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Experimental Fatigue Life Estimation of AA5083 Aluminium Alloys Welded by Two Welding Processes- Gas Metal Arc (GMA) Welding and Friction Stir Welding (FSW)

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Abstract
AA5083 aluminium alloys are widely used in automotive structure and naval structure due to its excellent corrosion resistance and weldibility. All such applications require joining of aluminium alloys in most effective and reliable method to withstand the fatigue failure. The main objective of the present work focuses on the investigation of mechanical properties (tensile strength, percentage of elongation, weld hardness and fatigue life) of AA5083 joint that are fabricated by two most popular welding processes- Friction Stir Welding (FSW) and Gas Metal Arc (GMA) welding. The commercial plates of AA5083 aluminium alloys were used in the study. The tensile properties and weld hardness were evaluated as per ASTMB-557M and ASTM E466 standards. Fatigue test was performed at stress ratio 0.1 with 20Hz frequency. Both welding processes lead to decrease of the material mechanical properties of the joint compared to parent metal. The FSW welding was found more effective to achieve better tensile properties and fatigue properties than GMA welding. Higher fatigue scatter was obtained in GMA welded specimens.

Keywords- Friction Stir Welding (FSW), Gas Metal Arc (GMA) Welding, Fatigue Life, Aluminium Alloys.

1. Introduction

Welding is the most popular joining method for mass production. Gas Metal Arc (GMA) welding is one of the frequently used effective fusion welding process, but the high heat input in GMA welding causes defects like porosity, distortion etc. in material (Posinasetti and Yarlagadda, 2005). Now a day, Friction Stir Welding (FSW) becomes more popular, as it doesn't require intensive arc heat. Also the FSW is environment friendly welding process and it is best suited for welding of low temperature materials like copper, brass and aluminium (Mishra and Ma, 2005).

The principle of operation of FSW includes a cylindrical shouldered tool with a profiled probe which is plunged with a constant rate between the two surfaces of plates or sheets. The parts to be welded together must be properly clamped, so that the weld prepared should be free from distortion and any other surface defect. The frictional heat generated between the welded tool and work piece cause the work piece to soften without reaching its melting point and allow tools to transverse along the weld line. The plasticized material obtained is now

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forged together with the help of mechanical pressure generated between the tool probe and pin profile (Ceschini et al., 2007).

Aluminium alloys are extensively used in structural applications due to its high strength to weight ratio. 5xxx aluminium alloys is one of the aluminium alloys, which is mostly used in auto-motive and aerospace applications (Sonsino et al., 1999). High corrosion resistance, good weldibility and sufficient strength of 5xxx aluminium alloy make it extensive applicable. In real situation, most of the failure is due to fatigue loading. The literature reveals that 90% of structural failure is due to fatigue failure. In the fatigue failure, material may fail before detection of visible cracks on surface of the material. Hence fatigue failure is very dangerous and it needs to be included in design of any structural components (Branco et al., 1999; Ravindra et al., 2011; Wang and Chen, 2009; Ericsson and Sandstrom, 2003).

Many researchers investigated the mechanical properties of GMA and FSW welded Al-alloys. An improved mechanical property was observed by them (Wang and Chen, 2009; Ericsson and Sandstrom, 2003). However, decreased mechanical propertiesin FSW welded joints is also reported (Malarvizhi and Balasubrmanian, 2011). It might be due to the improper selection of the FSW parameters. Hence, explanatory parameters of FSW are very important to obtain excellent mechanical properties. In the present Work, the fatigue life of welded AA5083-O aluminium alloys under constant amplitude loading is investigated. Both GMAW and FSW welding processes are used to join the metals and a comparison is made to investigate the suitability of welding process on the basis of mechanical strength.

2. Experimental Process

The plates of AA5083-O aluminium alloys of thickness 6 mm were welded by GMA and FSW welding processes. Single V groove and single weld pass were used in GMA welding. The filler wire ER5356 was used in GMA welding. FSW was also employed by proper clamping of the plates to avoid the distortion. The chemical compositions of AA5083-O and filler wire ER5356 are presented in Table 1. The welding parameters of GMAW and FSW are shown in Table 2.

Transverse tensile and fatigue specimens were made according to standard ASTMB-557M and ASTM E446 respectively. The CNC cutting process was used to make all types of specimen. Vickers hardness of weld was also obtained according to ASTM E 92.

Transverse tensile strength of joints and weld hardness were estimated experimentally to study the static mechanical properties of the welded joint. Fatigue life of the joints was investigated to study the dynamic properties of the joints. Tensile test and fatigue test were performed by servo hydraulic testing machine. In fatigue test, stress ratio R=0.1 and frequency 20Hz were used. The stress level was kept at 30% of tensile strength of the joint in

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fatigue testing. Vickers micro Hardness (VHN) of the weld was obtained experimentally with a load of 500g.

