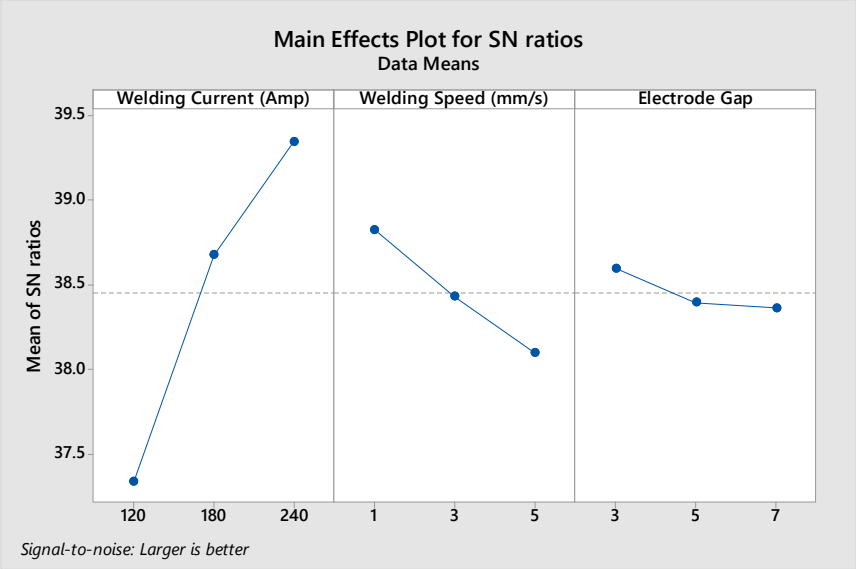

Fig 3: Mean of SN ratio of Hardness for E309L Filler Material

Figure 3 shows the effect of various parameters on S/N ratio of hardness for E309L Filler Material. It is clear that S/N ratio of hardness of weld bead is increasing with the increasing of Current from 120A to 180A and then S/N ratio of hardness again increases on further rising of current from 180A to 240A. It is clear that S/N ratio of hardness of weld bead decreases with the increasing of Welding Speed from 1mm/s to 3mm/s and further by increasing welding speed from 3mm/s to 5mm/s, the S/N ratio of hardness is again decreasing. It is shown from the above figure that the S/N ratio of hardness decreases by increasing electrode gap from 3 mm to 5 mm and after that by increasing electrode gap from 5mm to 7mm, the S/N ratio of hardness is slightly decreasing.

Table 2: Analysis of Variance for hardness for E309L Filler Material

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Welding Current (Amp)	2	562.074	281.037	361.33	0.003
Welding Speed (mm/s)	2	71.407	35.704	45.90	0.021
Electrode Gap	2	6.741	3.370	4.33	0.187
Error	2	1.556	0.778		
Total	8	641.778			

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Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.881917	99.76%	99.03%	95.09%

Table 2 shows the analysis of variance (ANOVA) of TIG welding parameters for optimizing the Hardness of weld bead. Probability values for welding current and welding speed are below 0.05, so that means welding current and welding speed are significant for hardness of weld bead as per ANOVA table.

