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EXPERIMENTAL STUDY AND SIMULATION ON TIG WELDING FOR COPPER AND ALUMINIUM COMPOSITES

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Abstract: Dissimilar metal welding with copper and aluminium composites in aeronautic applications is becoming a task. The different welding parameters are designed with the best strengthening samples taken before research.A total of 27 samples taken for the present work with different powerin put of weld among that six optimized samples taken from weld inspection results. Dissimilar combination welds were progressed, and the optimized final six samples after the visual inspection was finalized to check the mechanical characterization and microstructural study. Weld strength and the heat affected zones were characterized for the samples to check the hardness in both sides of the welds. The properties further incorporated in simulation to check the final deformation and weld stresses formed in the weld zone with transient thermal and structural analysis combination. A weld with 70 amp current given good results compare with all other samples, and its concluded that aluma steel rods of Ø3 with two step procedure increase the weld strength in samples.

Key words: *Composites, Dissimilar, TIG Welds, Characterization, Structural, Simulation , Ansys*

1.Introduction

Welding is a procedure that involves putting two crystal-to-crystal-bonded chunks of metal or other crystalline materials into close contact and fusing them. Based on the welding technique, the heat required for welding could come from natural gas or an electric arc or from electric resistance. [1] Alternatively, a filler rod can be used to melt between the fit surfaces and create a foundation. In addition to structures, bridges, ships, pressure vessels, and nuclear reactors, physical properties can be found in a wide range of other fields [2]. To its numerous advantages, including design freedom, cost savings, lower total weight, and improved structural performance [3] [4], welding is becoming increasingly popular in these sectors. Fusion welding can be classified as gas, arc, or high-energy beam welding, depending on the heat source. An electric arc is used to transport energy from the welding electrode to the base metal. When the arc is started a suitable quantity of power (energy transferred per unit time) and energy density is delivered to the electrode. The weld is formed by melting the base metal and the filler metal together. [5] [6]. Gas Welding with a non-consumable tungsten electrode is referred to as tungsten inert gas (TIG), and it is used in GTAW. No melting occurs when using the correct welding procedures and equipment. To perform the operation the tungsten electrode and the work piece are connected by an electrical source; the arc can approach 19,40^0 C. [7]. Filler metal can be used in GTAW welding. It is possible to add filler

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metal directly into the molten pool, but it is more difficult to do so when the metal is already molten. When filler metal is not used the metal is heated, melted, and flowed together by itself, and as the metal cools, coalescence occurs [8]. The weld requires minimal finishing. Weld quality has been connected to GTAW's widespread adoption as an assembly process because of the precision with which heat input and filler additives can be controlled [9] [10]. Among the industries where GTAW has been widely used include the atomic energy, aircraft, chemical and instrument industries, nuclear, food and maintenance and repair, and some manufacturing sectors Microstructure and mechanical characteristics of the metal undergo modifications, and the effects of these modifications can be deduced and evaluated.

2.Research methodology

The materials copper and aluminium composite is taken and as welding components for dissimilar weld amendment where the materials are machined for proper sampling for tests. When using the TIG welding process, there is a distinction between two types of welding. On the other hand, it is a sort of welding known as direct current welding. It is placed on the negative pole. Alloy steels and non-ferrous metals like copper and brass can be joined using this type of welding. On the other hand, it uses alternating current to weld metal. This method of welding is used to combine lightweight metals like aluminium and magnesium because the oxide layer is broken. Lightweight metals can also be welded with direct current, in which the electrode is linked to the positive pole. TIG welding may be used to weld any metal that can be welded using the fusion method.

2.1 *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 330^{0}C 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.

Table1: 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

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Nozzle diameter	10

3.Sample preparation combinations for weld check

Electrodes – copper based aluma steel weld rods @ Ø3mm

For welds – Each sample differed in current at 60, 70, and 80 A. Nine combinations were checked with three current inputs with 27 pieces done for different combinations—the visible perfected samples of two from each power variation, a total of six taken for final characterization.

