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Weldability of AA 5052 H32 aluminium alloy by TIG welding and FSW process – A comparative study

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Abstract

Aluminium 5xxx series alloys are the strongest non-heat treatable aluminium alloy. Its application found in automotive components and body structures due to its good formability, good strength, high corrosion resistance, and weight savings. In the present work, the influence of Tungsten Inert Gas (TIG) welding parameters on the quality of weld on AA 5052 H32 aluminium alloy plates were analyzed and the mechanical characterization of the joint so produced was compared with Friction stir (FS) welded joint. The selected input variable parameters are welding current and inert gas flow rate. Other parameters such as welding speed and arc voltage were kept constant throughout the study, based on the response from several trial runs conducted. The quality of the weld is measured in terms of ultimate tensile strength. A double side V-butt joints were fabricated by double pass on one side to ensure maximum strength of TIG welded joints. Macro and microstructural examination were conducted for both welding process.

Keywords: Aluminum Alloy 5052 H32, Friction Stir Welding, TIG welding, Tensile Strength, Microstructure.

1. Introduction

AA 5052 H32 is cold-rolled aluminium alloy having very high corrosion resistance with an industrial and marine environment, good formability, and good weldability out of other aluminium alloys and thus has been used for automotive and marine structural applications. Friction stir welding (FSW), is a solid state joining process and its application found in various industries like aerospace, marine, automobile, etc. due to its high-quality joints [1, 2]. Since no fusion of material is involved, it avoids many weld defects caused by metallurgical reaction and distortion in fusion welding. It can weld both similar and dissimilar materials that cannot be weld by the conventional welding process. In FSW process the welding parameters such as tool pin profile, rotational speed, welding speed, tool tilt angle, etc. are responsible for quality joints [3-6].

Tungsten Inert Gas (TIG) welding is a fusion welding process widely used for joining ferrous and nonferrous metals. The process produces quality joints. Selection of filler rod, shielding gas flow rate, welding current, polarity of weld, arc voltage, and welding speed are some of the variables that affect the quality of the weld [7, 8]. These variables are dependent and change in one generally requires a change in others to produce a good weld. The proper selection and levels of significant parameters are critical for quality welds.

Adalarasan et al. [7] developed a Taguchi’s L9 orthogonal array and grey relational analysis to optimize the welding parameters of TIG welded AA 6061 aluminium alloy. The process parameters such as arc voltage, current, welding speed, and gas flow rate were varied to find its effect on mechanical properties of the joints. The results concluded that the contribution of welding current and gas flow rate has significant effect on weld quality. Jose et al. [8] studied the influence of the welding parameters on the heat affected zone (HAZ) of aluminium structures. A response model is used to optimize the welding parameters to obtain a reduced HAZ. It was found that the greater temperature and lower cooling rate increased HAZ region. Sunil et al. [9] performed TIG welding on AA 7075-T6 aluminium alloy. Single V-butt joint is employed and the mechanical characteristics of the joint were determined experimentally and numerically and the results were compared.

Ahmed et al. [10] investigated the effect of welding speed on the tensile strength of the single V-butt TIG welded joint. Aluminium AA 6351 alloy is selected for experimentation with different bevel angle and bevel heights. It was found that tensile strength became higher with lower weld speed and at bevel angles between 30^0 to 45^0. Arun et al. [11] presented a work deals with the influence of TIG welding parameters in AA5083 aluminium alloy using factorial experimental design. Welding current and shielding gas flow rate were considered as the predominant input parameters. Ghazvinloo et al. [12] analyzed the effect of arc voltage, welding current and welding speed on mechanical properties of the joint of AA 6061 aluminium alloy. Result revealed that increase in heat input decreases the fatigue life whereas impact energy initially increased and then decreased.

Depending upon the welding process used, the strength of the weld differs for the same material. A comparative study on welding process for the same material is essential for the selection of the welding process. Several researchers compared TIG welded joints with FS welded joints for aluminium alloys to choose the right process [13-16]. It was found that FSW process is effective than TIG welded joints for most aluminium alloys. Quan et al. [17] proposed a double pass TIG butt welding on 2219-T8 aluminium alloy. The strength of the joint was enhanced and fracture occurred at the welded metal in the partially melted zone. From the survey, it was observed that a study of TIG welding and FSW process on AA 5052 H32 aluminium alloy was scarce. Hence an attempt was made in the work to find the effect of the welding current and inert gas flow rate on the tensile strength of the weld pool by TIG welding and the optimum result was compared with predetermined optimum FS welded joint. Macro and micro structures were examined for both welding process on the developed specimen and the reports were presented.