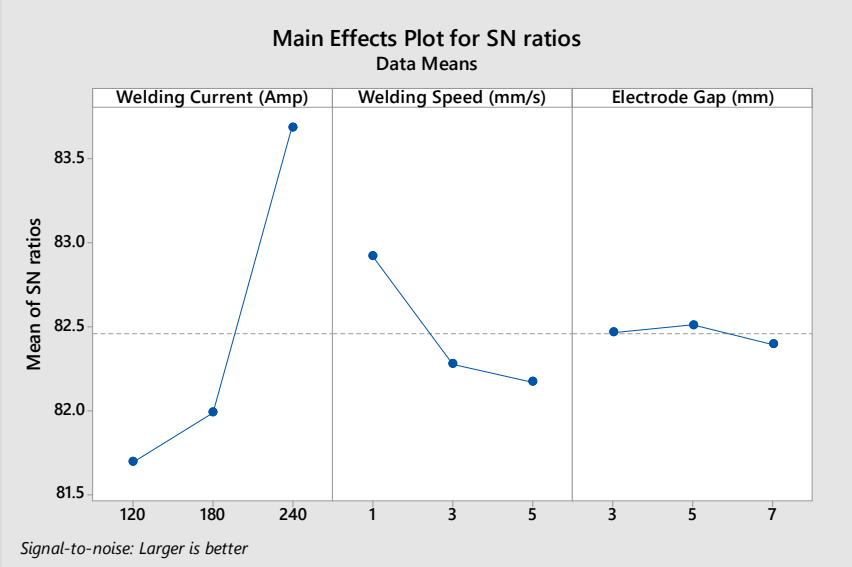

Fig 4: Mean of SN ratio of graph for Fatigue Strength for E309L Filler Material

Figure 4 shows the effect of various parameters on Mean of SN ratio of Fatigue Strength. It is clear that S/N ratio of fatigue strength increases with the increasing of welding current from 120A to 180A and by increasing of welding current further from 180A to 240A, and then S/N ratio of fatigue strength is again increasing. It is clear that there is decrease in S/N ratio of Fatigue Strength with the variation of Welding Speed from 1mm/s to 3mm/s and then there is continuous decreases of S/N ratio of fatigue strength by increasing welding speed from 3mm/s to 5mm/s. It is noted that the S/N ratio of fatigue strength almost remains constant by varying electrode gap from 3mm to 5mm and 5mm to 7mm.

Table 3: Analysis of Variance of fatigue strength for E309L Filler Material

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Welding Current (Amp)	2	17422486	8711243	271.19	0.004
Welding Speed (mm/s)	2	2295488	1147744	35.73	0.027
Electrode Gap (mm)	2	19538	9769	0.30	0.767
Error	2	64244	32122		
Total	8	19801756			

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Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
179.226	99.68%	98.70%	93.43%

Table 3 shows the analysis of variance (ANOVA) of TIG welding parameters for optimizing the fatigue strength. Probability values for welding current and welding speed are below 0.05, so that means welding current and welding speed parameter are significant parameter for fatigue strength as per ANOVA.

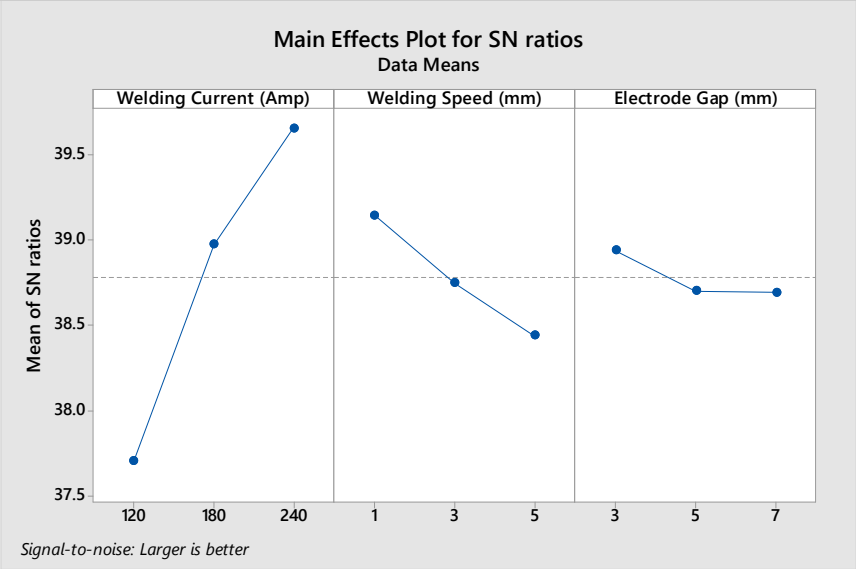

Fig 5: Mean of SN ratio of Hardness for ENiCu-7 Filler Material

Figure 5 shows the effect of various parameters on S/N ratio of hardness for ENiCu-7 Filler Material. It is clear that S/N ratio of hardness of weld bead is increasing with the increasing of Current from 120A to 180A and then S/N ratio of hardness again increases further rising of current from 180A to 240A. It is clear that S/N ratio of hardness of weld bead decreases with the increasing of Welding Speed from 1mm/s to 3mm/s and further by increasing welding speed from 3mm/s to 5mm/s, the S/N ratio of hardness is again decreasing. It is shown from the above figure that the S/N ratio of hardness decreases by increasing electrode gap from 3 mm to 5 mm and after that by increasing electrode gap from 5mm to 7mm, the S/N ratio of hardness remains almost constant.

