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Experimental Analysis of Dissimilar Weldments Ss316 And Monel400 in Gtaw Process

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ABSTRACT: Dissimilar metal welded components are becoming increasingly common in industrial applications especially in the nuclear sector. This project, investigates the Weld ability of dissimilar materials Monel 400 and SS316 of thickness 5mm with V groove configuration by Gas Tungsten Arc Welding (GTAW) technique employed ERNiCrMo-3 filler wire. Experiment has been conducted using following process parameters, the gas flow rate, voltage, current and no of passes. The mechanical properties like tensile strength, hardness are calculated at the welded joint. A metallurgical analysis for the optimum parameter is performing on the specimens and typically two distinct Heat Affected Zones (HAZ) are observing with variation in the micro structure. Residual stresses are evaluated at weld zone and observed maximum stress tensor in weldments due to continuous heat input.

Keywords: characterization, GTAW,Heat affected zone, Monel 400,Resudial stresses,

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I. INTRODUCTION

Bimetallic combinations of Monel 400 and AISI 316 are used widely in the heat exchangers, super heaters employed in the oil gasification plants and chemical processing equipments .The typical applications of the bimetallic welding of Monel - Stainless steel and Monel - low carbon steel have been reported by the researchers reported that the combination of Monel 400 and low carbon steel are employed in the oil gasification plants where they are exposed under corrosive medium of H2S, SO2 and SO3. Also it was reported that the sound weld can be obtained using ERNiCrMo-3 for welding Monel 400 and low carbon steel and the problem of sensitization could be minimized on using ENiCrFe-3 filler wire. Hence the choice of filler materials for dissimilar welding of the samples was based on the properties of toughness, thermal fatigue resistance and resistance to hot cracking tendency. Welding of dissimilar metals is really cumbersome and challenging task because of the differences existing in the coefficient of thermal expansion, thermal conductivity and the chemical composition existing between two metals. It is also difficult to examine the microstructure of dissimilar weldment as the preparation itself is tedious. So it is mandatory to select a suitable filler material to overcome or minimize these problems; however it is also difficult that no single filler metal would be suitable to solve all the problems.

II. EXPERIMENTATION OF DISIMILAR WELDMENTS

2.1 Experimentation

The major problem that arises when joining dissimilar metal welds is formation of inter-metallic compound in the welded region. These inter-metallic compounds should be checked in order to find problems related to crack sensitivity, ductility, corrosion, etc which make the study of microstructure significant. In a welding process two metals are joined together often by melting the work piece or by filler, when the molten metal cool down it takes the shape of solid joint. There are different methods of joining dissimilar metal; one of those methods is composite insert. As the name indicates, another material is inserted between two metals at the interface to complete the procedure.

2.2.3 TIG Welding Equipment

2.2.4 Experimental Set-Up

When selecting **TIG welding machine**, you should know how much power and sophistication are needed for the job. It is also necessary to ascertain the volume of such jobs currently on hand and the projected business for **TIG welding**. The next question is - does one need AC or DC power source. Professionals say that aluminum and magnesium are two metals that are best welded using the AC output from the power source. Steels and stainless steels are most often welded with DC output. To weld a variety of metals, use a combination AC/DC machine.

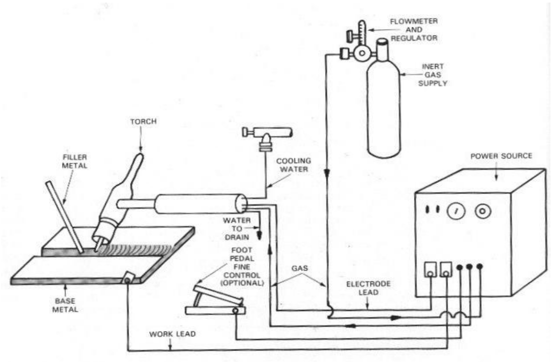


Fig 2.2 TIG welding process

If the power source is either moved around the shop, or taken from one site to another, then a **portable welder** is needed. There are two basic ways to accomplish portability - inverters and engine-driven welders. Inverters are now available that weigh around 13 kg and come with handles for easy shifting around. Engine-driven machines are used when a welder has no access to primary power for **welding**. Engine-driven power sources are needed for field maintenance, pipe welding, or construction work.

