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INVESTIGATION OF MECHANICAL PROPERTIES OF DISSIMILAR WELDMENT OF MONEL 400 AND AISI 304 BY USING TIG WELDING AND COMPARISON BY MIG WELDING

Abstract- In this experimental work, comparative analysis for welding of dissimilar metal MONEL 400 and AISI 304 by TIG welding and MIG welding. Nine experiments have conducted on dissimilar metal i.e. Monel 400 and AISI 304 by using each technique i.e. TIG and MIG welding techniques. The optimum welding condition for lower weld bead width was obtained as 8 (V) Voltage, 60 (amp) current, and 2 mm/s welding speed. From the pooled version of ANOVA for weld bead width by TIG welding, it has indicates that voltage is significant parameters which affecting the weld bead width. The optimum welding condition for lower weld bead width was obtained as 15 (V) Voltage, 150 (amp) current, and 4 mm/s welding speed. From ANOVA analysis for fatigue strength obtaining by TIG welding process indicates that voltage is significant parameters which affecting the fatigue strength.
Keywords: TIG welding, MIG welding, MONEL 400, AISI 304, weldbility, dissimilar weld.

1. INTRODUCTION

It has observed that the austenitic stainless steel (AISI 304) and MONEL 400 alloy possess a good combination of mechanical properties, formability, weldbility, and resistance to stress corrosion cracking and other forms of corrosion. Monel-400 is a nickel-based alloy that contains 20-29 percent copper, small amount of iron, manganese, silicon and carbon and rest nickel. It has high strength, good corrosion resistance, and weldability. Therefore, it has many applications like chemical processing equipment, marine fixtures and fasteners, boiler feed water heaters and other heat exchangers etc. Zhan et al. (2016) was compared the MIG welding and laser- MIG hybrid welding methods to get the more appropriate method to overcome the poor weldability of INVAR-36 alloy. According to the analysis of the experimental and simulated results, it has been proved that the Gauss and cone combined heat source model can characterize the laser-MIG hybrid welding heat source well. The stress and deformation simulation indicate that the peak value of deformation during MIG welding was 3 times larger than that of hybrid laser-MIG welding.Cunha et al. (2016) were conducted with the pulsed TIG process in order to investigate the RMS and meanwelding current effect. Different conditions of the pulsation (pulse amplitude) were employed at thesame mean or RMS welding current. The geometric aspects of the weld beads obtained, such as theirwidth and penetration, and the welded area were analyzed. It was found that the weld penetrationbehavior is closely related with mean welding current, while the weld width with the RMS value of thewelding current.Aissani et al. (2015) determination of the heat transfer properties in Tungsten-Inert-Gaswelding (TIG). Conversion of isotherms intomicrostructural information shows that the size of the fusion zone is four times smaller than the heataffected zone dimension.Ericsson and Sandstrom (2003) was to determine whether the fatigue strength of friction stir (FS) welds is influenced by thewelding speed, and also to compare the fatigue results with results for conventional arc-welding methods: MIG-pulse and TIG.The Al–Mg–Si alloy 6082 was FS welded in the T6 and T4 temper conditions, and MIG-pulse and TIG welded in T6. The TIG welds had better fatigue performance than the MIGpulsewelds.Nascimento and Voorwald (2010) study is to analyze the effects of corrosion and successive tungsten inert gas (TIG) weldingrepairs on the reverse bending fatigue strength of AISI 4130 steel used in components critical to theflight-safety. It was observed that the reverse bending fatigue strength of AISI 4130 steel decreasesdue to the corrosion and the TIG welding and re-welding processes.Harati et al. (2015) was studied the relative influences of residual stresses and weld toe geometry on the fatigue life of cruciformwelds. Fatigue strength of cruciform welds produced using Low Transformation Temperature(LTT) filler material has been compared to that of welds produced with a conventional filler material. An LTT weld has higher fatigue strength than conventional welds. A moderate decrease in residual stress ofabout 15% at the 300 MPa stress level had the same effect on fatigue strength as increasing the weldtoe radius by approximately 85% from 1.4 mm to 2.6 mm.Carofalo et. al. (2015) has been the mechanical properties of superalloy evaluated in case of weldedrepaired material and compared to base material. Test program considered flat specimens on base andTIG welded material subjected to static, low-cycle fatigue and creep test at different temperatures.Results of uniaxial tensile tests showed that the presence of welded material in the gage length specimendoes not have a relevant influence on yield strength and UTS. However, elongation at failure of TIGmaterial was reduced with respect to the base material.Li et. al. (2015) study was to evaluate microstructural and mechanical change of DP780 steel after tungsteninert gas (TIG) welding and the influence of notch locations on the fatigue crack growth (FCG) behavior. Thetempering of martensite in the sub-critical heat affected zone (HAZ) resulted in a lower Width (~220 HV)compared to the base material (~270 HV), failure was found to originate in the soft HAZ during tensile test.

