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COMPARATIVE ANALYSIS ON OPTIMIZED PARAMETERS OF HYBRID ALUMINIUM AND COPPER WELDS BY TWO STEP TIG WELDING

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Abstract: TIG welding is well known economical metal fastening process to fulfil industrial needs of present time. Regular metal welds with similar materials can be fastened easily and proved by many researches; dissimilar family welds of making complexity in weld process because of their physical and thermal properties variation. Among that copper hybridized with B4C and aluminium with SiC to elevate the strengthening properties while joining with TIG welding. Present research focused on the hybrid metal welding using Aluma steel weld rods of Ø3mm in two step welding. Initial welding performed at 70A power for alumina side and second step attached with copper hybrid metal. Experimental results given as properties consideration of boundary conditions for simulation for different loads. The model simulated for different thermal load conditions to check the deformation of weld at weld regions.

Key words: TIG, MMC, Reliability, Mechanical properties, Copper, Aluminium, Composites

1. Introduction

Welding is a reliable and efficient metal joining process and is widely used in construction, shipbuilding, steel bridges, nuclear power, chemical and petrochemical industries, and supporting frames for pressure vessels and piping due to the demand from the design point of view[1]. The void's presence in the TIG welds contributed to the reduced hardness of the joint [2]. The advantage of welding as a joining process includes high joint efficiency, simple set-up and low fabrication cost. Welding of dissimilar metals has been the object of investigation for many years; their technical and economical potential justifies their growing importance. Dissimilar metals or alloys are welded to gain flexibility, but this practice covers two weldings (TIG

and MIG) types of weld joints for mechanical properties and microstructures of copper and low alloy steel[3]. Present study selected dissimilar metal joints between filler and base materials (copper and Aluminium). These two welding processes (TIG with a 2-step process) are carried out under the same shielding gas (Argon). The filler materials (Aluma steel copper electrodes) were used for TIG, and the welding profile was preferred double-Groove welding; the bevel angle is 40°, and the root opening is 2mm. The objective of study is to understand the various welding parameter like welding current, voltage, gas flow rate, inert gas, welding speed, electrode etc[4]. It is noted that by maintaining a minimum gap, full penetration welding of the plate can be done, which gives strength almost similar



to the base material, and maximum penetration depth was acquired with a parametric combination of maximum current and minimum welding speed [5]. The investigation is based on the Taguchi approach[6], using Analysis of variance (ANOVA) to determine the influence of parameters with the optimal condition. Finally, the confirmation test has been carried out to compare the predicted tensile strength and hardness value with the experimental value. The hardness and microstructure of Tungsten Inert Gas (TIG) weld and arc weld of a mild steel joint have been compared. The hardness of the weld joint and the Heat Affected Zone (HAZ) of a hybrid joint is important when considering its performance during its application in industries[7]. The process parameters such as current, voltage, gas flow rate and electrode diameter for the TIG process are chosen carefully. The hardness test was conducted using the Rockwell hardness scale B, while the microstructure was evaluated using the metallurgical microscope. The welding process has been designed using Minitab software[8]. The best tensile test results recorded by sample No. 3, which welded by (8 gas flow rate and 70A current). The mean, Signal to Noise Ratios, and

ANOVA Test have been utilizing to find out the highly effective welding parameter (current and gas flow rate)[9]. Welding speed 24 cm/min -35 cm/min and arc length 2.4 mm-3.2mm used in present research by considering optimized parameters of Al welds from previous studies[10].

2. Material properties after preparing of MMC's for weld approach

The casting and reinforcing materials are preheated in the oven for 45 minutes. Stir casting equipment's furnace heats Al-6061 alloy to 800°C. Rotor speed should be set at 400 rpm to guarantee constant mixing of copper reinforcing material into the molten. Then, add the reinforcement to the molten metal using the same chamber by weight proportions. A stirrer rotating at high speed and going up and down should be used to evenly mix the molten metal. After it has been removed from the preheating furnace, place the die at the furnace's entrance forgings. Metal is poured into the die through the runners and risers as soon as the valve is slid open. After letting the die cool down for a while, remove the cast samples from the casting. Blade angle has been fixed for the stirring process and the design of experiments by Taguchi using Mini-Tab software.