2.3 Experimental Procedure

The candidate metals and the filler metal employed in this study were Monel 400, AISI 316 and ERNiCrMo-3 respectively and their chemical composition is represented in Table 1. The as-received candidate metals were sliced to the dimensions of 150 mm x 80 mm x 5 mm. Samples were made as per the standard V-groove butt configurations with a root face of 1 mm, included angle of 30° and the land face of 1.5 mm. These samples were clamped firmly in the fixture designed with a copper back plate so as to avoid distortions and bending during welding.

The process parameters were established from the open literatures as well as from the trial and error studies and represented in

Table 2.1 Process parameters

S.No	Welding Process	Weld materials	Current Amps	Voltage V	Gas flow rate(lpm)	No of Passes
1.	CCGTAW	SS316-SS316	130	12.5	15	3
2.	CCGTAW	SS316-Monel400	140	12.5	15	3
3.	CCGTAW	Monel400-Monel400	145	12.5	15	3

Followed by welding, the weldments were cut into different coupons using wire cut EDM (Electrical Discharge Machining) for further metallurgical and mechanical investigations. Metallographic examination was done on the composite region (which has the dimensions of 30 mm x 10 mm x 5 mm), covering all the zones including parent metals, heat affected zones (HAZ) and weld.

Fig 2.1 V Groove Cut

Fig 2.2 before welding

Fig 2.3 After welding

After welding, the weldments were characterized to determine for any macro/microscopic defects using X-Ray radiographic technique.Ensuing to the results of NDT analysis, the as-welded samples were cut to different coupons using wire cut EDM (Electrical Discharge Machining) to carry out metallurgical and mechanical tests. Macro and Microstructure studies were performed on the coupons covering all the zones of the weldments known as ‘composite zone

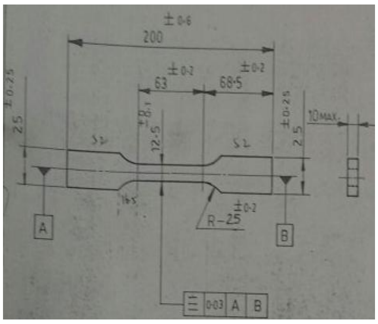
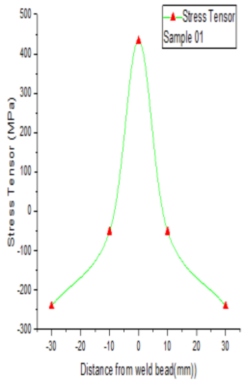


Fig 2.4 Dimensions of tensile cut

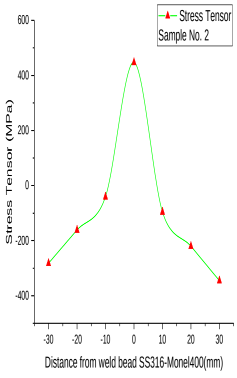
Fig 2.5 Sample tensile work piece

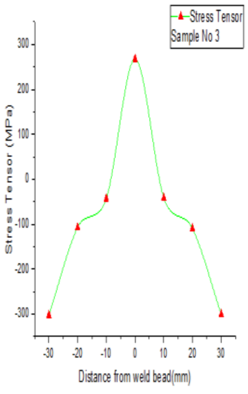
2.4 Residual Stresses

Residual Stresses (Sigma11) for weldments at different locations in the weldments as shown in following graphs. From the graph more residual stresses were developed at the weld bead due to higher heat input.The stress tensor values can be reduced by controlling of heat input. The high residual stresses were observed in similar weldment SS316 as compared to Monel weldments because, the heat distribution of in Monel material was uniform and directional.



