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Analysis and Experimental investigation of Weld Characteristics for TIG Welding in Dissimilar Metals

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Abstract — The aim of this work is to study the mechanical properties that affect the welding joint of metals. Stainless Steel 304 was welded to Mild steel using a TIG welding which also known as Gas tungsten arc welding (GTAW) or tungsten inert gas (TIG) welding The weld area and electrode is protected from oxidation and other atmospheric contamination is prevented by an inert shielding gas (argon or helium). Metals welding have great scope in advanced technology that includes high hardness, high strength and corrosion resistance properties. The combination of stainless steel has got large number of application in industry such as nuclear plant, and heat exchanger assembly etc. Due to the fact that low cost of mild steel and corrosion resistance property of stainless steel, all these application requires welding of the two which can perform the desired service requirement of the industry. The results indicate the optimum value of current and voltage which will be applied to developed to maximize the mechanical properties of welding the stainless steel 306 and Mild steel.

Keywords – Aluminium, SiC, MoS_2, Composites.

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1. INTRODUCTION

Dissimilar metal welding is defined in which weldments are made from metals of different compositions. A successful weld between dissimilar metals is one that is as strong as the weaker of the two metals being joined, The possessing takes place with sufficient tensile strength and ductility so that the joint will not fail in the weld. Nowadays, joining dissimilar metal is indispensable in manufacturing and constructing advanced equipment and machinery. Joining dissimilar metals is therefore to compose different properties of metals in order to minimize material costs and at the same time maximize the performance of the equipment and machinery. The problem of making weld between dissimilar metals which relates to the transition zone between the metals and the intermetallic compound formed in this transition zone. For the fusion type welding process it is important to investigate the phase diagram of the two metals involved. If there is mutual solubility of the two metals the dissimilar joints can be made successfully. If there is little or no solubility between the two metals to be joined the weld joint will not be successful. The intermetallic compounds that are formed between the dissimilar metals must be investigated to determine their crack sensitivity, ductility, susceptibility to corrosion, etc. Another factor involved in predicting a successful service life for dissimilar metals joint relates to the coefficient of thermal expansion of both materials. If these are widely different, there will be internal stresses set up in the intermetallic zone during any temperature change of the weldment. If the intermetallic zone is extremely brittle service failure may soon occur. The difference in melting temperature of the two metals that are to be joined must also be considered, since one metal will be molten long before the other when subjected to same heat source.

2. LITERATURE REVIEW

M. Sireesha, The studied the transition joints in power plants between ferrites steels and austenitic stainless steels which suffer from a mismatch in coefficients of thermal expansion (CTE) and the migration of carbon during service from the ferrites to the austenitic steel. The study shows the use of a trimetallic combination with an insert piece of intermediate CTE (coefficient of thermal expansion) provides for a more effective lowering of thermal stresses. In this work a trimetallic joint involving modified 9Cr+1Mo steel and 316LN austenitic stainless steel as the base materials and Alloy 800 as the intermediate piece. Nickel-based consumables produce welds exhibiting better tensile properties and improved thermal stability in relation to the austenitic steel filler materials. The absence of microstructural deterioration at high temperatures is considered particularly important in view of the usual operating conditions for these joints. From a consideration of thermal expansion coefficients also, the Inconel filler materials are seen to be superior to the stainless steel consumable.

P. BalaSrinivasan, The studied the microstructural evolution and hardness variations in a dissimilar weld joint comprising an austenitic stainless steel and a ferrites stainless steel (FSS) produced by GTAW. Further, the different regions of this resultant weldment were characterized for the general and pitting corrosion behavior in neutral and acidic chloride solutions. Thin section sheets (1.5 mm thickness) of an austenitic stainless steel (ASS) corresponding to AISI 316 and an FSS of grade AISI 430 were used. Autogenously welded joints between an austenitic and FSS could be produced by GTAW without the problems of hot cracking as the weld metal is over matched in terms of mechanical properties in relation to the FSS parent material.