Table;1Aluminium 6061 as base metal

S.NO	%SiC	RPM	TEMPERATURE	UTS (MPa)	Hardness (HV)
1	6	600	800	169.33	70.6
2	6	800	1000	188.55	61.2
3	6	1000	1200	164.7	78.1



4	8	600	1000	125.3	65.8
5	8	800	1200	164.27	55.9
6	8	1000	800	98.05	50.8
7	10	600	1200	175.3	58.9
8	10	800	800	179.94	53.6
9	10	1000	1000	98.46	47.9

Table 2: Copper alloy as base metal

S.NO	%B4C	RPM	TEMPERATURE	UTS(MPa)	Hardness(HV)
1	4	600	800	167.47	70.5
2	4	800	1000	188.51	61.8
3	4	1000	1200	164.80	78.4
4	6	600	1000	165.4	65.8
5	6	800	1200	186.32	55.9
6	6	1000	800	171.66	50.5
7	8	600	1200	188.90	58.9
8	8	800	800	179.94	53.6
9	8	1000	1000	176.75	47.6

Results obtained from the stir -castes samples of MMC's at 800 rpm and addition of 6% SiC added sample having

good tensile while at 1000 rpm it got high HV value; copper at 1200°C with low rpm of 600 with 8 % addition given good result.

3. Optimized results for parameters finalize using Taguchi- Mini tab

Table 3: Taguchi prediction for AL stir casted samples

S.NO	%SiC	RPM	TEMP(°C)	S/N	MEAN	St.Dev	Ln. St.Dev
1	6	600	800	39.617	124.816	73.593	4.295
2	6	800	1000	38.675	125.336	85.972	4.463
3	6	1000	1200	39.290	116.088	61.532	4.102
4	8	600	1000	37.625	90.237	42.369	3.726
5	8	800	1200	37.809	114.936	80.409	4.388
6	8	1000	800	36.459	74.886	29.333	3.472
7	10	600	1200	38.313	117.561	78.229	4.373
8	10	800	800	36.532	111.458	89.632	4.479
9	10	1000	1000	36.021	78.031	39.532	3.625

**Table 4: Taguchi prediction for Copper stir casted samples**

S.NO	%B4C	RPM	TEMP(⁰ C)	S/N	MEAN	St.Dev	Ln. St.Dev
1	4	600	800	39.584	120.058	66.77	4.205
2	4	800	1000	38.704	123.596	82.773	4.405
3	4	1000	1200	39.374	122.096	69.715	4.225
4	6	600	1000	38.100	116.096	79.049	4.367
5	6	800	1200	37.902	122.173	90.424	4.501
6	6	1000	800	37.033	109.521	78.848	4.36
7	8	600	1200	38.327	122.341	85.099	4.431
8	8	800	800	36.588	117.266	97.957	4.605
9	8	1000	1000	36.577	103.238	89.526	4.491

Optimized parameters for sintering of AL MMC is 800 rpm, 6% of SiC addition and 1000⁰C and for copper it is 1000 rpm, 8% B4C addition and 1200⁰C. Copper-reinforced composites have the maximum compressive strength at 8% reinforcement; this 7% improvement in compressive strength is 79.1 per cent significant. The maximum values for density Cu reinforced composites were obtained at 8%

reinforcement with a percentage increase of 2.76 per cent.

4. Experimental method for welding

TIG welding procedures: Tungsten Inert Gas (TIG) is the abbreviation for Tungsten Inert Gas (TIG). Wolfram, another name for tungsten, has a fusion point of 330⁰C or more, making it two to three times as hot as the typical metals used for welding. the same as inactive gas, which is a form of non-combustible and non-explosive gas.

Table5: Welding process conditions and parameters

Parameter	Value
Welding current/A	60,70,80A for Cu+B4c & AL+SiC
Shielding gas	Argon
Gas flow/(L·min ⁻¹)	12
Electrode	Aluma steel #1 #2
Welding pass	2
Plate thickness/mm	6
Welding speed/(mm·min ⁻¹)	50
Filler diameter/mm	3
Nozzle diameter	10



Figure1 showing welding rod- filler rod

Table:6 Composition

Material	Cu	P	Al	Si	Fe	C	O	Ca
Aluma-Steel	Bal.	5.0	0.4	0.7	0.2	13.2	3.3	0.1

The samples prepared as per the ASTM standards for tensile, hardness, microstructures, the weldments are polished for the higher magnification to

check the combination in both inter-phase zones after fixing at both ends to weld fixture.