Sample01 SS316-SS316





Sample03 Monel400-Monel400

2.5.1 Angular Distortion

- Weld tends to be wider at the top than the bottom, causing more solidification shrinkage and thermal contraction.
- For Double-V Edge Butt weld-joint , it depends upon root face and root gap
- Fillet weld-joints, it depends upon flange width, weld leg length and flange thickness.

- Depends Upon:

1. Width and depth of fusion zone relative to plate thickness.
2. Type of joint.
3. Weld pass sequence
4. Thermo-mechanical material properties
5. Heat input per unit length of weld, distribution of heat source density.
6.

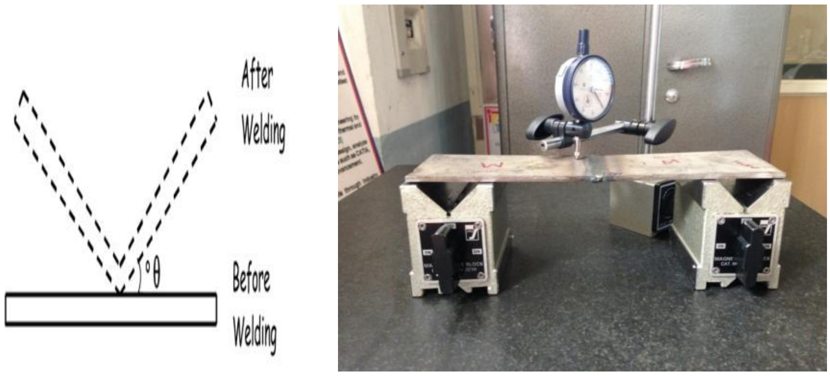


Fig 2.6 Angular distortion measurement

Angular distortion measured by dial gauge using flat surface plate. The height of the plate can be found by moving dial gauge from weld bead to base metal side. When the dial moves towards the base metal due to distortion effect the dial values change. Angular distortion $\alpha=\tan^{-1}(h/L)$, Where h height from datum line, L length of the base metal

II. RESULTS & DISCUSSION

3.1Macro and Microstructure Studies:

Visual examination, NDT analysis and the macroscopic studies clearly showed that the weldments obtained from the Constant Current GTA welding process were free from any of the macro/microscopic defects that include lack of penetration, fusion, porosity etc. The weld region has interdendritic network of the elements consisting of Ni, Cr, Fe, Cu and Nb. Also migrated grain boundaries were observed at the weld zone.

Microstructure

Fig 3.1 SS316-SS316 (CC) HAZ

Fig 3.2 SS316-SS316 (CC) Weld Zone

Fig 3.3: SS-Monel (CC) HAZ

Fig 3.4 SS-Monel (CC) Weld zone

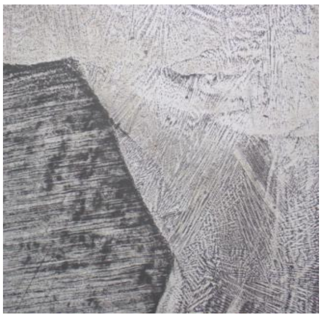


Fig 3.5: Monel-Monel (CC) HAZ

Fig 3.6 Monel-Monel (CC) Weld zone

3.2 **Mechanical Characterization of the weldments:**

3.2.1 Hardness Measurement

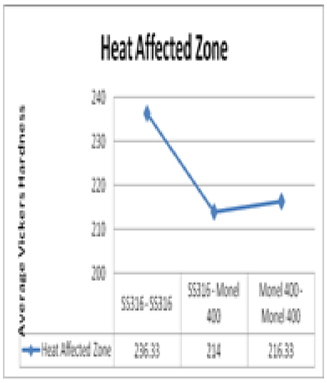
The Resistance of a metal to plastic deformation against Indentation, Scratching, Abrasion or Cutting. Vickers hardness profiles of the welded zones were measured on a cross- section perpendicular to the welding direction using a Vickers indenter with a 5kgf load for15 second. Hardness profile on the dissimilar weldments of Monel 400 and AISI 316 employing ERNiCrMo-3 filler wire clearly epitomized that the maximum hardness was found to be at the weld zone.

