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Title **DESIGN AND ANALYSIS OF FSW WELDED ALUMINUM COMPOSITE ALLOY PLATES**

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DESIGN AND ANALYSIS OF FSW WELDED ALUMINUM COMPOSITE ALLOY PLATES

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Abstract
Friction stir welding is a cutting-edge method for welding suitable metals. The AA6065 family of aluminium alloys is investigated. The base material is not melting in the FSW welding process since heat is created during the operation. After analysing the welding process, we check how several factors affect the weld's final product, including the tool's material and shape, the welding rate, the rotational rate, and the axial forces. Thermal and structural analysis has been carried out to check the temperature distribution and thermal flux variation (thermal stresses) on the final welded joint of the composite modelling. A FSW model has been developed in relation with thermal boundary conditions of FSW sample to check the Thermal boundary of welded joint. The temperature condition up to the heat transformation from the work pieces using (250^0C,300^0C, 350^0C,400^0C) temperature to validate simulation results has been tested by fixing single and both the ends to check the weld failures. It is noted that composite alloy material sustainability is better than compared with normal aluminium alloy joints.
Keywords: FSW, Composite Alloy plates, ANSYS.

1.0 INTRODUCTION

Welding is joining two materials together, usually using heat and pressure. The completed welded joint can be called an element. Some materials require the use of unique processes and techniques. Some are considered "non-wieldable." This term is not usually found in dictionaries but is useful and descriptive in engineering and manufacturing. A base material is required to make a junction. Many different objects can serve this purpose, although substrates and tubes are the most prevalent. Once the foundation is in place, fillers or consumables can be applied. You may thank these materials for their role in forming the joint and keeping everything in place. Flux-cored wires, consumable electrodes, etc., are various names for the same thing that refer to the form of the material. However, there are notable exceptions to this rule, such the use of fillers of highly various compositions when welding brittle cast iron, which results in a weld with widely varied properties. The phrase "dissimilar welds" is used to characterize the nature of these couplings.

Friction Stir welding (FSW):

FSW is a type of pressure welding that uses only solid-state materials. Through mechanical stirring, welding is performed in FSW as a rotating tool moves along the joint line. Materials in contact with the rotating tool get very hot and eventually melt.

As the tool travels down the joint line, the semisolid plastic in front of it is swept around and dumped behind it, layer by layer. Despite its initial focus on alloys, fusion softening techniques have since been applied to various metals and materials, especially those that are difficult to melt. Through friction between the workpiece and the instrument, the heat generated by the friction causes the atoms in the material to diffuse together, joining the ends of the workpiece. Welded may be made with this method without additional heat sources, as mechanical energy is converted directly to thermal energy. Rotational speed, solder speed, axial pressure, and tool profile are the primary determinants of the ideal balance of heat and pressure needed to form the weld.

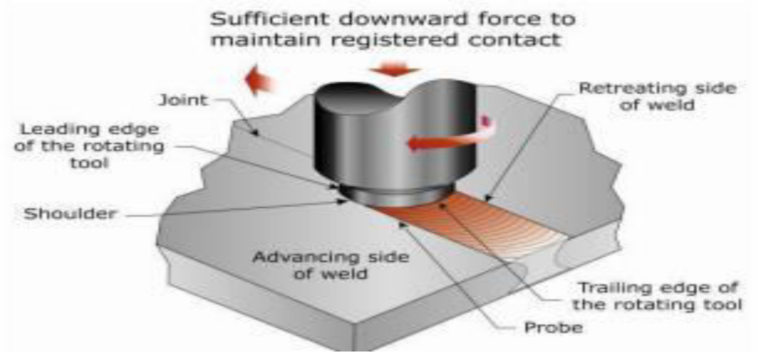

Figure 1: Friction stir welding

Friction Stir Welding (FSW) Principle:

Similarly, friction stir welding operates on the same principle as friction welding. Friction then heats the contact surface. In this way, the pairing's surface heat starts to diffuse. A metal-to-metal junction is formed when the pressure applied to these surfaces is high enough to speed up the metal diffusion mechanism. Friction welding theory is a foundation in technology. The plates are subjected to pressure and friction from a rotating tool in friction stir welding. This instrument can spin on its axis and move longitudinally at the point of contact between the spinning tool and the workpiece.

