A STUDY OF TENSILE STRENGTH OF MIG AND TIG WELDED DISSIMILAR JOINTS OF MILD STEEL AND STAINLESS STEEL

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ABSTRACT

The dissimilar metal joints of have been emerged as a structural material for various industrial applications which provides good combination of mechanical properties like strength, corrosion resistance with lower cost. Selections of joining process for such a material are difficult because of their physical and chemical properties. The stainless steel and mild steel dissimilar material joints are very common structural applications joining of stainless steel and mild steel is very critical because of carbon precipitation and loss of chromium leads to increase in porosity affects the quality of joint leads deteriorate strength. In the present study, stainless steel of grades 202, 304, 310 and 316 were welded with mild steel by Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG) welding processes. The percentage dilutions of joints were calculated and tensile strength of dissimilar metal joints was investigated. The results were compared for different joints made by TIG and MIG welding processes and it was observed that TIG welded dissimilar metal joints have better physical properties than MIG welded joints.

KEYWORDS

TIG, MIG, Tensile strength, dissimilar metal welding, stainless steel, mild steel

1. INTRODUCTION

The stainless steel is one of the most popular materials for structural applications, due to their excellent physical properties but increase the structural cost. The additional benefits and the design codes of stainless steels have focused their industrial use for conventional structural engineering applications such as civil construction, nuclear reactors, thermal power plants, vessels and heat exchangers for several industrial applications [1-5]. The better joint efficiency, simple process, low fabrication cost, welding reliability and efficient metal joining process are essential for production of many engineering and structural components [6]. The metallurgical changes such as micro-segregation, precipitation of secondary phases, presence of porosities, solidification cracking, grain growth in the heat affected zone and loss of materials by vaporization are the major problems which produces poor mechanical properties in stainless steel welds [18-19]. Therefore, for structural applications, the stainless steels are utilized efficiently by dissimilar steel welds between stainless and carbon steels with effective and economical utilization of the special properties of each steel dependent in the same structure [2-5]. The coarse grains and inter granular Chromium rich carbides along the grain boundaries in heat affected zone, is observed during conventional arc welding which deteriorates the mechanical properties of the joints [9-11]. The joining of stainless steels with plain carbon steels is common applications in thermal power industries, stainless steel piping is often exposed to high-temperature and pressure steam and carry on passes temperature and pressure may below a

certain level, the low-carbon and low-alloy steels pipe line perform adequately and reduce the overall cost of the structure [7, 8 and 12]. The dilution of the weld metal with the two base metals and the different coefficients of thermal expansion are two major criterions for dissimilar welding of stainless and low carbon steels [13]. Shielded metal arc welding (SMAW), Tungsten Inert Gas (TIG) welding and Metal Inert Gas (MIG) welding processes shows improve mechanical properties of stainless steel and low carbon joints [14]. TIG welding provides greater control over SMAW and MIG weld process, provides higher quality welds in a wide variety of metal and alloys. Therefore, it is most commonly used to join stainless steel and other metals [15-17]. Tensile properties and microstructure characterization of inertia friction welds have been done for 304L stainless steel and these values have a range from 600 to 732 MPa [14]. The optimization of friction welding parameters while welding stainless steels was carried out and ultimate tensile stress (UTS) of 560 MPa has been obtained for optimized friction welding conditions of 95 MPa friction pressure and 180 MPa upset pressure [5]. The evaluation of properties of dissimilar stainless steel welds shows that Tensile strength values ranging from 600 to 689 MPa [15]. In the present work, stainless steel of grades 202, 304, 310 and 316 were welded with mild steel by Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG) welding processes. The percentage dilutions of joints were calculated and tensile strength of dissimilar metal joint was investigated.

2. MATERIAL AND EXPERIMENTAL PROCEDURE

The materials used in the experiments were cylindrical rods of length 115 mm and diameters 15 mm. The chemical compositions of the mild steel and different stainless steels are shown in Table 1.