Most of researcher’s worked on characterization of mechanical properties of dissimilar welded joints and cracks propagations on welding bead, welding by different techniques on different materials. Study of initiation of crack from surface and its propagation into the interior is further needs much more work to arrest the cause and critical issues of failure. However, so far, studies on behavior of TIG welded of MONEL 400 and AISI 304 and comparison with MIG welding have not been found in literature. The aim of this paper is to investigate the weldability of dissimilar metal i.e. MONEL 400 and AISI 304 using Gas Tungsten Arc Welding (GTAW) process as well as using Metal Inert Gas Welding (MIGW) process and optimization of TIG and MIG welding parameters.

2. EXPERIMENTAL DESIGN

Experiments were designed by the Taguchi method using an L_9 orthogonal array. This design was selected based on three welding parameters with three levels each. The selected welding parameters for TIG welding and MIG welding shows as below in Table 1**.**

Table 1: Welding Parameters and their levels

Welding Type	Parameters	Unit	Level 1	Level 2	Level 3
TIG Welding	Voltage	Volt	8	10	15
	Current	Amp	60	80	100
	Weld Speed	mm/s	2	4	6
MIG Welding	Voltage	Volt	15	20	25
	Current	Amp	150	200	250
	Weld Speed	mm/s	2	4	6

Fig 1: Comparison of MIG and TIG welding Specimens

3. RESULTS AND DISCUSSIONS

After conducting the experiments as per the design matrix, for measuring, the output responses i.e. fatigue strength and weld bead width. The effect of TIG Welding parameters i.e. Voltage (V), Current (Amp), Weld speed (mm/s) is evaluated using Taguchi. The experiments were performed on TIG Welding Machine and measure the Weld bead Width. Now, after analyzing the experimental data from the test, the data is feed into the Minitabsoftware for finding the optimum value from the parameters being taken in thisexperimentation. Also later Signal to Noise ratio (S/Nratio) is evaluated using the Minitab software.

