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MICRO-HARDNESS AND MECHANICAL PROPERTIES OF 5052 ALUMINIUM ALLOY WELDMENTS USING PULSED AND NON-PULSED CURRENT GAS TUNGSTEN ARC WELDING

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ABSTRACT

Hardness is defined as the withstanding capability of metal against penetration. Welding produces metallurgical transformations. Evaluation of hardness gives insight into these transformations. A proper study on weldment micro hardness will pave the path to enhance the mechanical reliability of the weldment. Thus, a study on mechanical and microhardness properties of 5052 aluminum alloy weldment using nonpulsed and pulsed current welding at frequencies of 2,4,6Hz has been carried out in the present work.

KEYWORDS: 5052 Aluminum Alloy, Gas Tungsten Arc Welding, Micro Hardness, Ultimate Tensile Strength (UTS), Yield Strength (YS) & % Elongation

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Original Article

INTRODUCTION

In view of increased focus on defense and space applications where more precision is required, aluminum alloy products that need welding are in demand. Tungsten Inert Gas Welding and Metal Inert Gas Welding are the methods by which aluminum alloy components can be easily welded. For superior quality welds, Gas Tungsten Arc Welding (GTAW) method using AC current for welding of Aluminum test pieces.

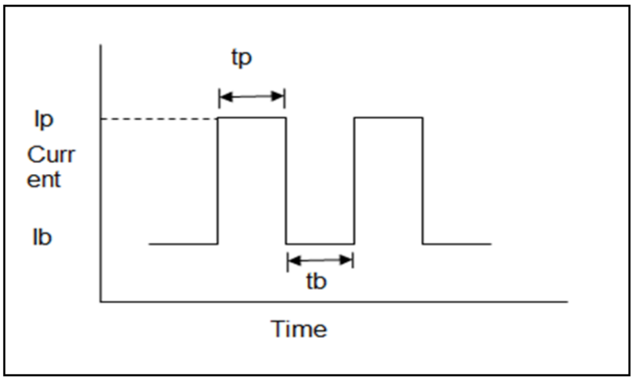
Pulsed Current Welding (PCW) is an additional advancement in the field of welding during the year 1960 as an alternative to constant current welding. Superior arc stability, decreased hot cracking sensitivity, fine grain size, slender heat affected zone, improved weld depth & width ratio, low porosity, regulated weld bead volume, less distortion and heat input, enhanced fusion zone control and reduced absorptive weld pool are the precise features of pulsed current welding process [1-8]. PCW is being extensively used in the aeronautical industry, manufacturing of rockets, rocket motors, missiles, and high-pressure storage tanks. Pulsed current welding can be generated by toggling between high and low levels of specified currents [9]. Figure 1 shows the pulsed waves which are rectangular shaped having characteristics such as base & peak currents and base and peak times. Not much work has been done on alloy steels welded with a pulsed current. Whatever has been done, is on the study of pulsed current affect, composition of shielded gas, weld shape and speed, joint strength, occurrence of weld defect while using PCW on 5083 alloy sheets [8], 304 and 310 stainless steel weldments angular distortion [9], to examine the microstructure[10] and weld bead geometry[11].

Some of the researchers [12, 13] have used pulsed current for enhancing mechanical and metallurgical properties and weld fusion zone grain refinement. This has led to the exploration of titanium and aluminum alloys where improved refinement in solidification structure is observed. Thus much work was done on medium strength aluminum alloys whereas little work is done on high strength aluminum alloys. In view of this, pulsed current welding effect on high strength aluminum alloy is taken up for study in the present work.

Reduced heat input and thermal disturbances have given fine grain structure in pulsed current welding. Whatever be the welding method, hardness value in, particular, is less in HAZ zone in comparison with weld and base metal regions. An absence of strengthener phase and coarse dendrite grains are the typical characteristics of this low hardness zone. Grain structure refinement enhanced the hardness values which were obtained by using pulsed current welding than non-pulsed current welding [14].

EXPERIMENTAL PROCEDURE

Sample pieces of 5052 aluminum alloy having machined sizes of 300mm x 150mm with different thickness of 1.5 and 2.5mm were welded separately by using methods of non-pulsed and pulsed current GTAW with filler wire material ER4043.