1. Cu+ B4C (1) + Al 6061(1)-
2. Cu+ B4C (1) + Al 6061(2)
3. Cu+ B4C (1) + Al 6061(3)
4. Cu+ B4C (2) + Al 6061(1)-
5. Cu+ B4C (2) + Al 6061(2)
6. Cu+ B4C (2) + Al 6061(3)
7. Cu+ B4C (3) + Al 6061(1)
8. Cu+ B4C (3) + Al 6061(2)
9. Cu+ B4C (3) + Al 6061(3)

GTWA welding is a well known process with economy based welding; present work had been done in two step process with aluma steel weld rods which can used for different material welds. Here the materials taken from stir casting with combination of metals as copper and aluminium mixed with B4C and SiC at different percentages, the out come divided in to 27 samples. Primarily the auminium samples weld with weld rod #1 which is having a combination of tungsten copper an alumina. The next process with copper rod of #2 with same diameter joining the both metals.

3.1Electrode for present research

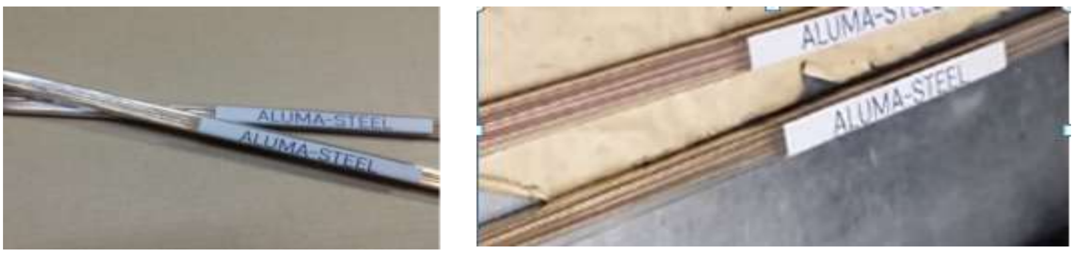

Figure1 showing welding rod- filler rod

Table2; Properties of electrode materials

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Material (%)	Cu	P	Al	Si	Fe	C	O	Ca
Aluma-steel	78.1	5	0.4	0.7	0.2	13.2	3.3	0.1

4.Sample evaluation and testing

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

Samples polished for micro structures as per ASTM766 at 200x magnification to verify the structure after weld joint, like way ASTM E384 and ASTM E345 for the tensile testing sample.

4.1 ***Micro structural analysis*****:**

Micro-structures of welded zones extracted by using OLYMPUS magnifier up to1000X.

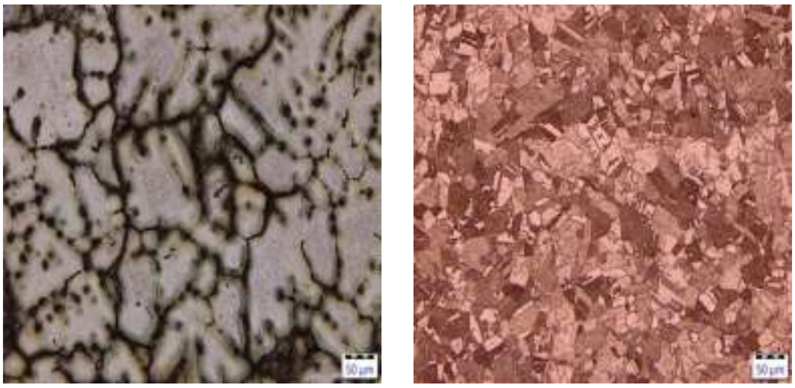

Figure:3 a) Al Base metal 200x b) CU Base metal 200x

Figure4: Sample -1

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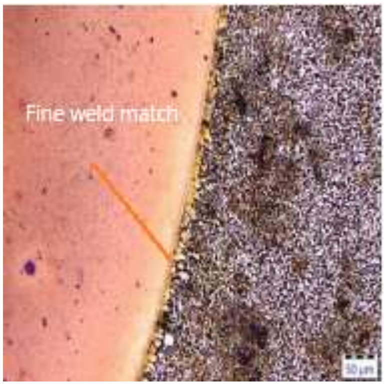

Figure:5 CU Weld interface 200x **Figure:6 Al Weld interface 200x**

By observing figure 3a, 3b the base metals structures evaluated doesn't go any cracks while fastening to weld fixture. By observing figure 4, 5 and 6 weld inter-phase between copper and the weld zone is good but the zone between aluminium inter-phase have a bit of cracking which can weak the strength value 134.7 at 60 amps of power. The weld inter-phase analyzed in figure 6 comparing base metal microstructure as shown in figure 3a not much variation found in material structure in HAZ; weld gap known as pores crack found at lower current. In copper end the weld attached clearly and added to base-metal with out any cracks. The hardness at HAZ is lower than the base metal but at weld zone the value increased because of weld rot composition.