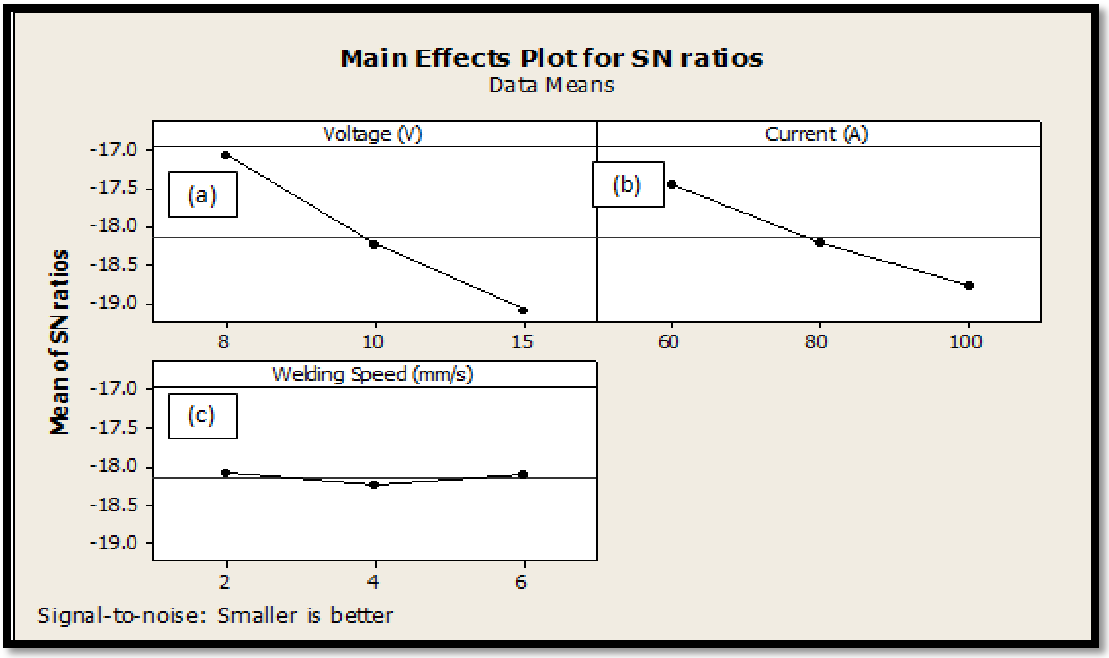

Fig2:Mean of SN ratio ofgraph for Weld bead Width

Fig. 2(a)shows the effect of Voltage on Mean of SN ratio of Weld bead Width. It is clear that there is decrease in Weld bead Width with the change of Voltage from 8V to 10V and then decreases further from 10V to 15V.Fig. 2 (b)shows the effect of current on Mean of SN ratio ofWeld bead Width. It is clear that there is decrease in Weld bead Width with the change of Current from 60A to 80A and then decreases continues further from 80A to 100A.Figure 2(c) shows the effect of welding speed on Mean of SN ratio of Weld bead Width. It is clear that there is slightly increase in Weld bead Width with the change of Weld Speed from 2mm/s to 4mm/s and then decreases from 4mm/s to 6mm/s.

Analysis of Variance for MEAN1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Voltage (V)	2	5.5563	5.5563	2.7781	32.90	0.029
Current (A)	2	2.2496	2.2496	1.1248	13.32	0.070
Welding Speed (mm/s)	2	0.0496	0.0496	0.0248	0.29	0.773
Error	2	0.1689	0.1689	0.0844		
Total	8	8.0244				

S = 0.290593   R-Sq = 97.90%   R-Sq(adj) = 91.58%

Fig 3:Analysis of Variance for Weld bead width for TIG Welding

Figure 3shows the analysis of variance (ANOVA) of welding parameters for optimizing the weld bead. In order to statistically analyze the results, ANOVA was performed. Process variables having p-value less than 0.05 are considered significant terms for the requisite response characteristics. Probability values for voltage is one of parameter have below 0.05, so that voltage parameter is significant for weld bead as per ANOVA.