- The butt joint and the work plates are to be welded together, with the solderable surfaces of both pieces coming into contact.
- The interface's revolving tool pin is now inserted into the work pieces until the tool shoulder makes contact with it. As a result of friction force boiling, plastic deformation of the material occurs.
- This is a stage in the joining process in which intermolecular diffusion due to friction force heating causes plastic deformation of the substance.

Applications:

- FSW is frequently used in the aircraft industry for welding various parts of planes such aircraft, fuel tanks, and the chassis.
- Wheels bearings, chassis, fuel tanks, and other vehicle structure welding applications.
- In the chemical industry, it is used to link pipes, exchangers, air conditioning units, and other equipment.

- Friction stir welding is also utilized in the electronic industry to link transit bar, aluminum to copper, connections, and other electronic equipment's.

2.0 LITERATURE REVIEW SUMMARY

In this chapter important research works related to FSW only focused for better understanding the present scenarios in process and methods of research.

Bonifaz, E.A et al. **[1]** the optimum shoulder diameter design criterion was established that would allow for the most efficient use of input torque for traction. According to the criterion, the ideal shoulder diameter is the value of a parameter that results in a 50/50 split of the applied torque between sticking and sliding. Shoulder diameter optimization is also affected by the tool's rpm. K.V. Jata et al. **[2]** FSW was carried out on T745-tempered aluminum alloy 7050 to investigate its influence on the material's microstructure and mechanical qualities. Grains in the original material are transformed into dynamically recrystallized grains using FSW. L.E. Svensson et al. **[3]** It investigated the impact of Friction Stir Welding on the microstructure and mechanical properties of welds made from the aluminum alloys AA 5083 and AA 6082. AA 5083 had a fracture close to its center, while AA 6082 had a fracture in its HAZ. AA 6082 demonstrated a decrease in tensile strength relative to the base strength material while still satisfying design criteria when tested in a transverse tensile mode. Fricke, S et al. **[4]** used a Ni foil interlayer to test laser penetration welding on steel and aluminum. Intermetallic compounds couldn't form because of the overlaps between the steel and aluminum in the fusing zone. When comparing this joint to one without a Ni-foil interlayer, it was found that in addition to FeAl3, a novel alloy Al0.9Ni1.1 formed between the fusing area and the alloy. Frigaard et al. **[5]** Creating a finite difference model of FSW heat flow in three dimensions. MATLAB 5.2 software was used for the analysis. Hardness profiles were measured at regular intervals after welding. The results indicated that thermal impacts were the primary reason for the reduction in strength. Nectarios Vidakis et al. **[6]** investigated the use of FSW on an increasing number of MEX 3D printed components. Plaques of poly (methyl methacrylate) (PMMA) were assembled into a factorial design experiment. It was determined how three FSW parameters affected the final weld product. Statistical modeling techniques were used to examine the tensile strength. Microscopic analysis of the weld zone's morphology was also performed. Preety Rani, **[7]** The primary objective of this study is to review and thoroughly examine the majority of research done on friction stir welding of aluminum alloys. Weld reactions, material flow, and microstructure as they relate to the effects of process variables are being studied. **T.** Rajkumar et al. **[8]** In his study, he discovered that AA6063 aluminum alloy has become more popular for use in the production of lightweight constructions due to its high strength-to-weight ratio and high corrosion resistance in the T6 heat-treated state. Vaibhav S et al. **[9]** A model was built using friction stir welding to predict the mechanical characteristics of AA 7075-T651 better. It is currently common practice in the manufacturing sector to apply soft computing methods for the modeling and optimization of process parameters. Vivek Patel et al. **[10]** This research shows AA6063-T6 alloys can HSFSW at rates of up to 4.0 m min1. Adopting aggressive material mixing, i.e., more tool rotation and plunge force allows for defect-free HSFSW joints.