Sample-2:

Figure:7 Sample -2

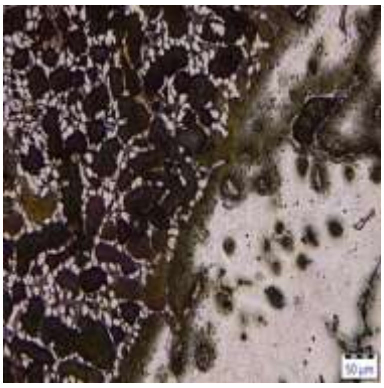

Figure:8 CU Weld interface 200x Figure:9 Al Weld interface 200x

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Observing figure 7, 8 and 9 weld interphase between copper and the weld zone is cracked but the zone between aluminium inter-phase is good , the material bonding between aluminium and weld zone mixed very fine but at the other end the crack can weak the strength value141.2 at 80 amps of power.

Sample -3:

Figure:10 Sample -3

Figure:11 CU Weld interface 200x **Figure:12 Al Weld interface 200x**

Observing figure 10, 11 and 12 weld interphase between copper and the weld zone is very fine and the zone between aluminium interphase is good which have the good strength value 145.3 at 70 amps of power. By observing both sides of weld-ment on heat affected zone the element distribution is good with the basemetal as well as interphase. Fine pores found and little pits found in heat affected zones because of Si particles. Overall weld is good compare with samples 1&2.

Sample-4

Figure:13 Sample -4

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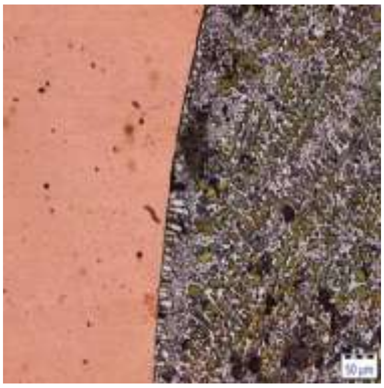


Figure:14 CU Weld interface 200x Figure:15 Al Weld interface 200x

Observing figure 13, 14 and 15 weld interphase between copper and the weld zone is very fine and the zone between aluminium interphase is good which have the strength value144.3 HV at 80 amps of power. Some lashes and pits found in the combination but the strength of weldment is good, alignment of plates also given good result, elemental distribution also fine in the all zones.

Sample-5

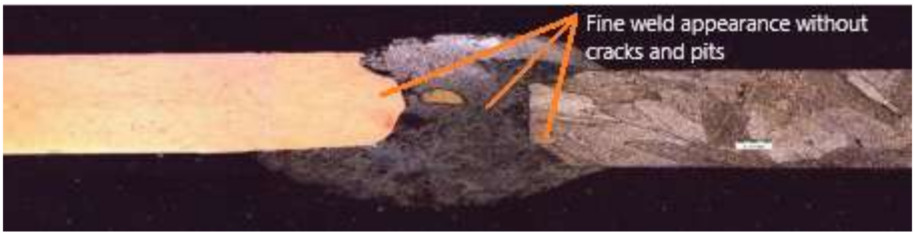
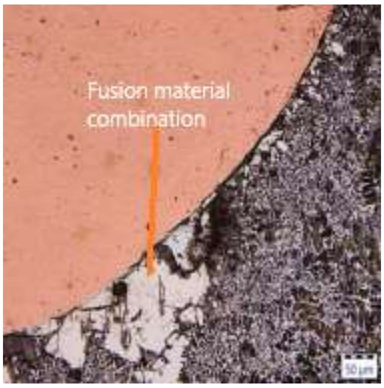