Table 4: Analysis of Variance for hardness for ENiCu-7 Filler Material

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Welding Current (Amp)	2	571.556	285.778	285.78	0.003
Welding Speed (mm)	2	74.000	37.000	37.00	0.026
Electrode Gap (mm)	2	9.556	4.778	4.78	0.173
Error	2	2.000	1.000		
Total	8	657.111			

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Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1	99.70%	98.78%	93.84%

Table 4 shows the analysis of variance (ANOVA) of TIG welding parameters for optimizing the Hardness of weld bead. Probability values for welding current and welding speed are below 0.05, so that means welding current and welding speed are significant for hardness of weld bead as per ANOVA.

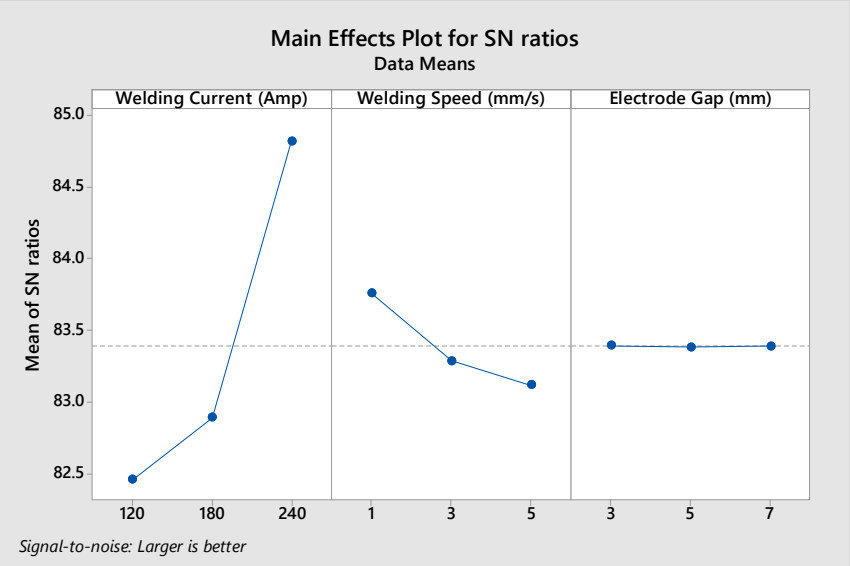

Fig 6: Mean of SN ratio of graph for Fatigue Strength for ENiCu-7 Filler Material

Figure 6 shows the effect of various parameters on Mean of SN ratio of Fatigue Strength. It is clear that S/N ratio of fatigue strength increases with the increasing of welding current from 120A to 180A and by increasing of welding current further from 180A to 240A, and then S/N ratio of fatigue strength is again increasing. It is clear that there is decrease in S/N ratio of Fatigue Strength with the variation of Welding Speed from 1mm/s to 3mm/s and then it continuously decreases further by increasing welding speed form 3mm/s to 5mm/s. It is noted that the S/N ratio of fatigue strength remains almost constant while varying electrode gap from 3mm to 5mm and 5mm to 7mm.

Table 5: Analysis of Variance of fatigue strength for ENiCu-7 Filler Material

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Welding Current (Amp)	2	29388283	14694141	897.95	0.001
Welding Speed (mm/s)	2	1875447	937723	57.30	0.017
Electrode Gap (mm)	2	8770	4385	0.27	0.789
Error	2	32728	16364		
Total	8	31305228			

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Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
127.922	99.90%	99.58%	97.88%

Table 5 shows the analysis of variance (ANOVA) of TIG welding parameters for optimizing the fatigue strength. Probability values for welding current and welding speed are below 0.05, so that means welding current and welding speed parameter are significant parameter for fatigue strength as per ANOVA.

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CONCLUSION

Followings are concluded from experimental work:

- For welding dissimilar metal i.e. MONEL 400 and AISI 304 by TIG process with E309L filler material, the optimum welding condition for higher hardness of weld bead width was obtained as 240 (amp) current, and 1 mm/s welding speed and 3 mm electrode gap.
- For welding dissimilar metal i.e. MONEL 400 and AISI 304 by TIG process with E309L filler material, the optimum welding condition for higher fatigue strength was obtained as 240 (amp) current, and 1 mm/s welding speed and 5 mm electrode gap.
- For welding dissimilar metal i.e. MONEL 400 and AISI 304 by TIG process with ENiCu-7 filler material, the optimum welding condition for higher hardness of weld bead width was obtained as 240 (amp) current, and 1 mm/s welding speed and 3 mm electrode gap.
- For welding dissimilar metal i.e. MONEL 400 and AISI 304 by TIG process with ENiCu-7 filler material, the optimum welding condition for higher fatigue strength was obtained as 240 (amp) current, and 1 mm/s welding speed and 3 mm electrode gap.

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