2. Experimentation

High strength aluminium magnesium alloy AA 5052-H32 cold rolled plates of size 100 mm × 50 mm × 6 mm were used for experiments. The chemical composition of the metal is shown in Table 1. Wire brushing is used for cleaning the adjoining surfaces for welding. The direction of welding was parallel to the rolling direction of the plate. A double side V-butt joints [Fig. 1] were fabricated by double pass on one side for TIG welding process. The process is performed using the AA 4043 filler rod of diameter 1.6 mm and using argon as shielding gas. The selected input variables for TIG welding are welding current and inert gas flow rate. Other parameters such as welding speed and arc voltage were kept constant.

Table 1
Chemical composition of AA 5052 H32 alloy

Element	Cu	Mn	Mg	Si	Cr	Fe	Ti	Al
Wt. %	0.01	0.08	2.33	0.14	0.18	0.29	0.02	Bal.

In FSW, the plates were welded in a single pass, using tapered square tool pin profile with a taper angle of 10^0 and pin length of 5.7 mm (Fig. 2). Parameters such as tool tilt angle, rotational speed, and welding speed were kept optimum at 1.5^0, 600 rpm, and 65 mm/min respectively. Photograph of the fabricated TIG and FS welded joints are shown in Fig. 3 and Fig. 4 respectively.

ASTM – E8 standard was followed for conducting the tensile test [18]. Tensile tests were carried out by UTM, FSA-M100 with 100 KN capacities. The results of experimental runs for various combinations of welding parameters are shown in Table 2. Microstructure examinations were carried out on the cross sections of the welded joints. The specimens for examination is initially cut by EDM, and progressively grind using different grades of emery paper, then polished using diamond paste, and finally etched with modified keller reagent.

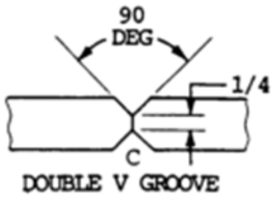

Fig. 1. Joint design for TIG welding


Fig. 2. Tool pin used for FSW

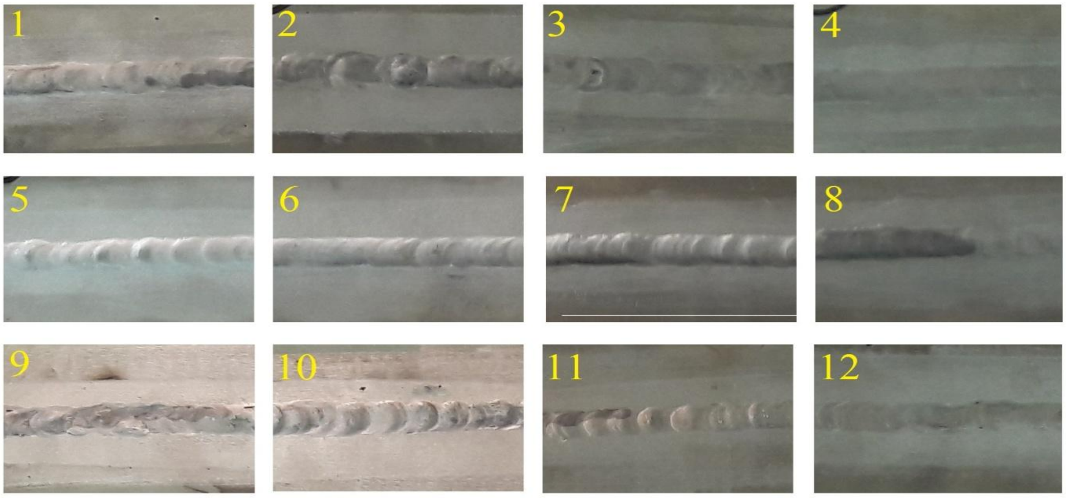

Fig. 3. Photograph of the joints fabricated by TIG welded process.