Figure:2 Sample preparation for micro structure, hardness, tensile

After weld joint, like way ASTM E384 and ASTM E345 for the tensile testing sample.

5. Test results of welded joints

Tested hardness and tensile samples as shown in figure2 and 3 with results after two step welding process for the strength and crack formation failures, UN-cracked 6samples results shown in the table 7 and 8

5.1 Hardness Testing results:

Material hardness testing measures a material's resistance to penetration in order to estimate its strength. When selecting materials, hardness test results can be particularly valuable because the evaluated hardness value shows how easily and accurately the material can be manufactured and how well it will wear. Metal hardness testing is normally carried out to evaluate the value of treatments and coatings.

Table:7 Tested samples hardness (HV) results



SAMPLE NO	ALBM	AL HAZ	Weld	CU HAZ	CU BM
SAMPLE-1	66.6	63.9	134.7	123.2	124.7
SAMPLE-2	63.4	53.6	141.2	74.9	124.7
SAMPLE-3	61.5	56.3	145.5	111.5	123.6
SAMPLE-4	62.9	56.4	144.3	97.6	122.8
SAMPLE-5	67.1	61.1	157.2	114.9	117.3
SAMPLE-6	59.2	55.9	109.3	105.2	111.5

5.2 Tensile test results:

Tensile testing is required to determine the metal's tensile strength, yield strength, ductility, and other properties. Measures how much a composite or plastic specimen may extend before breaking and how

much power is necessary. Composite materials are often tested in basic tension or flat-sandwich tension according to standard ds.



Figure 3: Tensile samples for testing and results in Table-8

SAMPLE NO	Weld strength (MPa)
SAMPLE-1	174.5
SAMPLE-2	162.37
SAMPLE-3	181.2
SAMPLE-4	274.3
SAMPLE-5	305.5
SAMPLE-6	145.8

6. Weld structure analysis

Simulation study on weld with temperature and power in put given in Ansys workbench to check the final

deformation of two metals, the properties and the boundary conditions taken from the experimental study to check thermal stresses in weld zone and HAZ.