3.0 RESEARCH METHODOLOGY

The processing techniques used in composite preparation and methods of fastening composites through FSW process. Friction stir welding is performed on the composite by considering parameters like rotation speed, traverse speed, and tool geometry. Friction stir welding is one of the prominent fastening processes for Al alloys when compared with other fastening techniques. Present case study deals with Al6065 alloy fastened with Al6065 composite using friction stir welding

MATERIALS

An aluminum-6065 cylinder with copper powder reinforcement of 75 µm was chosen as the matrix material for this study. Table1 lists the chemical composition of Al-6065. The Al-6065 alloy qualities of these composite include low-weight and high-strength, and the density of this alloy is 2.82 gr/c.c. As a reinforcement, copper powder has a high absorption coefficient and is 8.96 grams per cubic centimetres in density. The base material and the additives in the present research shown in figure (a) and (b).

Table 1: **Chemical composition of AA 6065 material**

Material %	Mg	Si	Fe	Cr	Cu	Al
AA6065	0.93	0.6	0.33	0.18	0.25	97.7

Table 2: **Mechanical properties of AA 6065 material**

Material %	Yield Strength (Mpa)	Tensile Strength (MPa)	Hardness (HRA)
AA6065	0.93	0.6	40

Raw Materials:

- Aluminum-6065 cylinder
- Copper powder reinforcement of 75 µm(2%, 4% and 6%)
- Al 2024
- Tool Material H13

Figure 2: (a): Al-6065 bar (b): Copper powder c) H13 Material

FRICTION STIR WELDING ON FABRICATED AMMC

Friction stir welding is done on the fabricated AMMC. The following tool geometries are used in the friction stir welding process

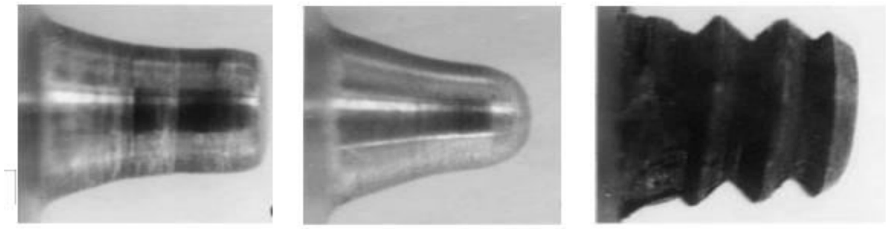

Figure 3: Tool Geometries (a) Cylindrical (b) Conical (c) Threaded

Figure 4: Friction Stir Welding Setup

In this investigation, a 6065 aluminium alloy was employed, and the joints were butted together. In order to reduce the probability of residual stresses, the welding plate was cut parallel to the direction of rolling, leaving it 101.6mm X 20mm X 5mm. In addition, tensile strength samples were produced in the standard way.

Figure 5: FSW Samples after Cooling

Introduction to Unigraphics (NX 12.0)

The NX program aids in the development and manufacture of products across their entire lifecycle, from the first conception of an idea through the final packaging of the finished good. By utilizing more digital product models and less assess the condition prototypes, design helps you to get items "straight to market, first time." As a result, businesses see increased sales, less Distribution, and higher-quality finished products.