C.R. Das, He had shown that it is difficult to simultaneously obtain good ductility, toughness and corrosion resistance in the weldment. Therefore, judicious selection of materials is an important for fabrication of DMW (Dissimilar metal weld) joints. In a nuclear power plant DMW joints are necessary for joining the different materials chosen for the various parts of the heat transfer circuit, with design life of components of up to 100 years and nominal operating temperature of 573–623 K. In this paper Weld ability of the dissimilar weld joint between austenitic 304L (N) stainless steel (SS) and martensitic 403 SS made by gas tungsten arc welding process using ERNiCr-3 filler metal has been studied. Two materials were joined using a K-type weld groove joint; with the straight edge on the 403 SS side buttered using ERNiCr-3 filler wire. Weld metal deposited by using ER308L, ER309L and ERNiCr-3 filler wires. ERNiCr-3 filler metal is preferable (to ER308L and ER 309L filler metals) for the DMW joint between 403 SS and 304L(N) SS. Buttering of 403 SS with ERNiCr-3 filler metal results in good bend ductility and high impact toughness of the HAZ. Also ERNiCr- 3 weld metal has higher strength at elevated temperatures.

Anwar Ul-Hamid, This paper reports the investigation into the failure of dissimilar weld metal joints in a piping system of a petrochemical plant. The process involved a reformed gas that passed through a water cooler followed by compression in a three stage centrifugal synthesis gas compressor. The outlet piping of the suction drum constituted weldments of carbon steel (CS) pipe and SS 304 elbow fittings. A number of cracks appeared at these weld joints after a relatively short period of service. Radiographic tests conducted onsite showed that the cracks were circumferential and developed along the weld seam adjacent to the CS pipe. The length of these cracks varied between 120 and 600 mm. Some of these joints leaked following weld repair in the past. One of these joints failed after two and half years of service following weld repair. The length of the crack formed at this point was 300 mm and it had occurred at the weld seam. Experimental results indicate that the joint between the CS pipe and the SS weld failed due to the development of a localized region of high hardness (e.g. martensitic) at its interface during cooling from welding temperature. The hydrogen rich gas transported through the pipe initiated cracking at this region.

Frederick W. Brust, This presented the results of investigation of PWSCC (Primary Water Stress Corrosion Cracking) in the bimetallic welds that join the hot leg to the reactor pressure vessel nozzle. The hot leg weld is a bimetallic weld joining a SA-508 (Class 2) reactor vessel nozzle with a type 304 stainless steel pipe using an Inconel weld procedure. The hot leg pipe carries reactor-heated water to the steam generator. It is then recirculated by the pump back through the „cold leg‟. Both the hot and cold leg stainless steel pipes are joined to the reactor vessel nozzles via bimetallic welds. The cracking of concern occurs in the Inconel weld only. The finite element alternating method (FEAM) was used to obtain stress intensity factors to perform the PWSCC. The analysis of the residual stress and PWSCC for Inconel buttering, PWHT, weld deposition, weld grind-out and repair, hydro testing, service temperature heat up, finally service. Tensile weld residual stresses, in addition to service loads, contribute to PWSCC (Primary Water Stress Corrosion Cracking) crack growth". [7] M.D. Mathew et al.(2006) "The characterized the creep properties of the base metal, weld metal and weld joint for 316L(N) SS welds at 873 and 923K at stress levels of 100–325MPa with rupture lives in the range of 100–33,000 h. The creep strength reduction factors for the weld joints were found to be higher than the RCCMR values implying that the actual creep strength of the weld joints is higher than the design values and that the difference between the strengths of base metal and weld metal is low. Weld strength reduction factors based on the strength of the weld metal is more conservative at 873 while at 923K at long term conditions; WSRF based on weld joint seems to be more conservative. Higher rupture life of the weld joint as compared to the weld metal is suggested to be resulting from the formation of a metallurgical notch.

S.S.M. Tavares, The characterized the microstructure, chemical composition, corrosion resistance and toughness of a multipass weld joint of super duplex stainless steel UNS S32750. A 9.0mmthick, 900mmdiameter pipe of super duplex UNS S32750 stainless steel was welded using GTAW (Gas Tungsten Arc Welding, root pass) and SMAW (Shielded Metal Arc Welding, filler passes) processes. High purity argon shielding gas was used in the root pass welding. The welding parameters were controlled in order to maintain the heat input in the 1.5–2.0 kJ/mm range for the root pass and 1.2–1.7 kJ/mm for the subsequent filler passes. From the microstructure and Charpy test it was concluded that, despite having lower austenite volume fraction (34.2%) the root pass presented a higher Charpy toughness (57 J) than the filler passes (10 J) at room temperature. But corrosion resistance of the root found to be slightly inferior to the filler passes in chloride media

3. EXPERIMENTAL INVESTIGATION

Mild steel is the most common form steel because its price is relatively low while it provides material properties that are acceptable for many applications. Mild steel contains 0.16–0.29% carbon. Therefore it is neither brittle nor ductile. Mild steel has a relatively low tensile strength but it is cheap and malleable. Surface hardness can be increased through carburizing. It is often used when large amounts of steel are needed for example in structural steels, the density of mild steel is approximately 7.85 g/cm3 (0.284 lb/in3) and the Young's modulus is 210,000 MPa (30,000,000 psi).