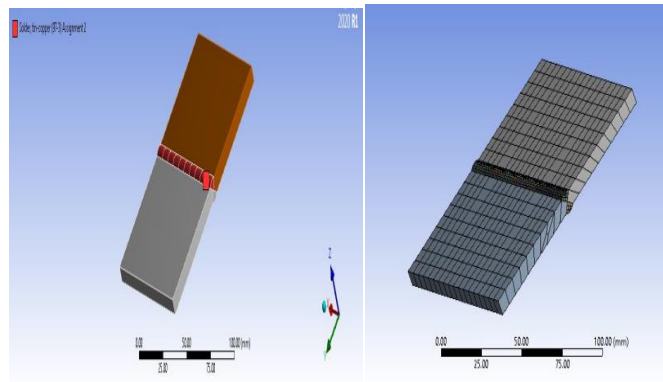
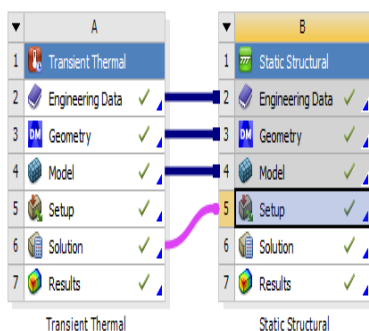
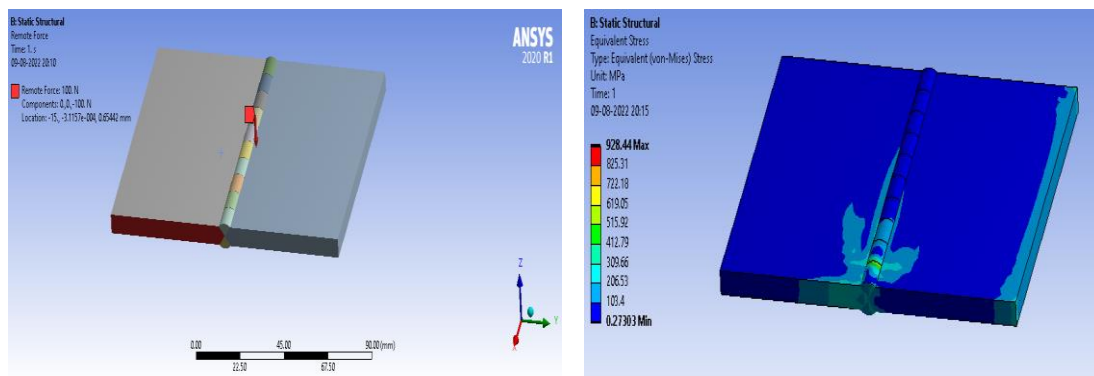
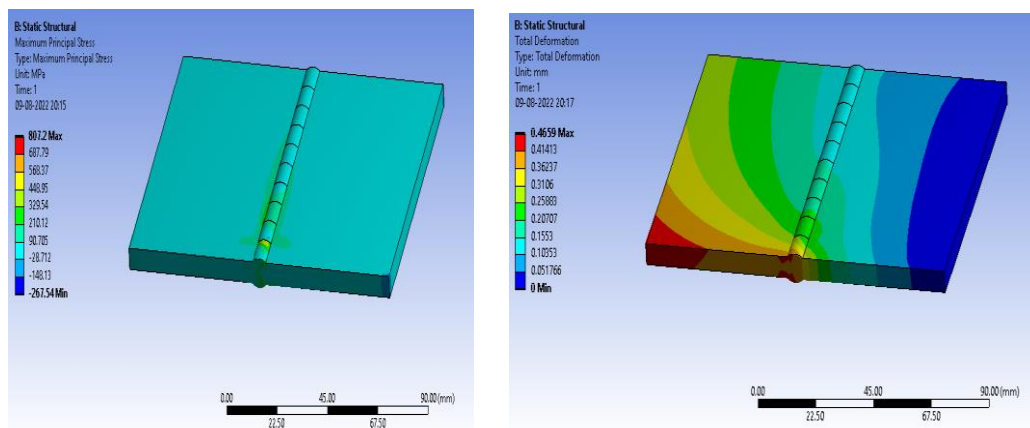


**Figure4:(a) analysis integration with structural (b) Geometry view and meshed view**

Experimental boundary conditions with high strength sample properties taken for the analysis to check the thermal stress distribution of fixed segment 10mm in the present work. HAZ contours were developed to check the weld movement as shown in figure 5a.

Static force application on weld body by using the remote load on weld surface of copper side to check the maximum deformed conditions at load weld joint. Analysis performed in two steps one with one end fix and another at both ends to check the deformed variation in the weld joint.

**Figure 5: (a) load on joint (b) equivalent von-mises stress at one end fixed****Figure6 : (a) Maximum stress (b) Total deformation**

