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Effect Of Transverse Weld Pool Oscillation (TWPO) on Tensile Properties of AA 6101 T6 Aluminium Alloy Welds

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Abstract

In AA6101 T6 aluminium alloy, the weld fusion zones typically exhibit coarse columnar grains because of the prevailing thermal conditions during weld metal solidification. This often causes inferior weld mechanical properties and poor resistance to hot cracking. But when Gas Metal Arc Welding(GMAW) process under oscillatory condition is used then enhancement in mechanical properties noticed. Total cooling rate increases due to weld pool oscillation. Stirring of the weld pool increases the effective value of the thermal conductivity of the liquid pool because heat transfer in the weld pool becomes more effective. This helps nuclei in the weld pool survive and hence promote the formation of equiaxed fine grains in the fusion zone. In the present work, tensile properties, micro hardness, microstructure of the GMAW joints have been evaluated, and the results are compared with oscillated GMAW joints. It is found that GMAW joints under oscillatory condition (optimum at amplitude 5 micro metre, Frequency 400 hertz) of AA6101 T6 alloy showed superior tensile properties compared with stationary GMAW joints, and this is mainly due to the formation of very fine, equiaxed microstructure in the weld zone.

Keywords AA6101 T6 aluminium alloy, Gas metal arc welding, Tensile properties, Grain size

I. Introduction

Mechanical properties of heat-treatable aluminum alloys can be improved by solution heat treatment (450-550 °C) and subsequent quenching [1]. Matsuda et [2] and Pearce and Kerr [3] increased the degree of grain refinement in aluminum alloys containing small amounts of titanium by electromagnetic pool stirring. Significant amounts of equiaxed grains were so produced in gas–tungsten arc welds of a 7004 aluminum alloy.They suggested that the increased grain refinement was due to heterogeneous nucleation and grain detachment. Scarbrough et [4] observed reduction in the size of columnar grains in the autogeneous GTA welds of iridium alloys by magnetic arc oscillation. Davies and Garland [5] produced grain refining in Gas tungsten arc welds of Al–2.5wt% Mg alloy by torch vibration. Resistance to weld solidification cracking was improved in these welds. Weiter Wu [6] experimentally confirmed that with welding, when vibration is applied during the welding process, solidification of the weld pool is affected. As the weld pool solidifies, dendrites can be broken up before they grow to become too large. This finer microstructure provides better mechanical properties and eliminate hot cracking sensitivity of the welds. In vibration welding, internal stress is dispersed as it forms. Stefan[7] stated that the better distortion control is achieved with the vibrator attached and activated on the work piece during welding. Also welding cracks are minimized and fatigue life is increased. This is due to that welding additive is better drawn into the joint and cooling rate is more uniform. Because of this less residual stress is built up and less current is needed during welding. However ,no systematic study & detailed comparison has been reported on the mechanical properties of GMAW joints of AA6101 T6 aluminium alloy, prepared under transverse oscillatory condition of weld pool. Hence ,in this investigation, an attempt has been to evaluate the mechanical properties of GMAW joints of AA6101 T6 alloy made under stationary and oscillatory condition.

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II. Experimental Work

The rolled plates of AA6101 T6 aluminium alloy were machined to the required dimensions (250 mm×70 mm). Single ‘V’ butt joint configuration, as shown in Figure 1, was prepared to fabricate GMA welded joints. .