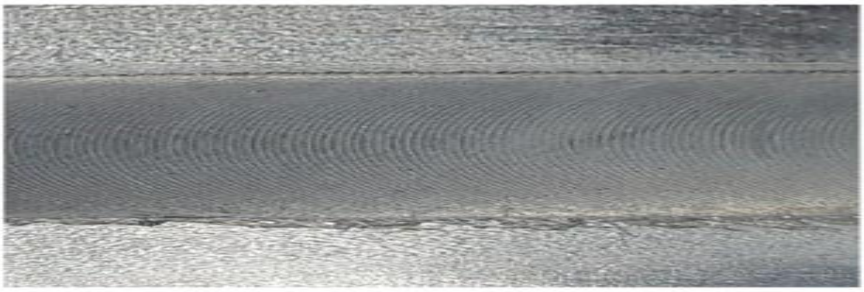
Fig. 4. Photograph of the joint fabricated by FSW process

Table 2

Combination of welding parameters and the observed response

Trials	Input parameters				Response			
	Weld Current (A)	Gas flow rate (lpm)	Arc Voltage (V)	Weld speed (mm/min)	YS (Mpa)	UTS (MPa)	% E at Yield	% E at Break
1	160	9	20	100	100.39	125.53	2.94	18.22
2	170	9	20	100	118.22	168.64	8.62	16.94
3	180	9	20	100	101.03	158.42	5.00	24.22
4	190	9	20	100	90.00	146.69	3.63	10.93
5	160	11	20	100	83.36	105.25	5.34	6.90
6	170	11	20	100	106.58	133.28	5.13	7.12
7	180	11	20	100	101.06	186.58	5.20	28.38
8	190	11	20	100	92.94	154.78	3.20	23.16
9	160	13	20	100	80.75	147.36	3.48	15.01
10	170	13	20	100	79.64	150.14	3.57	25.26
11	180	13	20	100	86.89	155.31	3.55	24.98
12	190	13	20	100	67.69	127.36	3.03	14.40

3. Results and discussion

3.1. Tensile test

Tensile tests were carried out on TIG welded plates. As per ASTM – E8 standard the specimens were prepared from the TIG welded plates. Photograph of the tensile tested specimens is displayed in Fig. 5. Interaction effects of welding current and inert gas flow rate on ultimate tensile strength (UTS) is shown in Fig. 6. The results reveal that for various inert gas flow rate, the increase in welding current initially increase the tensile strength, reaches a maximum value and then decrease. The increase in welding current improve the metal penetration during the TIG welding process, thereby improves weld properties. The lower value of current resulted in reduced fusion zone leads to poor joint strength. The higher and lower welding current lead to poor bonding due to high heat generation and low heat generation respectively. The optimum heat generation creates a quality weld. The result also shows that a moderate level of shielding gas flow rate (11 lpm) was necessary for better strength of joints. A lower level of gas flow rate cannot be recommended to produce better response. The maximum ultimate strength of the joint fabricated by TIG welding experimental runs is 186.58 MPa and that produced by FSW is 202.04 MPa. It is observed that the FSW process can produce a better joint than TIG welding process with AA 5052 H32 aluminium alloys.