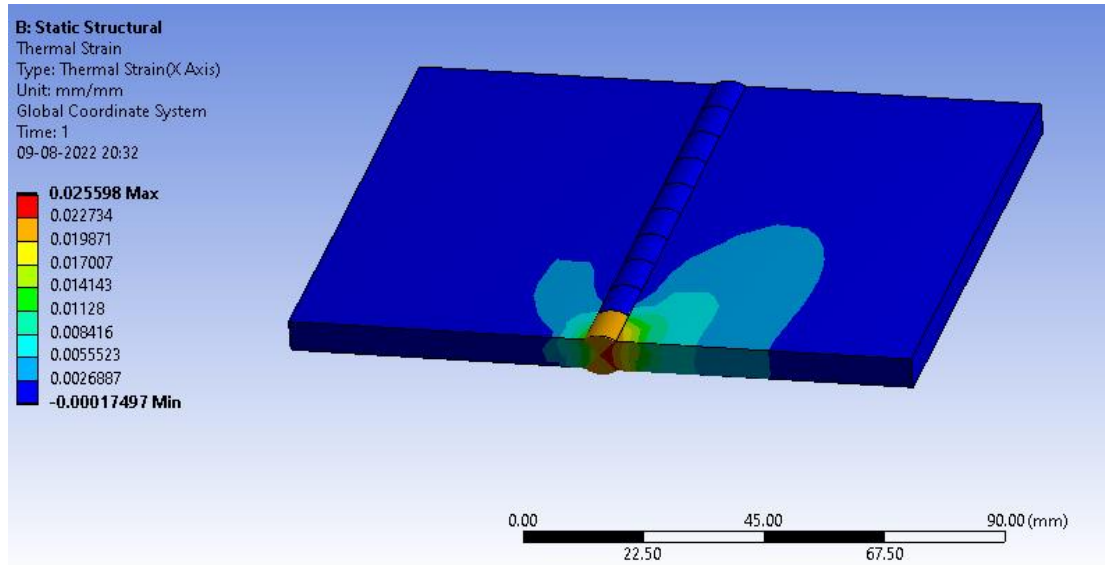


Figure7 : Thermal strain

Temperature distribution along with the welds are observed for the total length segregated to 10 segments for each connectivity on both sides of the weld. The total deformation found to be 0.45506mm as shown in figure6 in the overall weld with 0.255mm/mm strain energy of thermal contour found as shown

in figure7, directional deformation more at aluminium side. Minimum thermal deformation found for the sample properties of number 5 given as boundary condition. Stress distribution and deformation find more in Al composite side while copper side its very less.

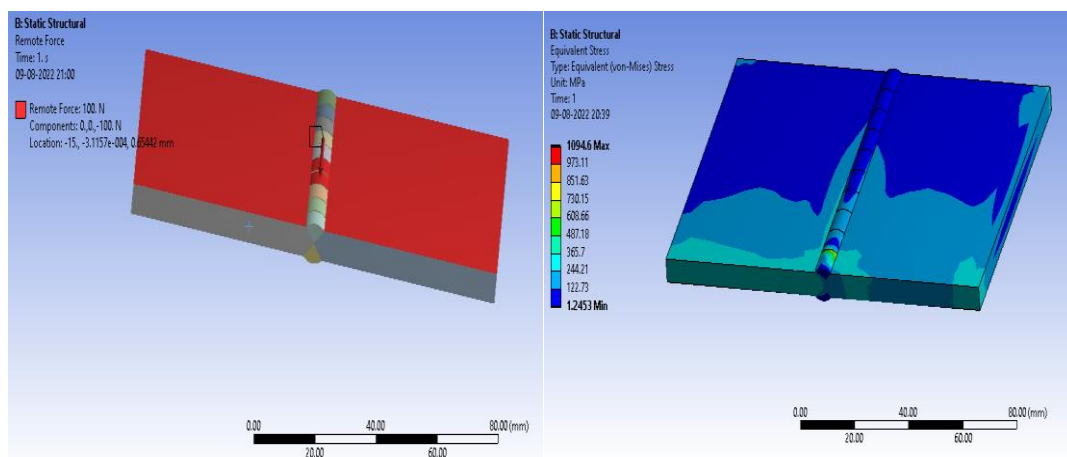


Figure8 : (a) load on joint (b) equivalent von-misses stress at two fixed ends

The total deformation found to be 0.385 mm in the overall weld as shown in figure 9 with 0.240 mm/mm strain energy as

shown in figure10 of thermal contour found, directional deformation more at aluminium side. Minimum thermal



deformation found for the sample properties of number 5 given as boundary condition. Stress distribution and

deformation find more in Al composite side while copper side its very less.