Conical tool Design:

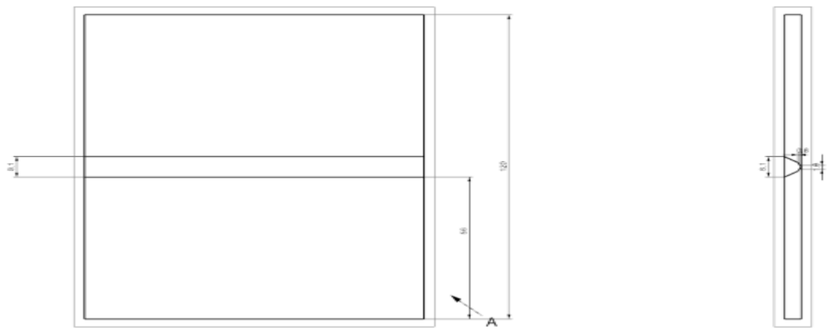

Figure 6: Geometry Model Conical tool

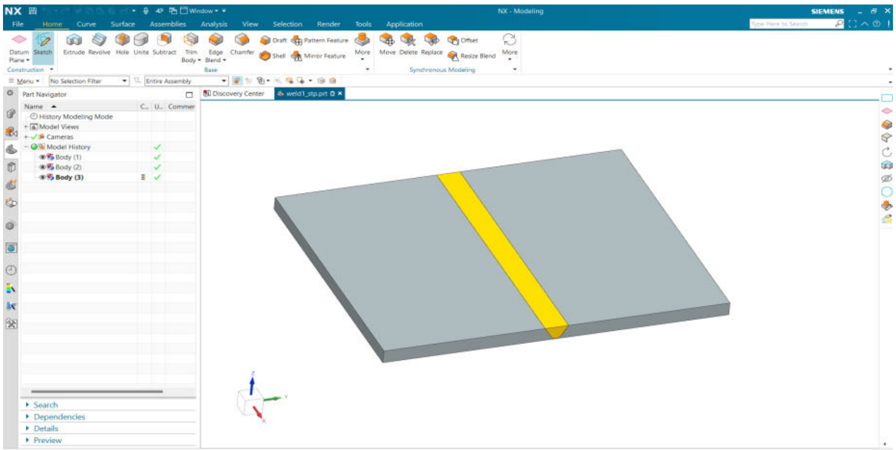

Figure 7: Design File Using NX 12.0

The following figures show the transient thermal analysis of FSW Welding using Conical tool.

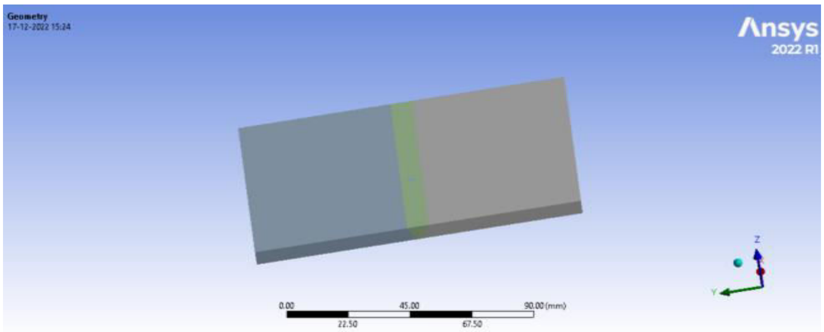

Figure 8: Imported model

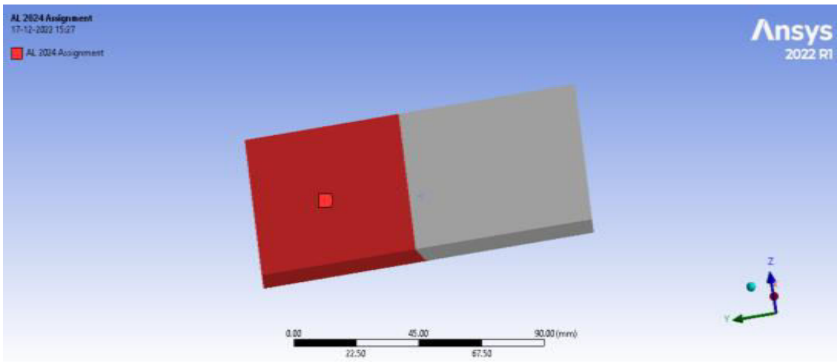

Figure 9: Material Assignment Al 2024

Conical tool Design:

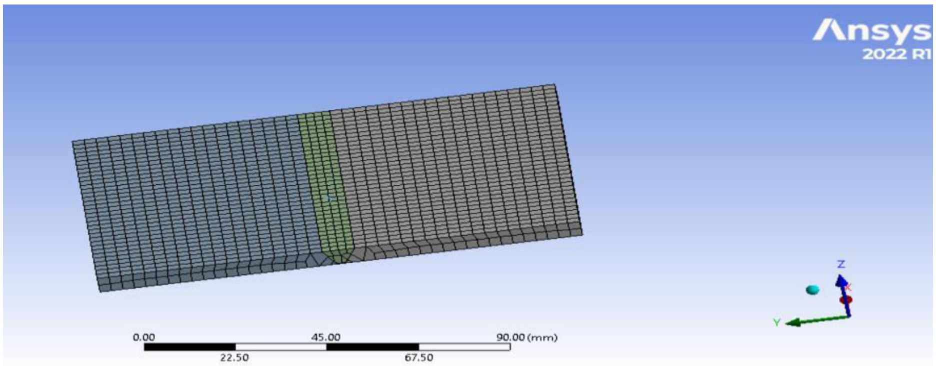

Figure 10: Meshed model

ANSYS has now deduced the component's elements. The next step is to specify how the modeled system should be segmented into discrete components.

4.0 RESULTS AND DISCUSSIONS

In addition to steady-state analysis, ANSYS can perform a transient analysis on any solid under thermal limit conditions. The effects of consistent thermal loads on a system or component can be calculated via a steady-state thermal analysis. It is common practice for users to do a steady-state analysis before performing a transient thermal analysis to understand better what values to use as their starting point. After all transient effects have faded, a steady-state analysis might be the final phase of a transient thermal study.

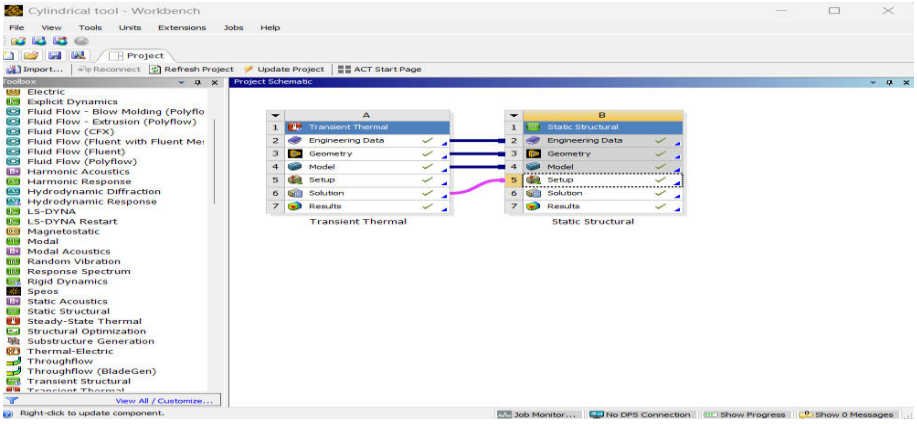

Figure 11: Ansys layout

Transient thermal Analysis:

Temperatures, thermal gradients, heat flows and heat flows inside an object due to constant thermal loads can be computed with ANSYS. Some examples of these weights are as follows:

- Convection
- Radiation
- Heat flow rates
- Heat fluxes (heat flow per unit area)
- Heat generation rates (heat flow per unit volume)
- Constant temperature boundaries