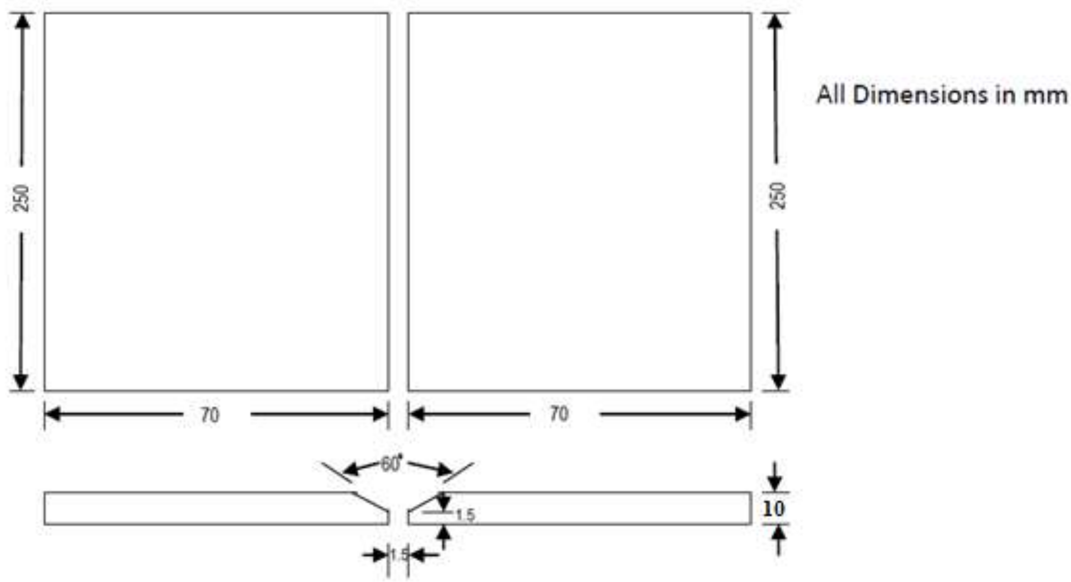

Fig. 1 Dimensions of joint configuration

Experimental set up had been fabricated in the workshop. The set-up shown in figure 2 consists of a hollow rectangular base plate (640mm×410mm×40mm). The base plate and the oscillatory table were made of mild steel plates. The oscillatory table rests on two shafts which are mounted on four bearings fixed over the base plate. The oscillatory table has a hole in the vertical plate for coupling the vibration exciter rigidly. The workpieces to be welded were clamped on the oscillatory table with the help of C-clamps and angle iron pieces. During welding the workpieces were oscillated at different frequencies and amplitudes of vibration with the help of an audio oscillator/power amplifier and vibration exciter. The frequencies and amplitudes of oscillations were measured with the help of a vibration meter along with a vibration pick-up. AA4043 (Al-5% Si) grade filler rod and wire used for GMA welding process. High purity (99.99%) argon gas was the shielding gas . Single V groove butt joint configuration as shown in fig. 1 was prepared to fabricate GMAW joints. Subsize flat tensile specimens were prepared from the weld metal region (longitudinal direction) alone as per the ASTM E8M standard to evaluate all weld metal tensile properties. The chemical composition of AA6101 T6 aluminium alloy and filler metal AA 4043 are given in Table I.