Figure16: Sample -5



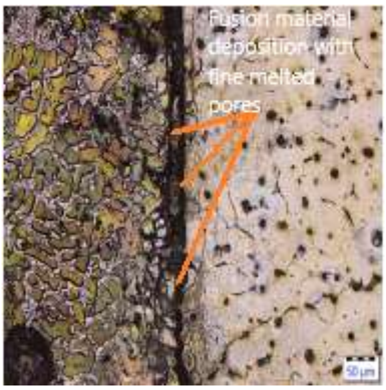


Figure:17 CU Weld interface 200x Figure:18 Al Weld interface 200x

Observing figure 16, 17and 18 weld interphase between copper and the weld zone is very fine and the zone between aluminium interphase is good which have the strength value157.2 at 70 amps of power. Compare to

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other combination this joint attained maximum strength because of fusion bonding of melted electrode particle deposition. Structural change found in the HAZ on both sides with fine pores.

Sample-6

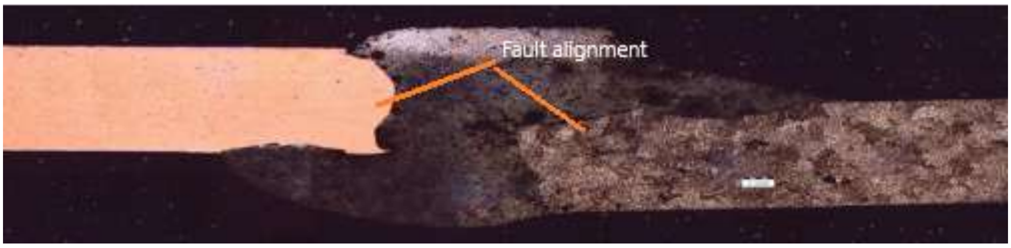

Figure:19 Sample -6

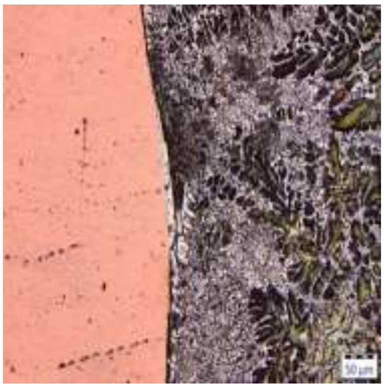

Figure: 20 CU Weld interface 200x

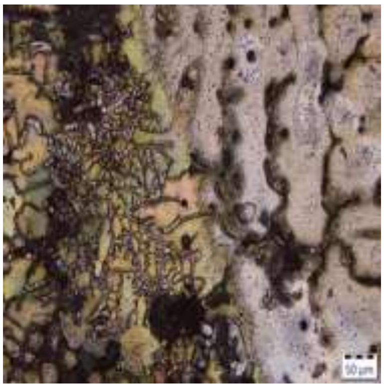

Figure:21 Al Weld interface 200x

Observing figure 13, 14 and 15 weld interphase between copper and the weld zone is very fine and the zone between aluminium interphase is having multi blow holes due to misalignment of plates which may waken the strength value (109.3)at 60 amps of power. Fusion deposition is good but multiple passes of fastening leads to misalignment.

4.2 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 weldments at different zones like base-metal, heat affected zone and weld area for 6 samples as given in table3.

Table:3 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

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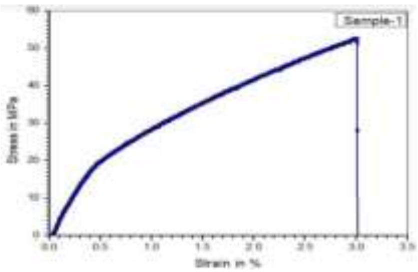
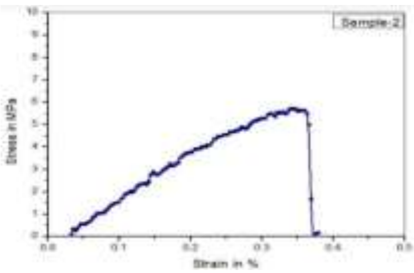
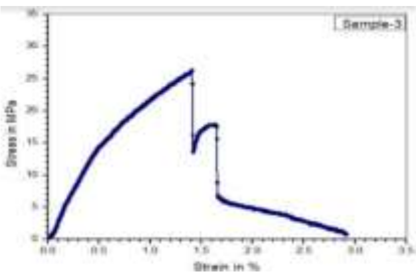
SAMPLE-3	61.5	56.3	145.5	111.5	123.6
SAMPLE-4	62.9	56.4	144.3	97.6	122.8
SAMPLE-5	67.1	61.1	157.2	114.9	117.3
SAMPLE-6	59.2	55.9	109.3	105.2	111.5