3. Results and Discussion

3.1 Tensile Strength and Hardness

The tensile strength of joint and weld hardness was evaluated based on the average of three values obtained on similar specimens. The stress at which the specimen got broken was termed as tensile strength of the joint, no matter where is the fracture point. The joint made by GMAW is referred as sample-1 and the joint made by FSW is referred as sample-2 in the manuscript. The average tensile strength of sample 1 and sample 2 were 240 MPa and 318MPa respectively (Figure 1). A 32.5% increase in tensile strength of FSW welded joint was observed.

The percentage elongation of sample-1 and sample-2 were recorded as 7.5% and 11.2% respectively (Figure 2). An increase of 49.3% in percentage elongation was reported for FSW welded specimens. The percentage elongation is indication of ductility of the material. The sample-2 exhibit comparatively more ductility. The ductility of a material strongly depends on the microstructure. The finer grain exhibits comparatively higher ductility and tensile strength (Sonsino et al., 1999).

GMA welding requires high heat input and consequently the higher input results coarse grain weld region and HAZ. GMA welding also results in welding defects, like porosity, blowholes etc. These reasons might be responsible for decreased tensile properties of GMAW welded specimen (Posinasetti and Yarlagadda, 2005).

Vickers hardness test was performed at three different locations (top, middle and bottom) of the weld metals. The average weld hardness values for sample-1 and sample-2 were recorded as 85 VHN and 99.2 VHN respectively (Figure 3). An increment of 16.7% in hardness of weld metal was obtained when FSW process was implemented. The refined and defect free micro-structure is responsible for the increase in hardness for FSW welded joint (Mishra and Ma, 2005).

3.2 Fatigue Life

The experiments were performed to record the life of specimens at constant amplitude loading condition. The stress level used were: maximum stress (σ_{max}) = 30% of tensile stress, stress ratio (R) = 0.1 and frequency = 20 Hz. The number of cycles to failure of the specimens was recorded for each type of joints (sample-1 and sample-2). The results are presented in Figure 4. The fatigue life was calculated based on the average of five values. The FSW welded specimens exhibited comparatively longer fatigue life. In case of GMA welded joint, the theoretical analysis and the experimental evidence reveal that the fatigue crack was imitated in the HAZ and then propagate into the weld metal to finally cause the failure

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(Branco et al., 1999). The fine grains result into more grains boundary area, and hence offer more resistance to fatigue crack extension. The intense heat input in GMAW welding process, causes the elongated grains with inclusions and blowholes. These defects certainly decrease the mechanical properties of the joint (Ravindra et al., 2011). Comparatively lesser crack growth rate was observed in case of FSW welded joint. The finer equiaxed grains might be responsible for lesser crack growth rate in sample 2.

4. Conclusion

GMA and FSW welding were obtained to fabricate the joint of AA5083 aluminium alloy. The tensile properties (Tensile strength, % elongation and weld hardness) and fatigue life of joints were investigated. Based on the present investigated the following points can be concluded:

- FSW is able to join AA5083-O aluminum alloy with comparatively better mechanical properties.
- FSW is a solid state welding process. In GMA welding, the melting of material occurs and GMA weld is more prone to inclusions and blowholes.
- The 32.5% increase in average tensile strength was observed in FSW welded specimens. However approximately 2% experiments also showed comparatively higher tensile strength in GMAW welded joint.
- Approximately 49.3% increase in average percentage of elongation was observed in FSW welded specimen.
- An increase of 16.7% in weld hardness was observed in FSW joint.
- FSW joint exhibited longer fatigue life than GMA welded joint. An increase of in fatigue life was observed for FSW welded joint.

Material	Si	Cu	Fe	Zn	Mg	Ni	Mn	Cr	Ti	Sn	Pb	Al
5083 O	0.07	0.01	0.13	0.04	4.65	0.02	0.87	0.04	0.03	0.02	0.03	Bal.
ER 5356	0.03	0.01	0.15	0.01	4.83	-	0.14	0.11	0.09	-	-	Bal.