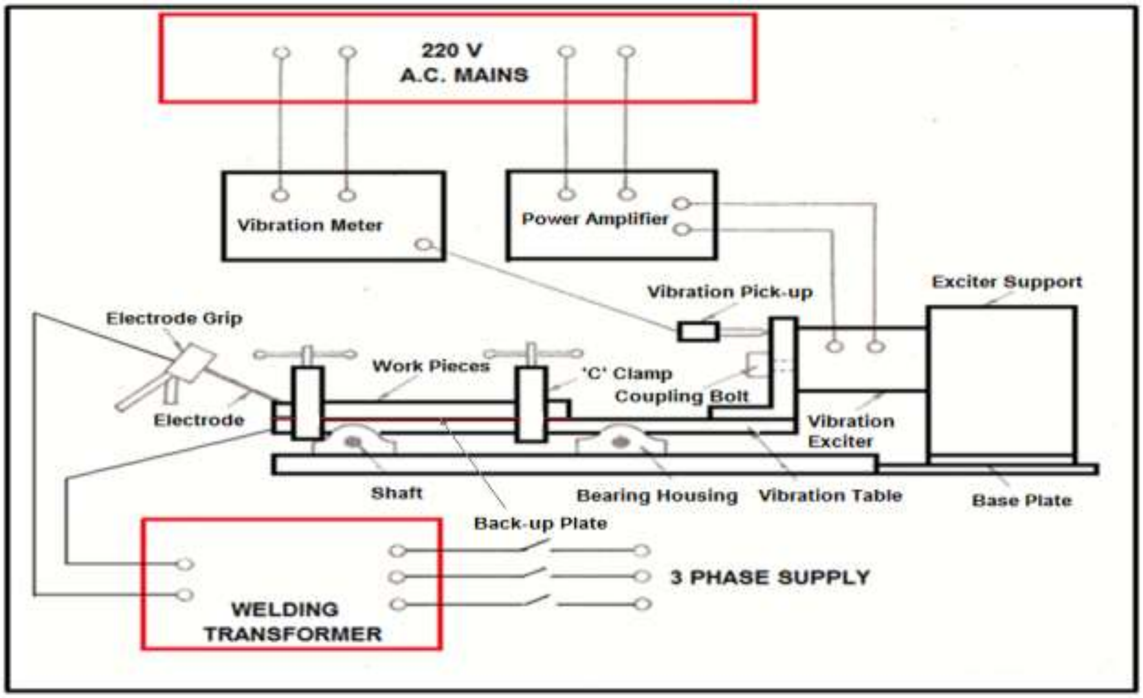

Fig. 2 Block diagram of experimental setup

TABLE I. The chemical composition of AA6101 T6 aluminium alloy and filler metal AA 4043

Type of material	Mg	Si	Fe	Cu	Cr	Mn	Zn	Ti	Al
Base metal AA 6101 T6	0.46	0.47	0.48	0.05	0.03	0.03	0.01		Remainder
Filler metal AA 4043	<0.01	6	0.22	0.094		< 0.01			Remainder

American Society for Testing of Materials (ASTM E8M) guidelines were followed for preparing the test specimens. The tensile specimens were prepared to evaluate yield strength, tensile strength, elongation and reduction in cross sectional area. V notched charpy specimens were prepared to evaluate the toughness of the joints. Tensile testing was carried out using a 5 Ton Instron Machine . The 0.2% offset yield strength was derived from the load-displacement diagram. Vicker's microhardness tester was used for measuring the hardness of the weld metal with a 10 kg load.

Microstructural examination was carried out using a light optical microscope incorporated with an image analyzing software . The specimens for metallographic examination were sectioned to the required sizes from the joint comprising weld metal, HAZ and base metal regions and polished using different grades of emery papers. Final polishing was done using the diamond compound (1 µm particle size) in the disc polishing machine. Specimens were etched with 0.5 ml HF(40%) and 100 ml distilled water to reveal the microstructure.

III. Results

A. Tensile properties

Sub size tensile test specimens (figure 3) of AA6101 T6 aluminium alloy weld were used for testing. The tensile properties such as yield strength, ultimate tensile strength, percentage elongation , reduction in area of AA6101 T6 aluminium alloy joints were evaluated.

In each condition, three specimens were tested, and the average of the three results is presented in Table II . The yield strength and ultimate tensile strength of GMAW joints (stationary) are 98.04 Mega Pascal and 162.08 Mega Pascal respectively. However, the yield strength and ultimate tensile strength of GMAW joints (optimum oscillatory condition)are 121.25 Mega Pascal and 199.58 Mega Pascal respectively (figure 4). This indicates that there is a increment of 23.67 % and 23.13% in yield strength and ultimate tensile strength values due to oscillatory GMA welding compared to stationary weld. Elongation and reduction in the cross-sectional area of the weld prepared under stationary GMA welding are 11.40 % and 30.46 % respectively. However, the elongation and reduction in the cross sectional area of GMAW joints(optimum oscillatory condition) are 14.16 % and 40.32 % respectively.