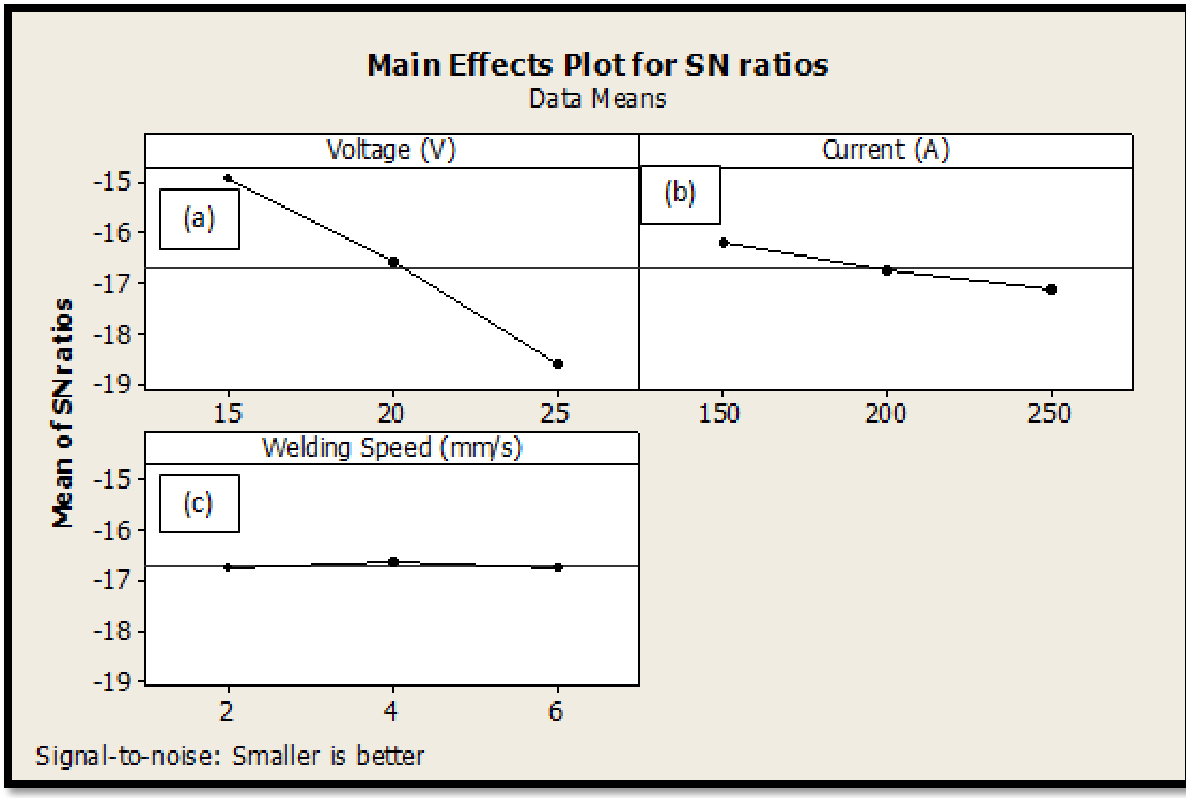

Fig 4:Mean of SN ratio ofgraph for Weld bead Width for MIG Welding

Fig. 4(a)shows the effect of voltage on Mean of SN ratio of Weld bead Width. It is clear that there is decrease in Weld bead Width with the change of Voltage from 15V to 20V and then decreases further from 20V to 25V.Fig. 4(b)shows the effect of current on Mean of SN ratio of Weld bead Width. It is clear that there is decrease in Weld bead Width with the change of Current from 150A to 200A and then decreases continuously from 200A to 250A.Figure 4(c) shows the effect of welding speed on Mean of SN ratio of Weld bead Width. It is clear that there is slightly increase in Weld bead Width with the change of Weld Speed from 2mm/s to 4mm/s and then decreases slightly from 4mm/s to 6mm/s.

Analysis of Variance for MEAN1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Voltage (V)	2	12.9696	12.9696	6.4848	833.76	0.001
Current (A)	2	0.7874	0.7874	0.3937	50.62	0.019
Welding Speed (mm/s)	2	0.0096	0.0096	0.0048	0.62	0.618
Error	2	0.0156	0.0156	0.0078		
Total	8	13.7822				

S = 0.0881917 R-Sq = 99.89% R-Sq(adj) = 99.55%

Fig 5:Analysis of Variance for Weld bead width for MIG Welding

Figure 5shows the analysis of variance (ANOVA) of MIG welding parameters for optimizing the weld bead. In order to statistically analyze the results, ANOVA was performed. Process variables having p-value less than 0.05 are considered significant terms for the requisite response characteristics. Probability values for voltage and current parameter have below 0.05, so that voltage and current parameter are significant parameter for weld bead as per ANOVA.