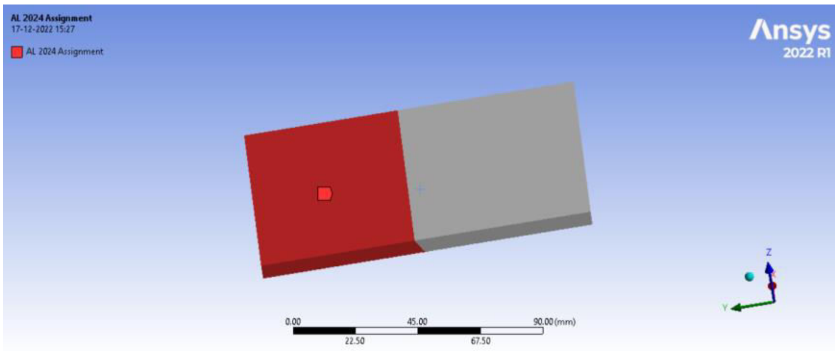

Figure 12: Material Assignment for clamping work piece

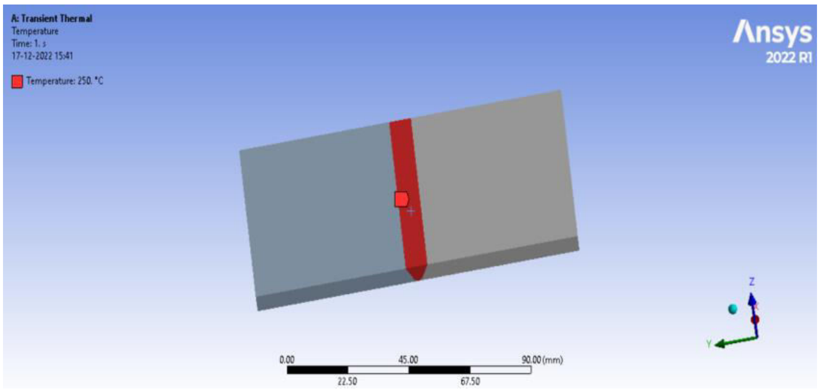

Figure 13: Temperature assignment for thermal distribution at 250^{0}C

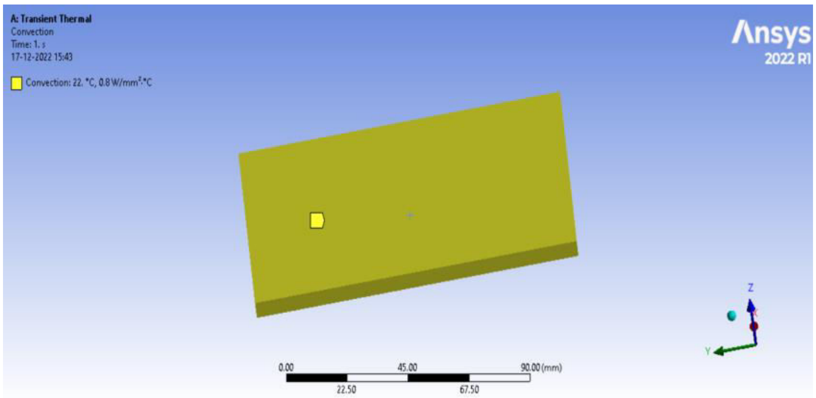

Figure 14: Convection to room temperature

Analysis of FSW using conical tool

The design and analysis of welding fixtures based on transient thermal analysis. Welding fixtures is designed to hold and support the work piece securely during the welding process. The heat transformation from the work piece could lead the temperature rises and impacts to the welding fixtures using (250^{0}C,300^{0}C, 350^{0}C,400^{0}C) temperature to validate

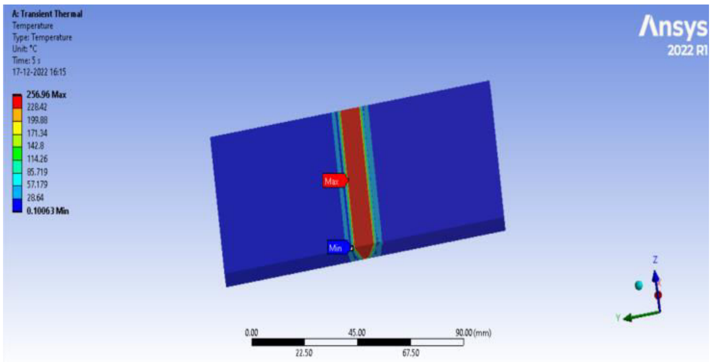

Figure 15: Temperature distribution to HAZ with 250^{0}C

From figure 15 it is shown that the temperature elevated with tool momentum and the distribution to HAZ is up to 170^{0}C.