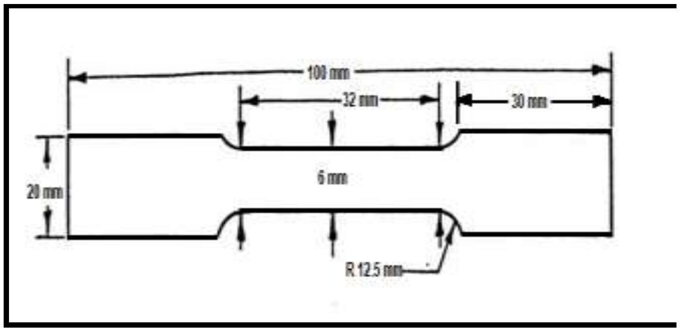

Fig. 3 Sub size tensile test specimen

TABLE II. Mechanical properties of full penetration AA6101 T6 with AA4043 filler metal MIG welds prepared without and with TWPO

TWPO parameters		Weld Properties				Comparison of without and with TWPO welds			
Freq. (Hz)	Amp. (µm)	0.2 % YS (MPa)	UTS (MPa)	% E	% R (in area)	% Increase in			
						YS	UTS	% E	%R (in area)
0	0	98.04	162.08	11.40	30.46				
400 (Optimum Value)	5 (Optimum Value)	121.25	199.58	14.16	40.32	23.67	23.13	2.76	9.86

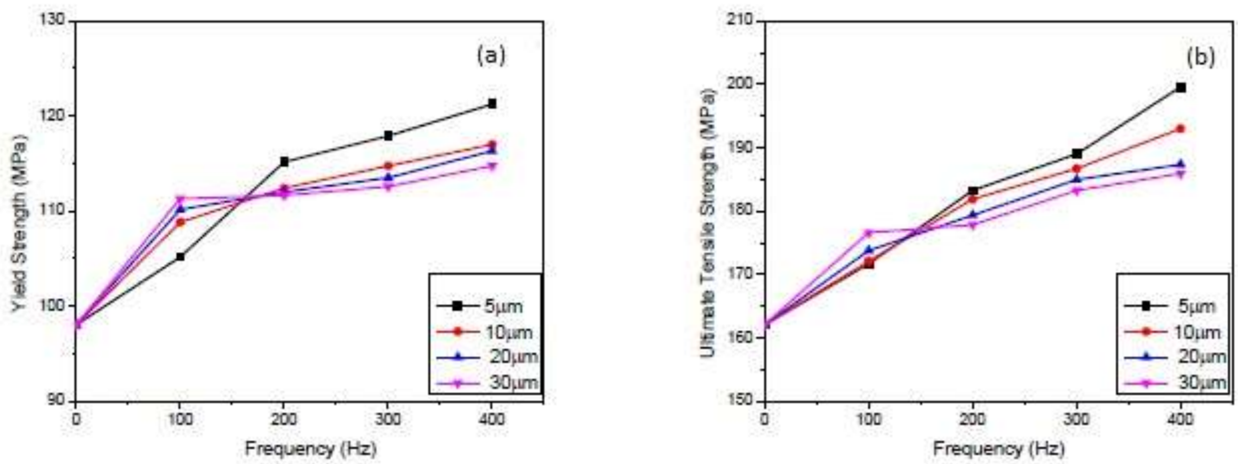

Fig. 4 Effect of amplitude and frequency on (a) Yield strength (b) Ultimate tensile strength

B. Hardness

The microhardness across the weld cross section was measured using a Vickers Micro-hardness testing machine, and the values are presented in Table III.
The hardness of the weld metal prepared under stationary condition is 53 Vicker pyramid number. However, the hardness of the GMAW joints under oscillatory condition in the weld metal region is 65 Vicker pyramid number (optimum). This suggest that the hardness is increased in the weld metal region of GMAW joints due to weld pool oscillation as shown in figure5.