Peak Current I_p, Base Current I_b Peak Time t_p and Base Time t_b

Figure 1: Parameters Used for Pulsed GTAW

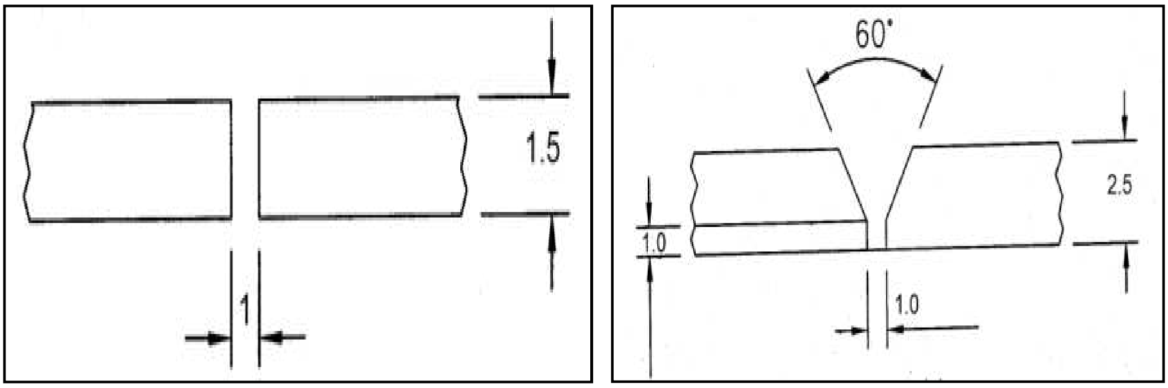


Figure 2: Edge Preparation of Weld Specimens

ER4043 has better properties of ductility and offers good weld strength and better resistance against weld cracks compared to other filler materials [15]. Tables 1-3 show the 5052 aluminum alloy and ER4043 chemical composition and mechanical properties. ER4043 has a low melting point compared to 5052 aluminum alloy. Due to this, the filler is more plastic during cooling which helps to ease the crack causing contraction stresses.

Sample aluminum pieces were treated first with hot sodium hydroxide for 10 minutes, later immersed in Nitric acid solution with 15 minutes duration and finally with water. Welding machine used was **Lincoln Electrical square wave TIG355**GTAW with AC which was shown in figure 3. Welding currents such as AC or DC decides the selection of tungsten electrode. While using AC current, Zirconated tungsten (EWZr) electrodes are preferred as they retain hemispherical shape. A 2% Zirconated tungsten electrode having 3 mm diameter is used for welding of 5052 aluminum alloy in this experiment. Figure 2 shows the edge preparation of 5052 aluminum sample whereas Figure 3 shows the welding machine used. Welded samples were subjected to Tensile and Micro-Hardness tests as per ASTM E8 standards after completion of welding. Figure 4 shows the tensile tested samples. Tables 4 and 5 show the mechanical properties of 1.5mm & 2.5mm thick welded samples and welded parameters used for both pulsed and nonpulsed current welding.

Figure 3: Lincoln Electrical Square Wave TIG 355 M/C

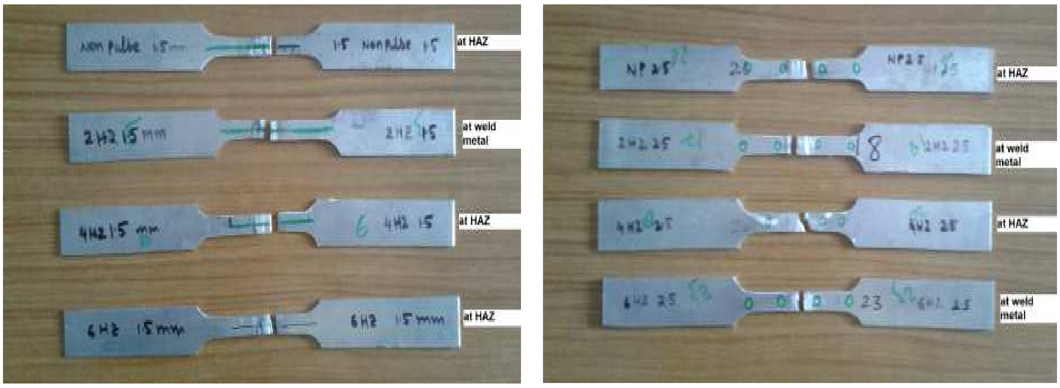


Figure 4: Tensile Test Specimens after the Test (1.5 & 2.5mm Thick)

Table 1: Chemical Compositions of Work Material 5052 Aluminum Alloy

	Chemical Composition % wt								
Material	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Zn**	**Ti**	**Cr**	**Al**
5052 Aluminium Alloy	0.092	0.249	0.015	0.013	2.281	0.012	0.016	0.25	Balance

Table 2: Chemical Compositions of Filler Wire

	Chemical Composition % wt							
Material	**Cu**	**Si**	**Mn**	**Mg**	**Fe**	**Cr**	**Ti**	**Al**
ER4043	0.17	4.5 – 6.0	0.24	0.05	0.05	0.05	0.05	Balance