Table 1 Physical Properties of MS 1040

Physical Properties	Metric	Imperial
Density	7.85 g/cm^3	0.284 lb/in^3

Table 2. Chemical Properties of MS 1040

Grade	C	Si	Mn	S	P	Cr	Ni	Cu
1040	0.17-0.24	0.17-0.37	0.7-1.00	≤0.035	≤0.035	≤0.25	≤0.25	≤0.25

Table 3. Mechanical Properties of MS 1040

Grade	**Tensile Strength (Mpa)**	**Yield Strength (Mpa)**	**Elongation in 100-150 mm (%)**	**Reduction in Area**	**Hardness**
1040	≥380	≥210	≥25	≥50	≤111HB

This grade of steel is used for forged parts where the strength and toughness of the material are appropriate. C1040 may be used to manufacture the forged crankshafts and couplings along with a range of parts where the properties of heat-treated C1040 are suited to their applications.

Stainless steel is notable for its corrosion resistance and it is widely used for food handling and cutlery among many other applications. Stainless steel is used for corrosion-resistant tools such as this nutcracker Stainless steel does not readily corrodible rust or stain with water as ordinary steel does. However, it is not fully stain-proof in low-oxygen, high-salinity, or poor air-circulation environments.

There are various grades and surface finishes of stainless steel to suit the environment the alloy must endure. Stainless steel is used where both the properties of steel and corrosion resistance are required.

Stainless steels resistance to corrosion and staining, low maintenance, and familiar luster make it an ideal material for many applications. The alloy is milled into coils, sheets, plates, bars, wire, and tubing to be used in cookware, cutlery, household hardware, surgical instruments, major appliances, industrial equipment like in sugar refineries, automotive, aerospace, structural alloy and construction material in large buildings. Storage tanks and tankers used to transport orange juice and other food are often made of stainless steel, because of its corrosion resistance. This also influences its use in commercial kitchens and food processing plants, as it can be steam-cleaned and sterilized and does not need paint or other surface finishes.

Here Tungsten Inert Gas welding is used to fabricate the work metals. The TIG welding parameters consists of welding equipments with power sources, types of electrode, shielding gases, types of current, and gas flow rate. TIG welding process can weld practically all ferrous and nonferrous materials. For welding dissimilar metals, TIG is the process of choice permitting carbon steels to be joined to stainless or to copper alloys. Welding dissimilar metals requires special attention to electrode composition, welding technique, and other factors, and involves additional cost. TIG welding is a welding process that uses a power source, a shielding gas and a TIG hand piece. The power is fed out of the power source down the TIG hand piece and is delivered to a tungsten electrode which is fitted into the hand piece. An electric arc is then created between the tungsten electrode and the work piece. The tungsten and the welding zone are protected from the surrounding air by a gas shield which is inert gas. The electric arc can produce maximum temperatures and this heat can be much focused as local heat. The weld pool can be used to join the base metal with or without filler material.

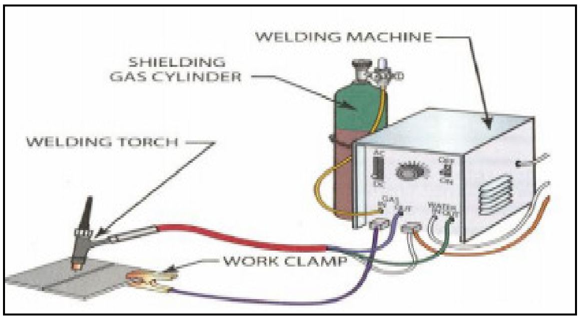

Figure 1. TIG Process

During TIG welding, an arc is maintained between a tungsten electrode and the work piece in an inert atmosphere. Depending on the weld preparation and the work piece thickness it is possible to work with or without filler. The filler can be introduced manually or automatically. The process itself can be manual and partly mechanized.

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter.