TABLE III. Measured values of FZ attributes for AA6101 T6 with AA4043 filler metal MIG welds

LWPO Parameters		Fusion Zone Attributes	
Frequency (Hz)	Amplitude (µm)	Grain size (µm)	Micro hardness (VPN)
0	0	44.9	50-53
400 (Optimum Value)	5 (Optimum Value)	3.3	63-65

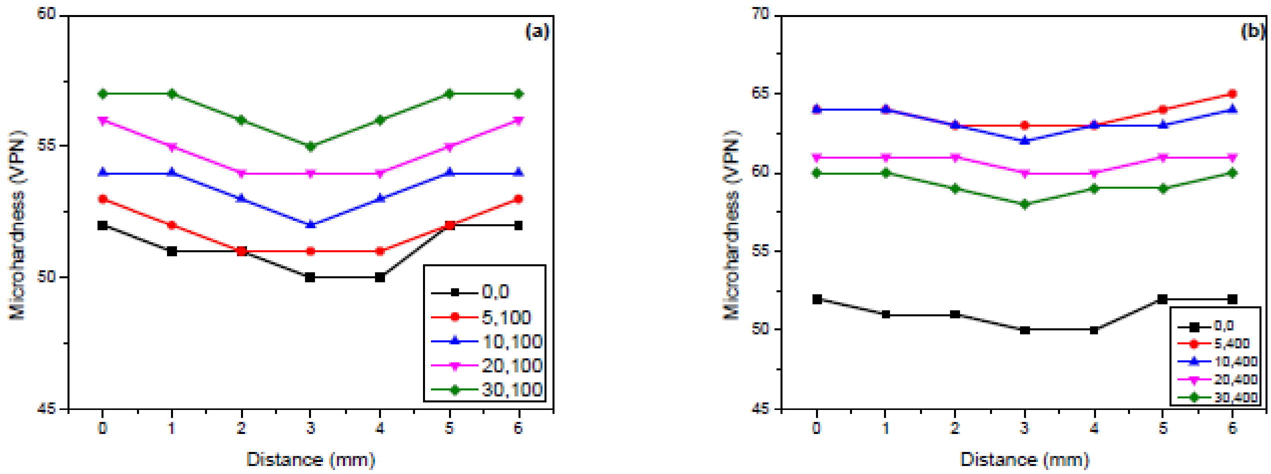

Fig. 5 Effect of TWPO on microhardness of AA6101 T6 aluminium alloy+ AA4043 (Al-5% Si) filler metal weld between extreme ends at (a) Amplitude: 0-30µm,Frequency:100Hz(b) Amplitude: 0-30µm,Frequency:400Hz

C. Microstructures

Microstructure of all the joints was examined at different locations, but most of the tensile specimens failed in the weld metal region, and the optical micrographs taken at the weld metal region alone are displayed in Figure 6 for comparison purpose. The stationary weld metal contains coarse and elongated grains with uniformly distributed very fine precipitates . The fusion zone of GMAW joints prepared under oscillatory condition contain dendritic structure and this may be due to the fast heating of base metal and fast cooling of molten metal due to welding heat. Dendrite arm spacing plays an important role to increase in mechanical properties .