Table 1. Chemical compositions of materials

GMA welding		*FSW welding*	
Joint:	Butt joint, single V	Joint:	Butt joint
Welding current:	210A	Tool rotational speed:	1000 rpm
Welding voltage:	22 V	Welding speed:	80 mm/min
Argon gas flow rate:	18 lit/min	Shoulder diameter:	15 mm
Welding speed:	200 mm/min	Pin diameter:	6 mm
Electrode diameter:	1.2 mm	Pitch angle:	2^0

Table 2. Important welding parameters of GMA welding and FSW

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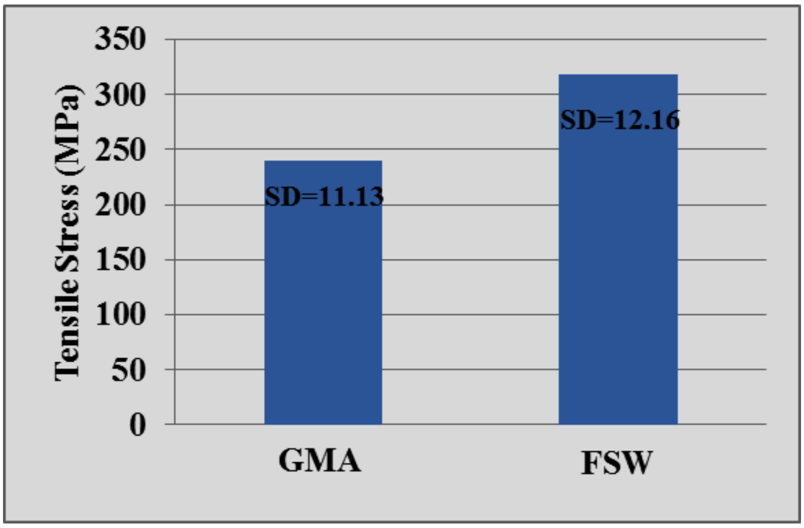

Figure 1. Tensile stress of GMA and FSW welded joints

Figure 2. Percentage of elongation of GMA and FSW welded joints

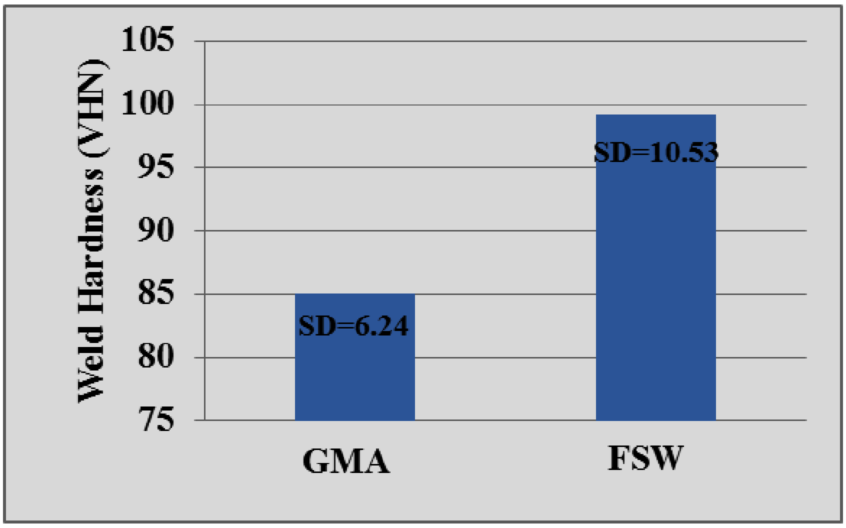

Figure 3. Weld hardness of GMA and FSW welded joints

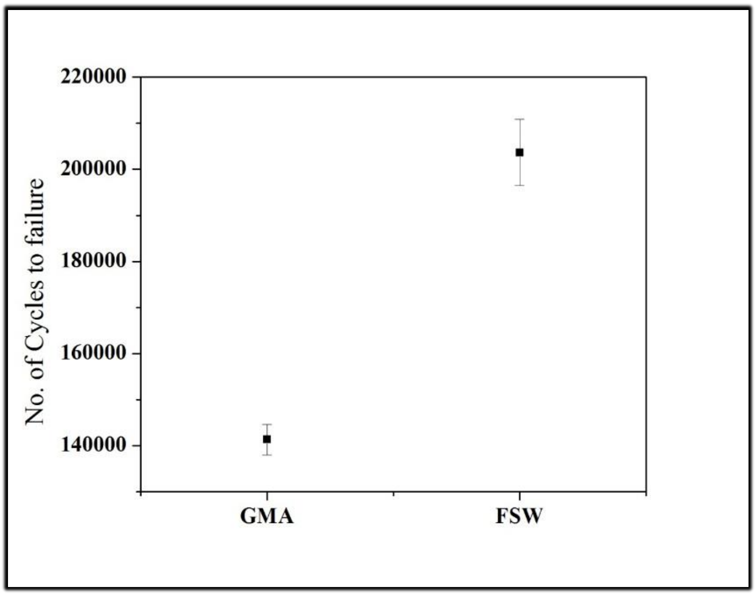

Figure 4. Variation of fatigue life obtained for GMA and FSW welded joints

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