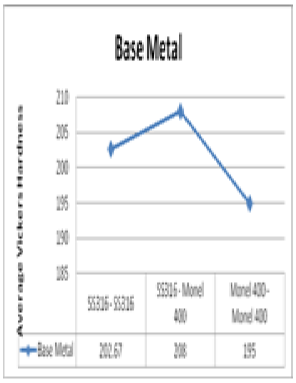
The average hardness at the weld zone was found to be 234.0 HV whereas the average hardness value at the Monel 400 side was 208 HV and 202HV at AISI 316 side

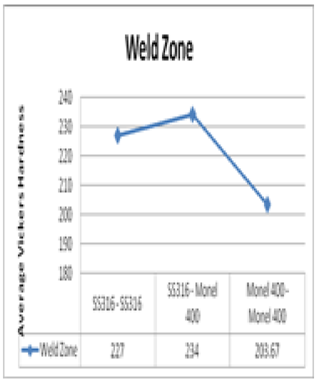
S.No	Weld Sample	Avg. Vickers hardness (HV)		
		Base metal	HAZ	Weld Zone
1.	SS316-SS316	202.67	236.33	227.0
2.	SS316-Monel400	208.00	214.00	234.00
3.	Monel400-Monel400	195.00	216.33	203.67

Table 3.1 Vickers hardness values

The Graphs indicates the Vickers hardness values vs length from weld zone to last position base materials with weld zones







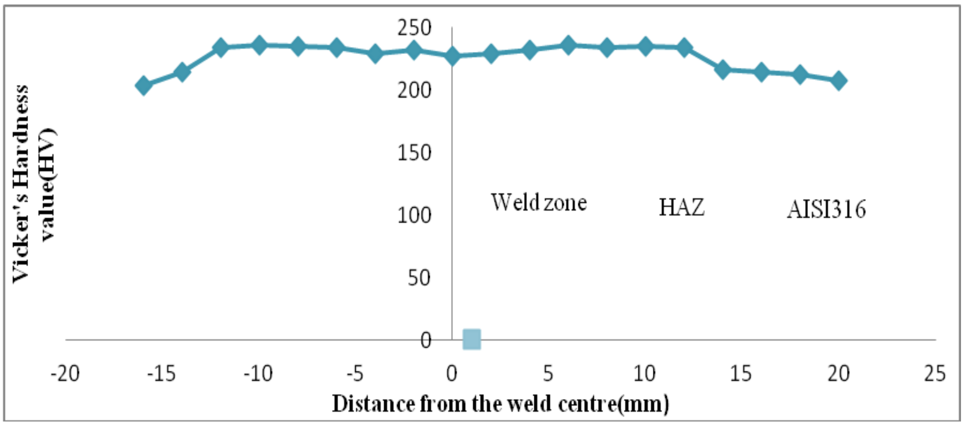


Fig 3.2 Hardness value Vs Distance from weld centre

3.2.2 Tensile Properties of the weldments

Tensile samples were cut from sections of the weld outside of the transient zones of size specimen width 12.5mm and specimen thickness 4.97mm and initial gauge length 63mm. tensile test is conducted on Instron 5500R - 4507 - 200kN standard samples of the weldments. Tensile studies were conducted on the standard samples to assess the mechanical properties of the weldments.