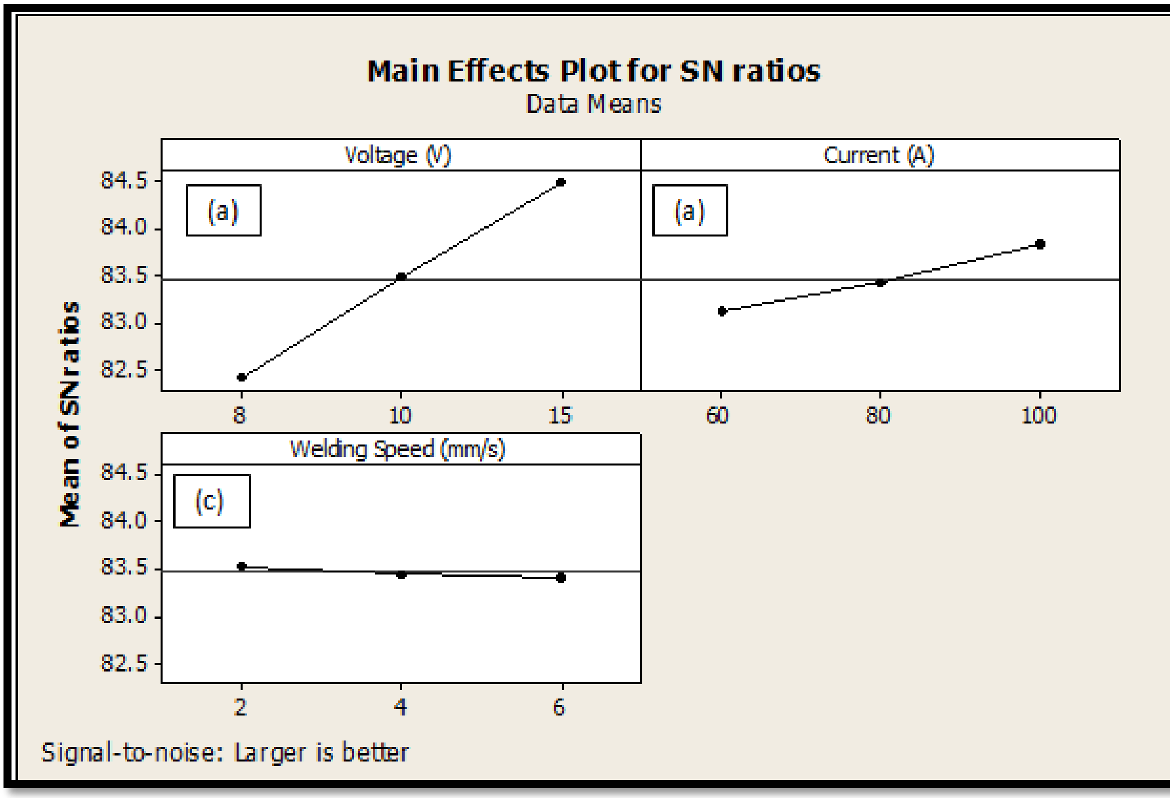

Fig6:Mean of SN ratio ofgraph for Fatigue Strength by TIG welding

Fig. 6(a)shows the effect of voltage on Mean of SN ratio ofFatigue Strength. It is clear that there is increase in Fatigue Strength with the change of Voltage from 8V to 10V and then increases further from 10V to 15V.Fig. 6(b)shows the effect of current on Mean of SN ratio ofFatigue Strength. It is clear that there is increase in Fatigue Strength with the change of Current from 60A to 80A and then increases further from 80A to 100A.Figure 6(c) shows the effect of welding speed on Mean of SN ratio ofFatigue Strength. It is clear that there is slightly decrease in Fatigue Strength with the change of Weld Speed from 2mm/s to 4mm/s and then decreases from 4mm/s to 6mm/s.