4.3 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 standards.

Tensile test conducted using Universal testing machine for the 6 samples selected. The machine generated graphs added with digital value of the sample updated in table 4.

Table:4 Tested samples of tensile test

SAMPLE NO	Weld strength (MPa)	Tensile Graph
SAMPLE-1	174.5	
SAMPLE-2	162.37	
SAMPLE-3	181.2	

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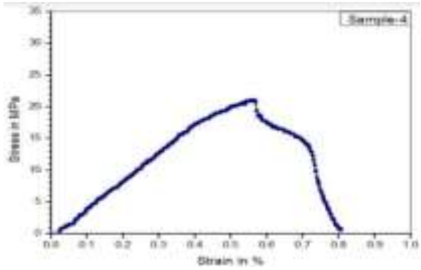
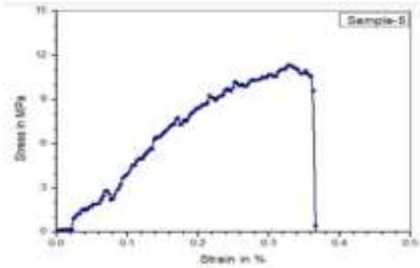
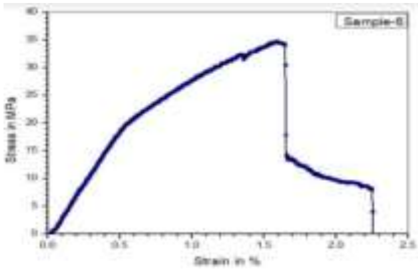
SAMPLE-4	274.3	
SAMPLE-5	305.5	
SAMPLE-6	145.8	

5. Simulation study

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 stessen in weld zone and HAZ.

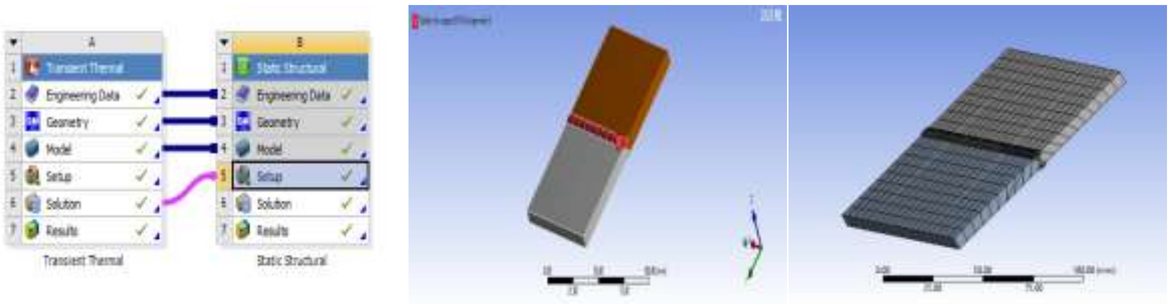


Figure:22 &23 Geometry view and meshed view

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. Material assignment with meshed condition shown in figure22 and 23

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5.1Temperature distribution in weld zone