Fig. 5. Photograph of the tensile tested specimens

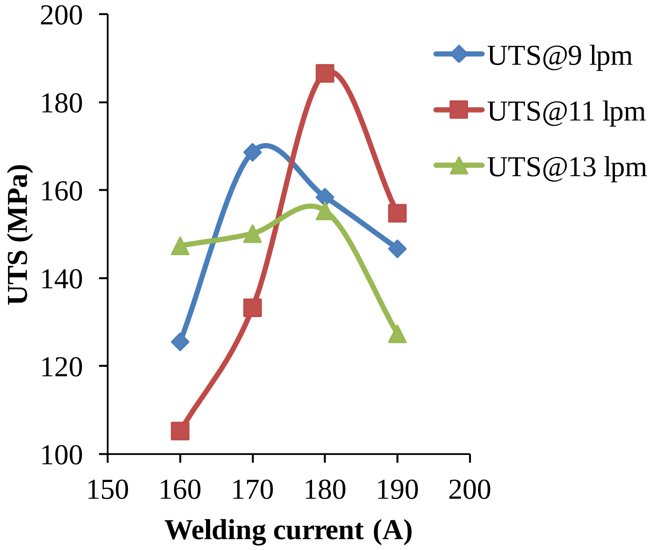

Fig. 6. Interaction effects of welding current and inert gas flow rate on UTS

3.2. Macro and microstructures

The optical macrograph and optical microstructure of the both TIG and FS welded joints obtained with an optimal setting of parameters is shown in Fig. 7 and Fig. 8 respectively. Defects such as voids, cracks, and unbonded zones are not observed in and around the weld area for weld fabricated by both processes (Fig. 7). Compared to the parent metal, grain growth was visualized at the weld area (fusion zone) in TIG welds (Fig. 8b). Grain growth is due to the elevated temperature during fusion welding. Coarsening of grain reduces the strength in the fusion zone. Dendritic structure appeared at fusion zone was due to the faster heating and cooling of the weld metal. Fig. 8c shows a clear visualization of dendritic spacing at weld site. At heat hazard region (HAZ) the dendritic structure gets reduced (Fig. 8d). Relatively fine dendritic structure was observed at HAZ. Fine grain structure was observed at SZ of the plates welded by FSW due to recrystallization at stir zone (Fig. 8e).

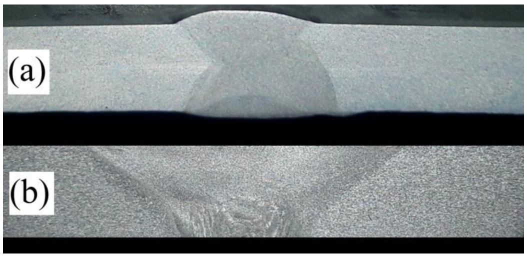

Fig. 7. Cross sectional macrograph of the welded specimen produced by: (a) TIG welding, (b) FSW

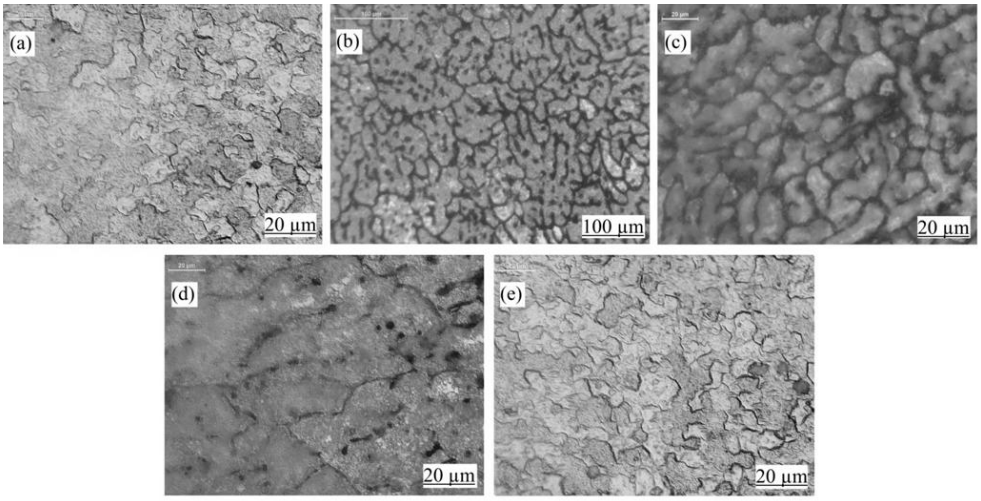

Fig. 8. Optical micrographs of (a) parent metal, (b) & (c) weld site of TIG welded plate at different magnification, (d) HAZ of TIG welded plate and (e) stir zone of FS welded plate.

4. Conclusions

The present work made a comparative study on the metallographic and mechanical properties of the joints obtained by the TIG welding and FSW processes with AA 5052 H32 aluminium alloy. The following conclusions can be drawn:

1) The joint fabricated by the FSW process were found to posses better metallographic and mechanical properties than those fabricated by using the TIG welding process.

2) The welding current and inert gas flow rate play a significant role in determining the quality of the TIG welded joint.

3) In TIG welding, the joint fabricated by a welding current of 180 Ampere, inert gas flow rate of 11 lpm, welding speed of 100 mm/min, and an arc voltage of 20 V exhibited superior tensile properties compared to other joints.

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