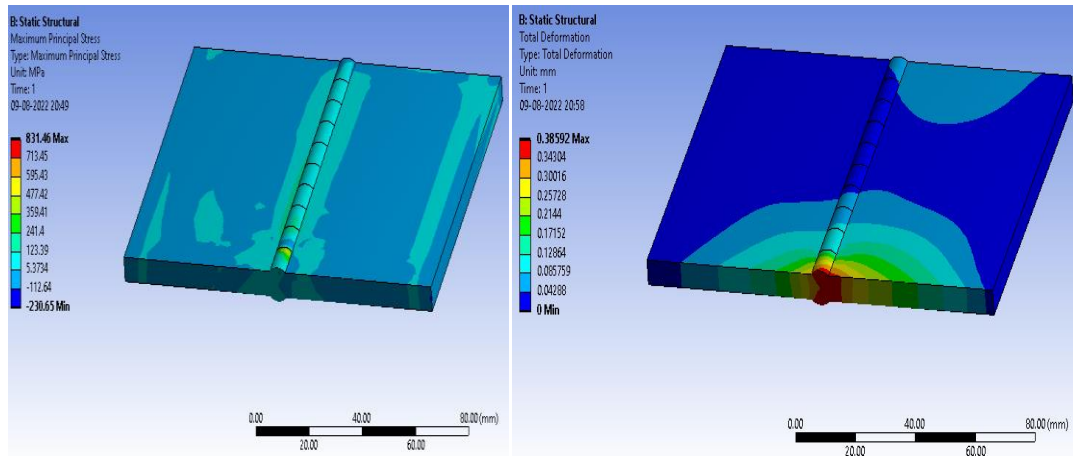


Figure9 : (a) Maximum stress (b) Total deformation

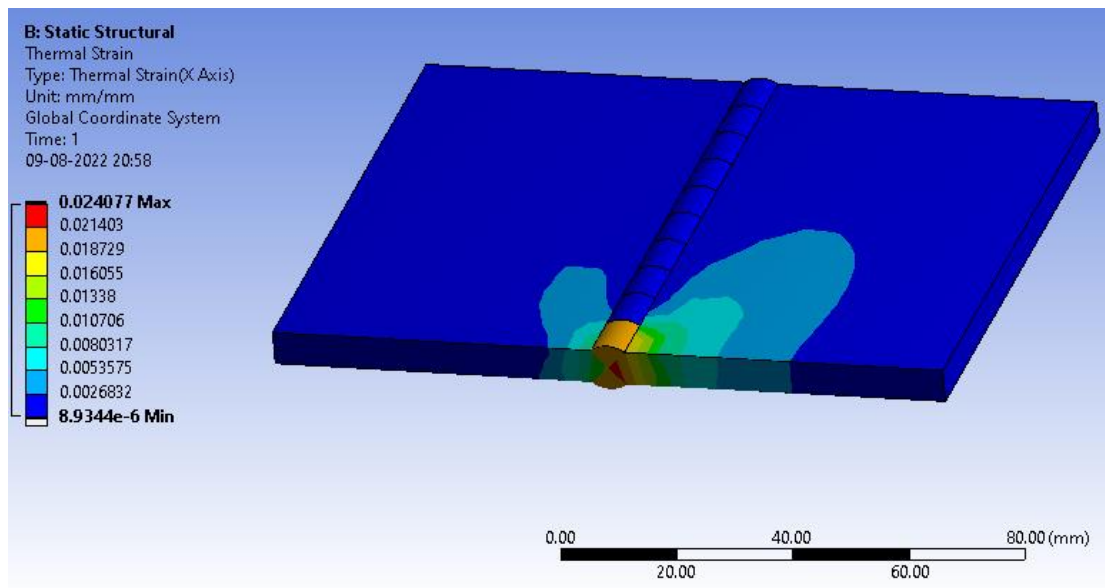


Figure10 : Thermal strain at 2 fixed ends

7. Conclusions

Composite welding process with experimentation for the mechanical properties of weldments studied in the present approach with simulation check for structural deformation. From the stir casting process it is observed that strength attainment by the addition of SiC to

carbon at low percentage i.e 6% and 8% of B4C to copper. Stir-casting method is a prominent process to get good mechanical properties after fabrication. Regular weldment of similar metals by GTAW(known as TIG) will give promising results of its same physical, mechanical and thermal properties, composite material welds in the present study given equal



result by fastening it with special copper electrodes namely aluma steel. Two step welding process achieved better result than direct weld which is observed in simulation of thermal welds. Load bearing deformations observed by fixing both ends, a decrement in structural deformation noted 0.385mm comparatively less with single end fixing 0.455mm. Thermal strain also less with both ends fixed condition. The work is a value addition for future researches of composite welds of dis-similar family base metals.

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