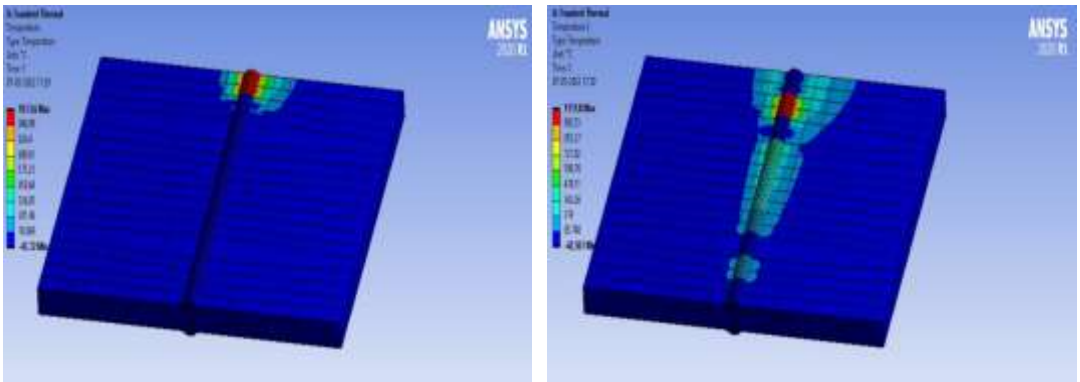

Figure:24 Temperature and heat effected zones 1&2

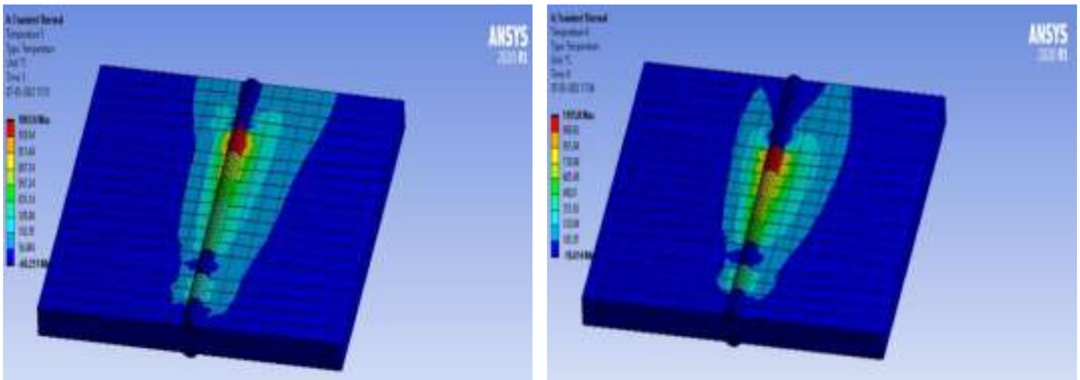

Figure:25 Temperature and heat effected zones 3&4

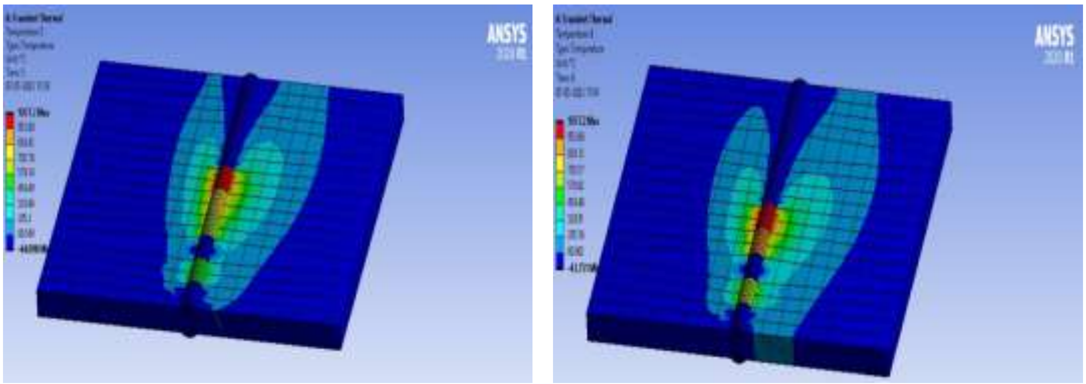

Figure:26 Temperature and heat effected zones 5&6

From figure 24 to 26 the temperature distribution fro initial phase much both metals reacts same when weld progress temperature found more at copper side because of its high thermal conductivity. Cooling taken accordingly in aluminium and SiC added side and the copper side temperature stabilizing after progressing time can observe in figures 27 and 28..