Table 1. Percentage of Chromium and Nickel in mild steel and Stainless Steel

Alloys (%)	Stainless Steel (SS) Grades				Mild Steel (MS)
	202	304	310	316	
Cr	14.38	18.21	25.36	16.65	0.069
Ni	01.03	08.06	20.89	11.28	0.01
C	0.15	0.08	0.08	0.08	0.18
Mn	7.50	2.00	2.00	2.00	0.80
S	0.03	0.03	0.03	0.03	0.040
P	0.06	0.045	0.045	0.045	0.040
Si	1.00	0.75	1.50	0.75	0.40
Mo	-	-	-	3.00	-
N	-	0.10	-	0.10	-

The specimens were turned to 12 mm diameter in a lathe machine and faced to prepare the weld surfaces. Further, debarring was done with emery paper and the surfaces to be welded were cleaned with acetone prior to welding. TIG and MIG welding process were used for welding different grades of steel with mild steel. The welding joint was designed double 'v' groove with angle 90°. The E309L rod of 2 mm diameter filler material was used for all welding process. Uphill welding progression was used for all joints. The process parameters selected for TIG and MIG welding processes are shown in the Table 2. The strength of the welds were examined by carrying out tensile tests, specimen are shown in Figure 1 and specimen of different grade stainless steel and mild steel are tabulated in Table 3 .

Figure 1. Tensile Test Specimen

Table 2. Parameters used during TIG and MIG welding –

SN	Parameters	Specification	MIG	TIG
1	Shielding gas	Type	Ar and CO ₂ (98% & 2%)	CO ₂
		Flow rate	7-12 liter/min	
2	Current	Type	DC	DC
		Polarity	Electrode negative	Electrode Positive
		Current Range	60-400 Amps	50-70 Amps
		Voltage Range	26-56 Volts	10-14 Volts
3	Pass	Type	Multiple	Multiple
4	Electrodes	Number	Single	Single
		size	-	1.6
		Type	Copper coated MS wire	98 tungsten, 2% thoriated
5	Filler Rod	Type and material	Rod, E309L	

Table 3. Test Samples Prepared by TIG and MIG Welding

Test Samples (TS)	Material 1	Material 2
TS 1	SS 202	MS
TS 2	SS 304	MS
TS 3	SS 310	MS
TS 4	SS 316	MS

3. RESULT AND DISCUSSION

The welding of different grades of stainless steels was carried out with mild steel. The dilatation in welding zone was calculated and tensile test was carried out for each welded sample of TIG and MIG welding processes.

3.1 Dilution in Welded Zone

The percentage dilution of stainless steel and mild steel welded zone was calculated tabulated in Table 4 for TIG welded dissimilar metal joints and MIG welded dissimilar metal joints percentage dilution tabulated in Table 5. The length of welded zone is better in MIG welded joint than TIG welded joint. The percentage dilution in stainless steel is higher in MIG welded joint, where as in TIG welded joint dilution in mild steel is higher. The overall percentage dilutions in weld zone of MIG welded joint are higher than TIG welded test samples except dissimilar joint of SS 310 and mild steel and the comparison of the same shown in Figure 2.

Table 4. Total dilution in TIG welded SS and MS samples

Test Samples	Welded length (mm)			Diameter (mm)	Percentage Dilution		
	Weld Zone	in SS	in MS		of SS	of MS	in weld zone
TS 1	13	3.0	2.0	10	23.070	15.38	38.45
TS 2	13	2.5	2.5	10	19.23	19.23	38.46
TS 3	15	3.0	4.0	10	20.00	26.60	46.60
TS 4	14	3.5	2.0	10	25.00	14.28	39.20

Table 5. Total dilution in MIG welded SS and MS samples

Test Samples	Welded length (mm)			Diameter (mm)	Percentage Dilution		
	Welded Zone	in SS	in MS		of SS	of MS	in weld zone
TS 1	15	4.0	2.0	10	26.60	13.33	39.90
TS 2	12	3.5	1.5	10	29.16	12.50	41.66
TS 3	16	4.0	5.0	10	26.60	13.33	39.90
TS 4	15	3.5	4.0	10	25.00	28.57	53.57

Figure 2. Percentage Dilution in TIG and MIG welded test samples

3.2 Tensile Test

Tensile testing were carried out using Universal Testing Machine of 400 KN capacity and the geometry of the test specimen is as shown in Fig. 1. Mechanical proprieties of TIG and MIG welded dissimilar welds of stainless steel and mild steel after tensile test are tabulated in Table 6 and 7 respectively. Tensile strengths of welded test samples vary from 394 to 457 MPa depending upon the welding conditions. All the specimens broke in the weld region and parentage of elongation measured across the weldment using an extensometer show ductility ranging from 4.9% to 6.6%. The variation of average values of ultimate tensile value, yield strength and percentage elongation for each test sample has been plotted in Figure 3 and 4 respectively for TIG and MIG welded joints.