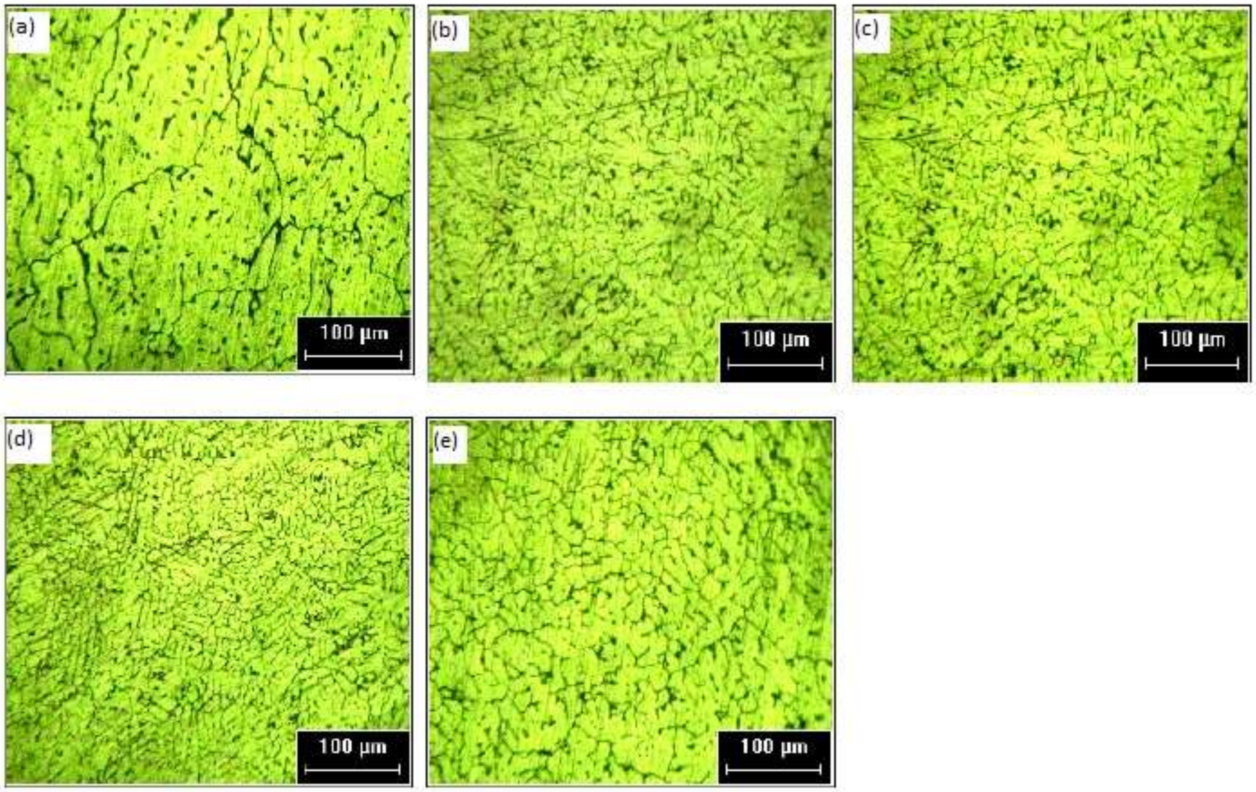

Fig.6 Fusion Zone microstructure of AA6101 T6 aluminium alloy+ AA4043 (Al-5% Si) filler metal welds a)Amplitude:0µm, Frequency:0Hz b)Amplitude:5µm,Frequency:100Hz c) Amplitude:30 µm,Frequency:100Hz d) Amplitude:5 µm,Frequency:400Hz e) Amplitude:30 µm,Frequency:400 Hz

IV. Discussion

Transverse tensile properties of the welded joints presented in Table II & III indicated that the GMAW joint prepared under oscillatory condition are exhibiting superior tensile properties compared to GMAW under stationary condition.

V. Conclusions

In this paper, the Tensile properties of GMAW joints of AA6101 T6 aluminum alloy were evaluated. From this investigation, the following important conclusions have been derived:

(i) Yield strength of welds prepared under oscillatory conditions improves as compared to stationary prepared welds. Percentage increase in yield strength for welded specimens prepared under transverse oscillatory conditions at 400 Hertz frequency and 5micro metre amplitude of oscillations is about 23.67% ,higher than stationary welded specimen respectively.

(ii) There is appreciable increase in ultimate tensile strength of welds fabricated under transverse oscillatory conditions with respect to the ultimate tensile strength of stationary prepared welds. Percentage increase at 400 Hertz frequency and 5micro metre amplitude of oscillations is about 23.13 % , higher than stationary welded specimen respectively.

iii) The percentage elongation in case of welds fabricated under oscillatory conditions increases slightly when compared with percentage elongation of stationary prepared welds. Percentage increase in elongation for welded specimens prepared under transverse oscillatory conditions at 400 Hertz frequency and 5micro metre amplitude of oscillations is about 2.76 % ,higher than stationary welded specimen respectively.

iv) Microhardness of welds fabricated under oscillatory conditions show increased values at extreme ends of welds along transverse direction.

v) The best results are obtained at 400 Hertz -5micro metre for transverse oscillated welds

VI. References

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