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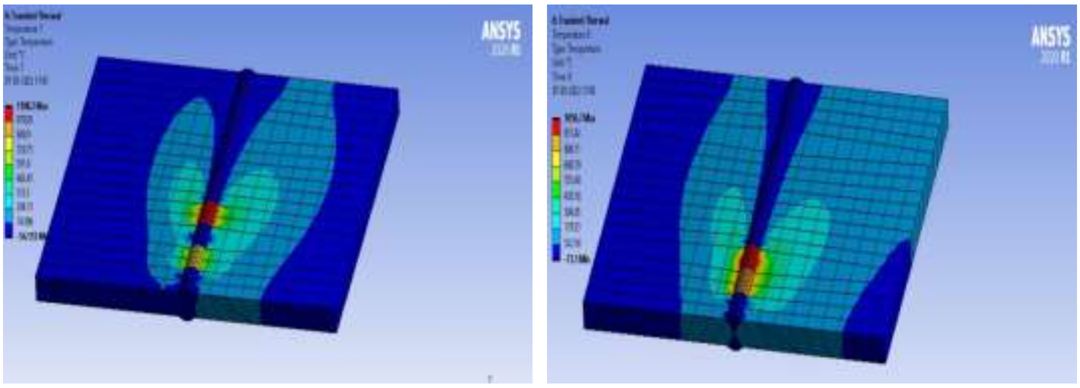

Figure:27 Temperature and heat effected zones 7&8

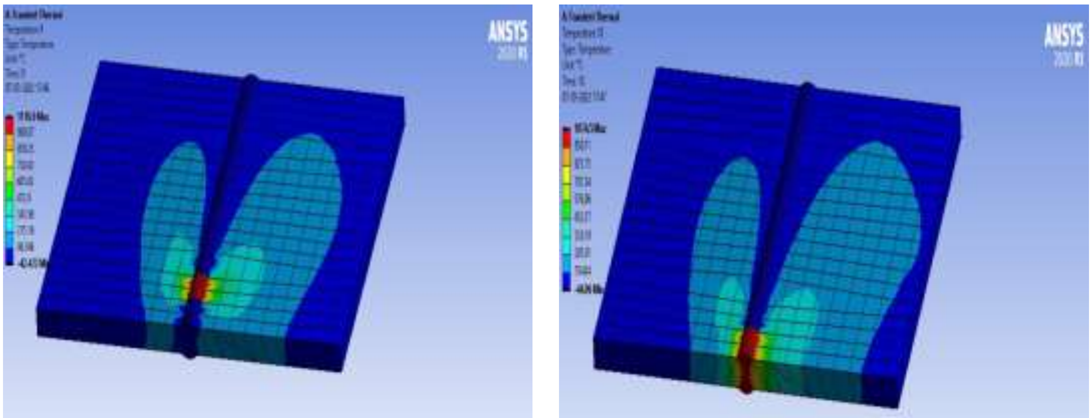

Figure:28 Temperature and heat effected zones 9&10

5.2 structural deformation study

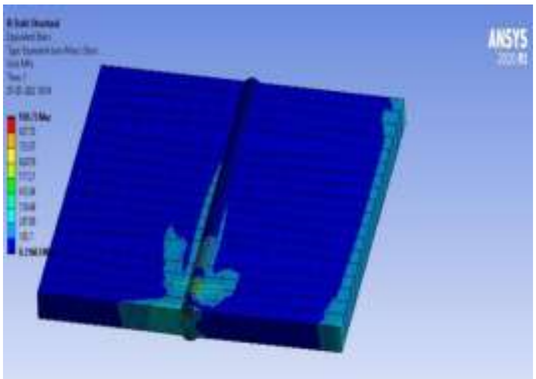

Figure:29 isotropic thermal stresses in weld zone

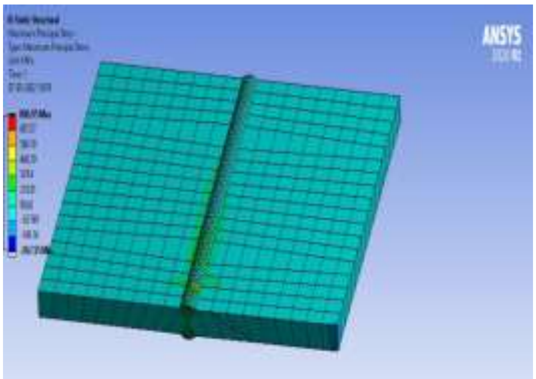

Figure: 30 Maximum principal stress

Discussions: Temperature distribution along with the welds are observed for the total length segregted to 10 segments for each connectivity on both sides of the weld. The total deformation found to be 0.45506mm in the overall weld with 0.255mm/mm strain energy 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.