Table 6. Mechanical Properties of TIG welded SS and MS samples

Test Samples	UTS (MPa)	Average UTS (MPa)	Yield Strength (MPa)	Average Yield Strength (MPa)	% elongation	Average % elongation	Fracture Location
TS 1	430	429.2	287	279.8	5.7	5.66	Weld
	412		289		5.6		
	433		271		5.7		
	436		269		5.6		
	435		283		5.7		
TS 2	397	398.8	282	282.2	4.9	5.16	Weld
	402		286		5.3		
	400		274		5.0		
	401		289		5.3		
	394		280		5.3		
TS 3	410	413.2	269	263.6	5.1	5.12	Weld
	415		257		5.1		
	406		259		5.1		
	415		272		5.1		
	420		261		5.2		
TS 4	437	443.4	215	218.6	5.9	5.92	Weld
	443		221		5.7		
	448		225		6.1		
	432		219		6.0		
	457		213		5.9

(a)

(b)

(c)

Figure 3. Variation of (a) Average UTS (b) Average Yield Stress and (c) Average Percentage elongation in TIG welded test samples

The TIG welded test sample of SS 316 and Mild Steel has recorded maximum ultimate tensile stress, where as SS 304 and Mild Steel has recorded the lowest ultimate tensile stress. The yield strength of TIG welded test samples of SS 202 and SS304 are better than other and in the same range but SS 316 have the poor yield strength as compare with other samples. The TIG welded test sample of SS 316 has the highest percentage elongation and SS 304 and SS 310 has shown lower percentage elongation.

Table 7. Mechanical properties of MIG welded SS and MS samples

Test Sample s	UTS (MPa)	Average UTS (MPa)	Yield Strength (MPa)	Average Yield Strength (MPa)	% elongation	Average % elongation	Fracture Location
TS 1	392	396.4	268	272.2	5.0	4.84	Weld
	400		273		4.8		
	386		275		4.9		
	400		279		4.7		
	404		266		4.8		
TS 2	378	381	207	213.6	4.7	4.7	Weld
	386		220		4.7		
	373		201		4.7		
	387		225		4.7		
	381		215		4.7		
TS 3	423	418.2	256	264.4	5.3	5.32	Weld
	409		259		5.3		
	411		266		5.4		
	413		276		5.3		
	435		265		5.3		
TS 4	366	380.8	235	234.6	6.5	6.5	Weld
	387		241		6.6		
	387		239		6.4		
	386		229		6.5		
	378		229		6.5

(a)

(b)

(c)

Figure 4. Variation of (a) Average UTS (b) Average Yield Stress and (c) Average Percentage elongation in MIG welded test samples

The MIG welded test sample of SS 310 and Mild Steel has recorded maximum ultimate tensile stress where as test samples of SS 304 and SS 316 has recorded the lowest ultimate tensile stress. The yield strength of MIG welded test samples of SS 202 is highest but SS 304 has the poor yield strength in comparison with other samples. The TIG welded test sample of SS 316 has the highest percentage elongation and SS 304 recorded lowest percentage elongation.

4. CONCLUSIONS

During the study, mild steel and different grades of stainless steel were joined using TIG and MIG welding process. The tensile strength and dilution of welded joints were investigated. The selection of different grades of stainless steel used for welding play an important role in deciding the properties of the weld. From the study, following conclusions can be drawn –

1. Tungsten Inert Gas Welding is more suitable than Metal Inert Gas welding for dissimilar metal welding of mild steel and stainless steel, TIG welding process provides better strength. It may be because of less porosity in dissimilar metal welds during TIG welding and carbon precipitation which comes out due to welding is also less. The low percentage of free carbon allows the product (welded stainless steel with mild steel) better corrosion resistivity, ductility and strength.
2. The main flaw which occurs in welding dissimilar material by MIG is the development of cracks during the welding, which needs more effort for achieving similar weld has by TIG welding.
3. The percentage dilution in stainless steel is higher in MIG welded dissimilar joints which may be the reason of chromium loss due carbon precipitation in the joints and lower corrosion resistance.
4. The dissimilar metal joint of SS 316 and mild steel has the best ductility for both TIG and MIG welding processes.
5. The yield strength of dissimilar joint of SS 202 and mild steel is best for both TIG and MIG welding process.
6. The dissimilar metal joint of SS 304 and mild steel has poor ultimate tensile stress for both TIG and MIG welding processes.

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