Table 3: Mechanical Properties of 5052 Aluminium Alloy

Material	UTS(MPa)	0.2% Y.S(MPa)Min	% Elongation
5052 Aluminium Alloy	285	180	10

Table 4: Mechanical Properties of 1.5 mm Thick Weldments

S. NO	Sample Description		Trial no	UTS(Mpa)	0.2%S(Mpa)	% of Elongation
1	Base Material		1	286.42	214.32	8.5
			2	272.13	211.66	9.0
			3	274.24	210.72	9.0
2	Non-Pulsed Current GTAW		1	251.59	190.80	4.4
			2	253.64	193.42	6.0
			3	249.32	195.61	4.4
3	Pulsed current GTAW	Pulse=2Hz	1	238.57	189.68	4.0
			2	250.28	189.88	4.5
			3	257.54	199.46	6.4
		Pulse=4Hz	1	244.89	189.76	4.0
			2	254.44	191.75	7.0
			3	220.84	120.65	3.5
		Pulse=6Hz	1	253.55	192.0	8.0
			2	240.54	195.9	4.6
			3	250.58	185.90	9.0

Table 5: Mechanical Properties of 2.5 mm Thick Weldments

S. NO	Sample Description		Trial no	UTS(Mpa)	0.2%Y S(Mpa)	% of Elongation
1	Base Material		1	296.62	228.29	13.0
			2	295.93	227.50	12.0
			3	291.84	226.84	12.0
2	Non-Pulsed Current GTAW		1	288.51	207.3	4.0
			2	282.45	210.8	4.0
			3	298.90	215.3	5.0
3	Pulsed current GTAW	Pulse=2Hz	1	320.35	230.1	4.0
			2	304.15	220.8	6.2
			3	271.32	145.56	3.0
		Pulse=4Hz	1	250.43	182.71	3.0
			2	216.80	168.98	3.0
			3	253.95	182.92	3.0
		Pulse=6Hz	1	282.25	202.42	3.5
			2	258.50	160.84	3.0
			3	262.30	170.35	3.0

RESULTS AND DISCUSSIONS

Mechanical Properties

A 10 Ton capacity universal testing machine was used to test the tensile test workpieces. Tensile test results of 1.5mm thickness sample were shown in table 4, whereas Table 5 shows the results of 2.5mm thickness sample. 1.5mm thickness sample displayed failures at weld metal and heat affected zone. On the contrary, 2.5mm thickness sample failed at parent metal.

With low frequency i.e 2Hz pulsed welding, both 1.5mm and 2.5mm thickness weldments showed maximum UTS, 0.2% Yield strength compared to high frequencies of 4, 6Hz and non-pulsed current welding. Values of maximum UTS, 0.2% for 1.5mm and 2.5mm thickness weldments with 2Hz frequency are 257.54 Mpa, 199.46 Mpa, and 304.15 Mpa, 220.8 Mpa. Elongation percentage values for 1.5mm thickness samples increased with an increase in the frequency of current whereas 2.5mm thickness sample showed opposite behavior. 2.5mm thickness sample showed an elongation percentage value of 6.2 with a frequency of 2Hz. Ductility observed to be comparatively more in 1.5mm thickness sample with pulsed welding than non-pulsed current welding.

Figures 5 and 6 show the 1.5mm and 2.5mm thickness sample mechanical performance curves respectively.