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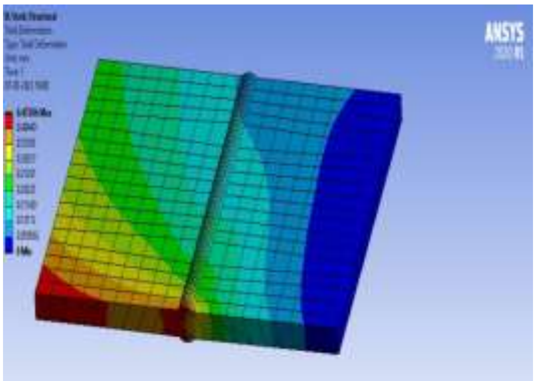

Figure: 31 Total deformation

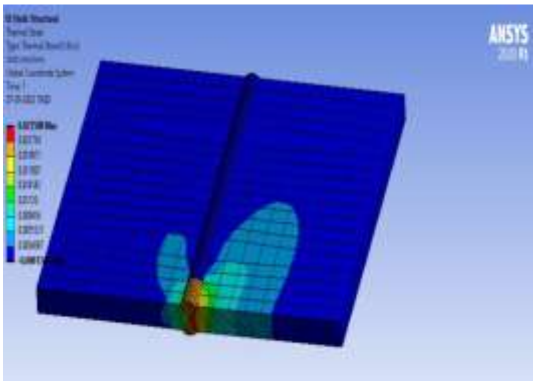

Figure: 32 Thermal stress

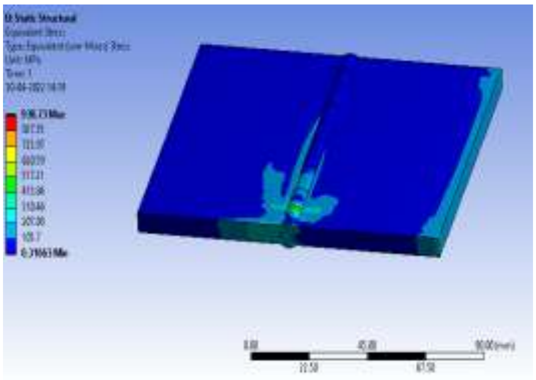

Figure:33 Equivalent stress

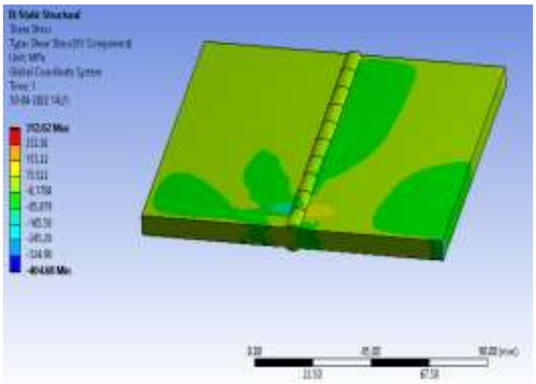

Figure:34 Shear stress

6.0 Conclusions

The present work observed both experimental and simulation study on dissimilar metal weldments, in the practical approach its clearly found that weldment for the present composites found to be good at 70 amp current. The value of maximum hardness found to be 157.2 and the tensile strength is 120MPa. Deformations and bending are very less after cooling of weldment and the structure is stable. By giving the obtained properties to simulation very less deformation less than 0.5mm found after thermal stresse act on both materials. Porous cracks find in some samples with weld speed difference the composite of CU with B4C 8% and Al with 6% SiC given good weld output in GTAW welding.

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