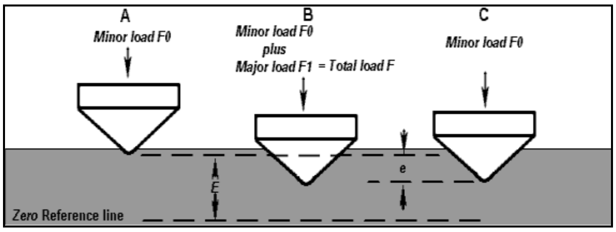

Figure 2. Rockwell Hardness Principle

The indenter is forced into the test material under a preliminary minor load F0 usually 10 kgf. When equilibrium has been reached, an indicating device which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration.

When equilibrium has again been reach the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery makes reducing the depth of penetration. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

Tension test is widely used to provide basic design information on the strength of materials and is an acceptance test for the specification of materials. The major parameters that describe the stress-strain curve obtained during the tension test are ultimate tensile strength (UTS), yield strength reduction in area (RA%). Toughness, Resilience, Poisson’s ratio (ν) can also be found by the use of this testing technique.

Figure 3. Universal Testing Machine

Bend tests deform the test material at the midpoint causing a concave surface or a bend to form without the occurrence of fracture and typically performed to determine the ductility or resistance to fracture of that material.

Figure 4. Bending Test Machine

4. RESULTS AND DISCUSSION

The results of hardness test by Rockwell hardness were discussed below. The specification of the sample is AL 7075+B4C3%+SIC 3% and the method of testing is ASTM E18:2016.

Table 4. Hardness Test Result

Sample ID	Observed Values (HRA)			Average
	1	2	3	
Al7075-B4C - SIC	78	78	79	78

Figure 5. Hardness Test Sample

The results of Tensile test by Universal Testing Machine were discussed below.

- Test File Name : CL C73.Utm.
- Test Type : Tensile Test
- Test Standard : ASTMA370:2017

Input Data

- Specimen shape : Flat
- Specimen type : ST-MS
- Specimen width : 19.8 mm
- Final Gauge Length : 0 mm
- Specimen C S Area : 98.21 mm2

Output Data

- Load at peak : 49.880 KN
- Tensile Strength : 507.902 N/mm2

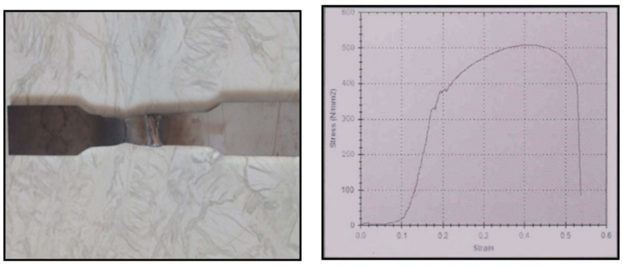

Figure 6. Tensile Test Sample & Stress-Strain Curve

The results of Tensile test by Universal Testing Machine were discussed below.

- Test File Name : CL L 74.Utm
- Test Type : Bending Test
- Test Standard : ASTM A 370:2017

Input Data

- Specimen shape : Flat
- Specimen Description : ST-MS
- Specimen width : 19.96 mm
- Specimen thickness : 5.06 mm
- Specimen C S area : 100.6 mm2

Output Data

- Load at peak : 3.140 KN
- C.H.Travel at peak : 14.380 mm
- Bend Strength :31.213 N/mm2

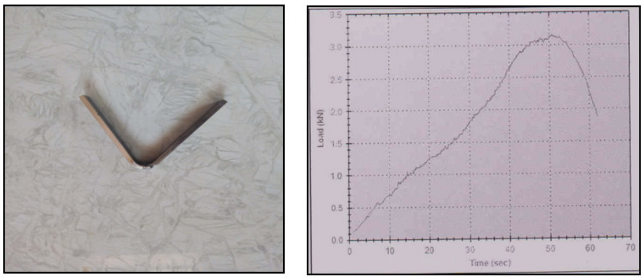

Figure 7. Bending Test Sample & Load vs Elongation Curve

5. CONCLUSION

Thus in this Experimental work presents a study of mechanical properties in a welding joint between mild 1040 steel and Stainless steel 304, using SS filler rod in different current ampere & pressure. The purpose of the present research was to optimize the welding process parameters and to find out their optimized values in hardness, tensile, bending and also to minimize the wear characteristic which increase the quality of weld and productivity in its area.

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