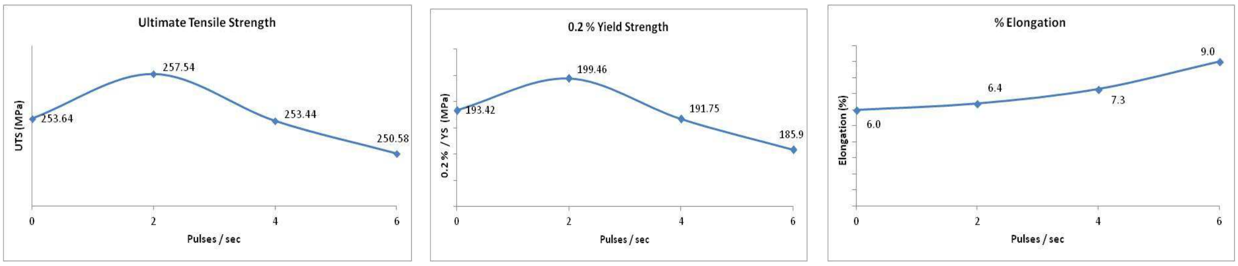


Figure 5: Mechanical Properties Performance Curves of 1.5 mm thick Weldments

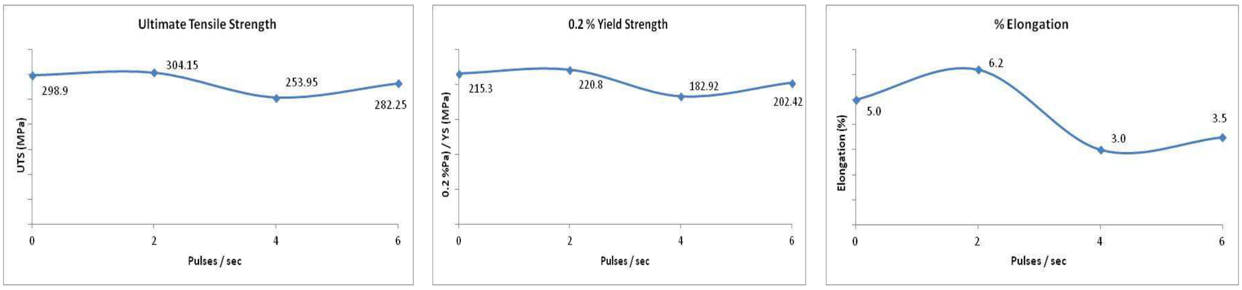


Figure 6: Mechanical Properties Performance Curves of 2.5 mm thick Weldments

Micro-Hardness

Vickers microhardness machine HV1000 ZDT was used to test welded samples for hardness. Hardness variation observed to be minimum between welded and heat affected zones with non-pulsed welding and it has significantly decreased and approached the value of parent material. Peak hardness values observed to be 95HV for non-pulsed current welding in weld zone and 112HV for pulsed current welding with 2Hz frequency compared to other frequencies. Microhardness values for 1.5mm thickness sample is shown in Figure 7 and Figure 8 shows the values for 2.5mm thickness sample.

Weld strength observed to be more with pulsed current welding than non-pulsed welding. This can be attributed to microstructure refinement with pulsed current welding which helps in a fine precipitate homogeneous matrix. Because microstructure is casted, fusion zone normally gives minimum hardness values. This zone consists of phases of interdendritic segregate, coarse dendritic grains and none of strengthening phases. Enhanced microstructure and minimal separation of strengthening phases caused better hardness values with pulsed current welding compared to non-pulsed welding. Improved hardness values in the vicinity of fusion boundary in pulsed current welding can perhaps be ascribed to age hardening which might have caused by sizeable no of alloying elements present in solid solution at closing stages of the thermal cycle.

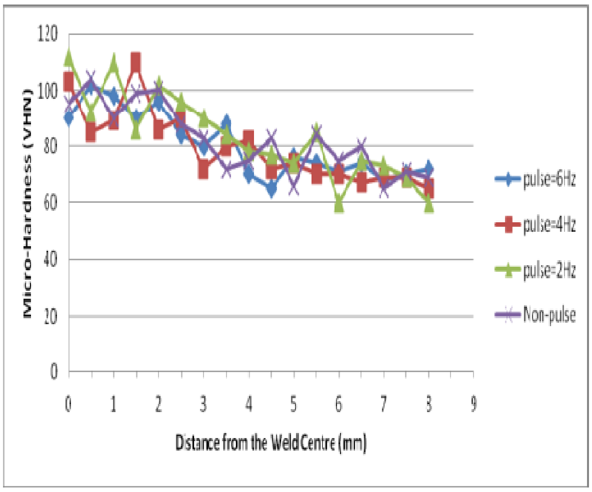


Figure 7: Micro-Hardness Profiles of 1.5mm Weldments

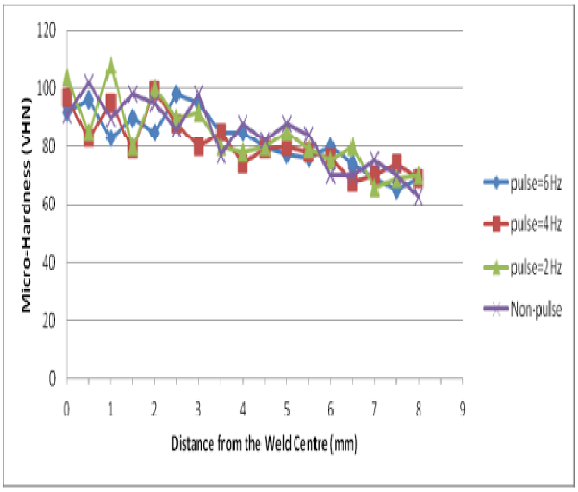


Figure 8: Micro-Hardness Profiles of 2.5 mm Weldments

CONCLUSIONS

Mechanical properties, as well as metallurgical ones, were found to be more affected by pulsed current welding. Pulsed current welding observed to have given maximum Ultimate Tensile Strength, 0.2% Yield Strength and % elongation compared to non-pulsed current welding. A hardness of weldment also appears to be superior with pulsed current welding. Pulsed current welding has generated refined grain size in the fusion zone. This refined grain size generation can be attributed to the enhancement of tensile strength and hardness properties of the weldment.

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