Analysis of Variance for Fatigue Cycles (No. of Cycle), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Voltage (V)	2	18914961	18914961	9457480	166.74	0.006
Current (A)	2	2171366	2171366	1085683	19.14	0.050
Welding Speed (mm/s)	2	143660	143660	71830	1.27	0.441
Error	2	113438	113438	56719		
Total	8	21343425				

S = 238.157   R-Sq = 99.47%   R-Sq(adj) = 97.87%

Fig 7:Analysis of Variance of fatigue strength for TIG Welding

Figure 7shows the analysis of variance (ANOVA) of TIG welding parameters for optimizing the fatigue strength. In order to statistically analyze the results, ANOVA was performed. Process variables having p-value less than 0.05 are considered significant terms for the requisite response characteristics. Probability values for voltage parameter have below 0.05, so that voltage parameter is significant parameter for fatigue strength as per ANOVA.

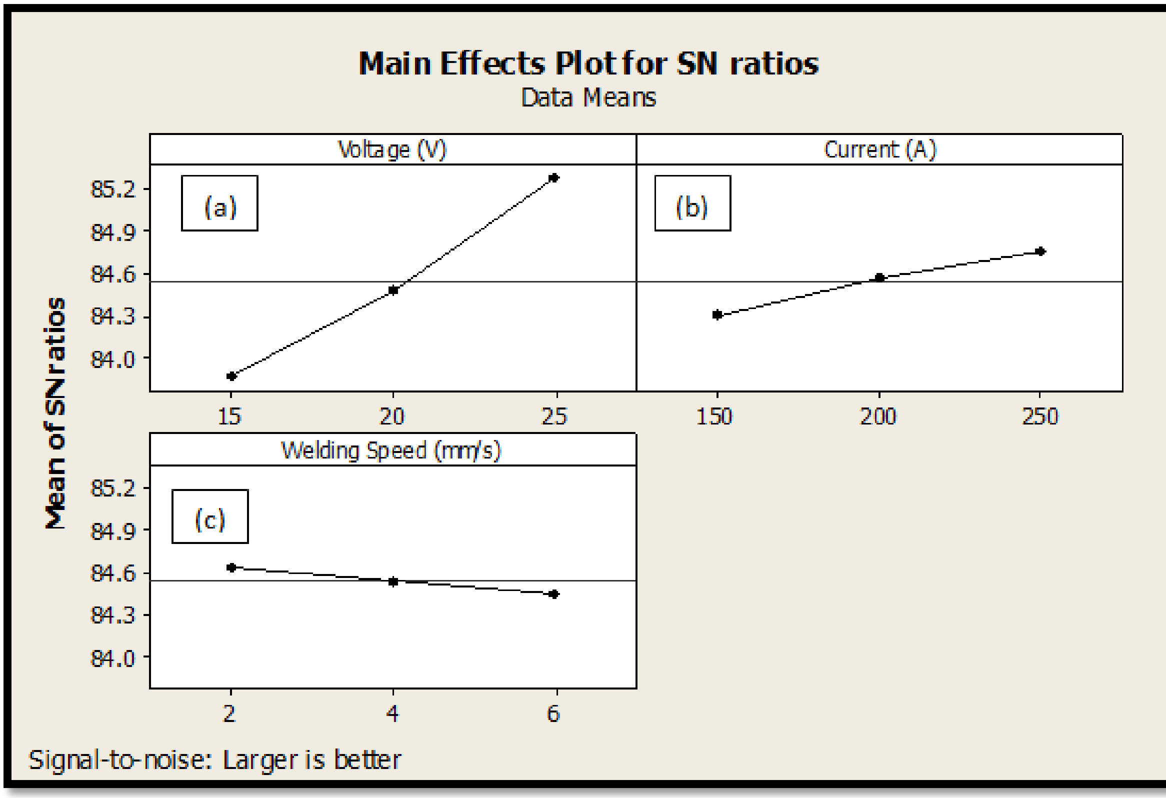

Fig8:Mean of SN ratio ofgraph for Fatigue Strength

Fig. 8(a)shows the effect of voltage on Mean of SN ratio ofFatigue Strength. It is clear that there is increase in Fatigue Strength with the change of Voltage from 15V to 20V and then increases further from 20V to 25V.Fig. 8(b)shows the effect of current on Mean of SN ratio ofFatigue Strength. It is clear that there is increase in Fatigue Strength with the change of Current from 150A to 200A and then increases continuously from 200A to 250A.Figure 8(c) shows the effect of welding speed on Mean of SN ratio ofFatigue Strength. It is clear that there is slightly decrease in Fatigue Strength with the change of Weld Speed from 2mm/s to 4mm/s and then decreases slightly from 4mm/s to 6mm/s.

Analysis of Variance for Fatigue Cycles (No. of Cycle), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Voltage (V)	2	11587553	11587553	5793776	3336.79	0.000
Current (A)	2	1166253	1166253	583126	335.84	0.003
Welding Speed (mm/s)	2	232872	232872	116436	67.06	0.015
Error	2	3473	3473	1736		
Total	8	12990150				

S = 41.6693 R-Sq = 99.97% R-Sq(adj) = 99.89%

Fig 9:Analysis of Variance of fatigue strength for MIG Welding