Fig 3.3 Specimens after Tensile test

Table 3.2 Tensile test values

Sl.no	Welding process	Weldments	Height (h)	Angular Distortion(Degrees)
1.	CCGTAW	SS316- SS316	1.56	0.595
2.	CCGTAW	SS316- Monel400	1.49	0.571
3.	CCGTAW	Monel400- Monel400	0.15	0.057

S. No .	Welding Process	Weld Sample	Original Gauge length(mm)	Final Gauge length (mm)	Max. Load kN	Ultimate Tensile strength(UTS)MPa	% Elongation
1.	GTAW	SS316- SS316	50	76.79	35.1	556.3	53.58
2.	GTAW	SS316- Monel400	50	63.24	32.6	543.6	26.48
3.	GTAW	Monel400 - Monel400	50	68.37	32.7	533.7	36.74

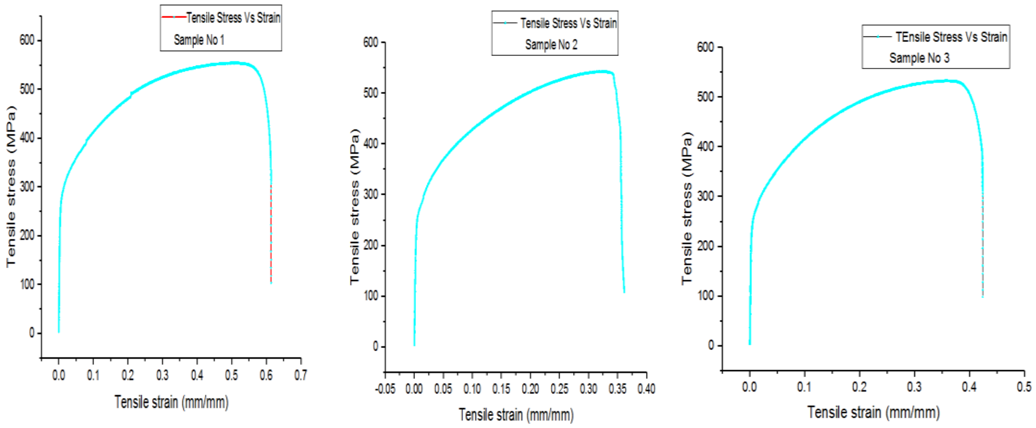


Table 3.3 Angular distortion values

IV. CONCLUSIONS

It is inferred from the macrostructure studies that successful joints of Monel 400 and AISI 316 could be obtained from the GTA welding process employing ERNiCrMo-3. Microstructure studies clearly attributed to the formation of migrated grain boundaries at the weld zone. In these studies, multi-pass GTA welding is employed for joining these metals which normally yields higher heat input which could cause the migration of grain boundaries.. It was noticed in all the trials that the tensile fracture occurred at the parent metal of AISI 316 side. This could be attributed to the greater hardness persisting in the weld zone due to the presence of the metallic carbides which enhanced the strength of the weldments.

Based on the current studies, the major conclusions drawn from this study are reported as follows:

1. GTA welding process could be employed to join Monel 400 and AISI 316 employing ERNiCrMo-3 filler wire.
2. The radiography results showed the defect of lack of penetration, thus the result concludes that the defect does not create a major impact.
3. Tensile failure occurred at the parent metal of AISI 316 in the trials of the dissimilar weldment.
4. The hardness has showed that the sample with the minimal tensile strength has the maximum hardness, which concludes that, the increase in hardness results in the decrease of the tensile strength.
5. Due to the higher heat inputs, there is the prominent formation of coarse grains at the heat affected zones of both the metals in CCGTA welding process.
6. The welding process GTA welding process devolved more Residual stresses due to continuous heat input.
7. The Monel400 alloy does not respond to heat treatment except for annealing after cold working. Due to this property the angular distortion is very low in the welding process.
8. The range of residual stress distribution became wider when welding current increases.
9. Due to low difference of thermal expansion coefficient of two base metals, contraction in two base metals is not distinctly different.
10. Increasing the welding speed also increases the cooling rate and finally the welding residual stresses in the weld zone.

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