Figure 9shows the analysis of variance (ANOVA) of MIG welding parameters for optimizing the fatigue strength. In order to statistically analyze the results, ANOVA was performed. Process variables having p-value less than 0.05 are considered significant terms for the requisite response characteristics. Probability values for all parameter have below 0.05, so that voltage, current and welding speed parameter are significant parameter for fatigue strength as per ANOVA.

4. CONCLUSIONS

In this thesis work, dissimilar weld have been conducted on MONEL 400 and AISI 304 by TIG welding and MIG welding. A total of nine experiments have been carried out on dissimilar metal i.e. Monel 400 and AISI 304 by both process TIG and MIG to find out the best possible welding parameters. Followings are concluded fromexperimental work;

1. For welding dissimilar metal i.e. Monel 400 and AISI 304 by TIG process, the optimum welding condition for lower weld bead width was obtained as 8 (V) Voltage, 60 (amp) current, and 2 mm/s welding speed.

2. The pooled version of ANOVA for weld bead width by TIG welding indicates that voltage is significant parameters which affecting the weld bead width.
3. For welding dissimilar metal i.e. Monel 400 and AISI 304 by MIG process, the optimum welding condition for lower weld bead width was obtained as 15 (V) Voltage, 150 (amp) current, and 4 mm/s welding speed.
4. The pooled version of ANOVA for weld bead width by MIG welding indicates that voltage and current are the significant parameters which affecting the weld bead width.
5. For welding dissimilar metal i.e. Monel 400 and AISI 304 by TIG process, the optimum welding condition for higher fatigue strength was obtained as 15 (V) Voltage, 100 (amp) current, and 4 mm/s welding speed.
6. The pooled version of ANOVA for fatigue strength obtaining by TIG welding process indicates that voltage is significant parameters which affecting the fatigue strength.
7. For welding dissimilar metal i.e. Monel 400 and AISI 304 by MIG process, the optimum welding condition for higher fatigue strength was obtained as 25 (V) Voltage, 250 (amp) current, and 4 mm/s welding speed.
8. The pooled version of ANOVA for fatigue strength obtaining by MIG welding process indicates that voltage, current, and welding speed are significant parameters which affecting the fatigue strength.

5. REFERENCES

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