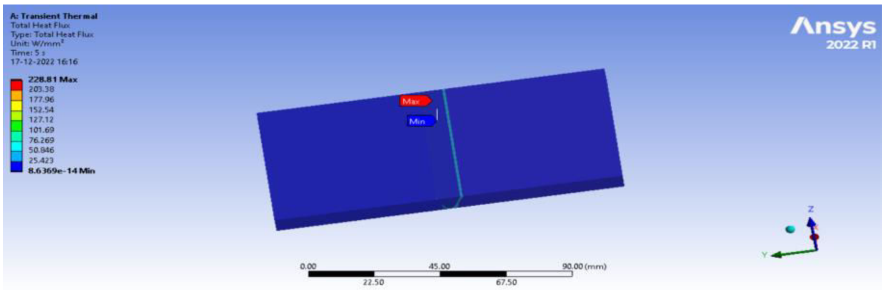

Figure 16: Total heat flux

Heat flux has been formed at the bottom of mated plate and the temperature and the thermal flux temperature is 76.2

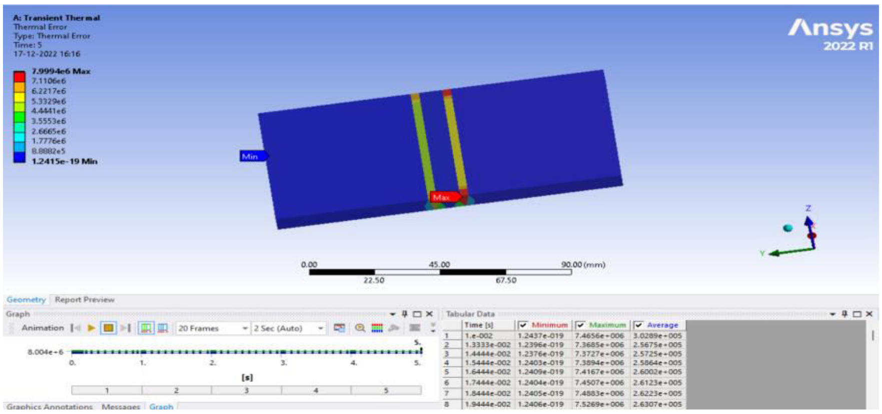

Figure 17: Thermal error

Thermal variations shown at the edges of heat affected zones with a maximum value of 8% as shown in figure

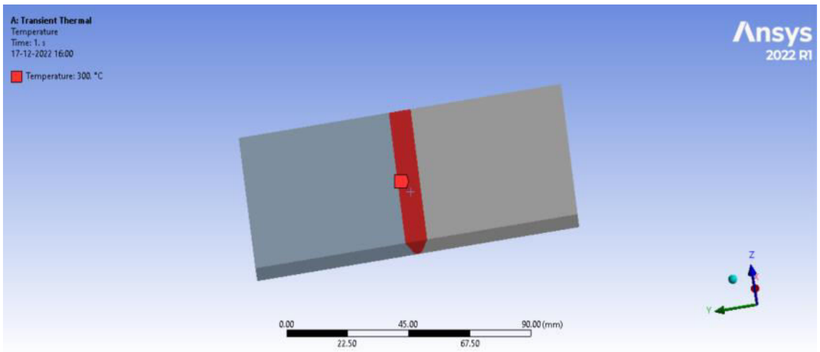

Figure 18: Temperature 300^{0}C assignment to friction welded zone

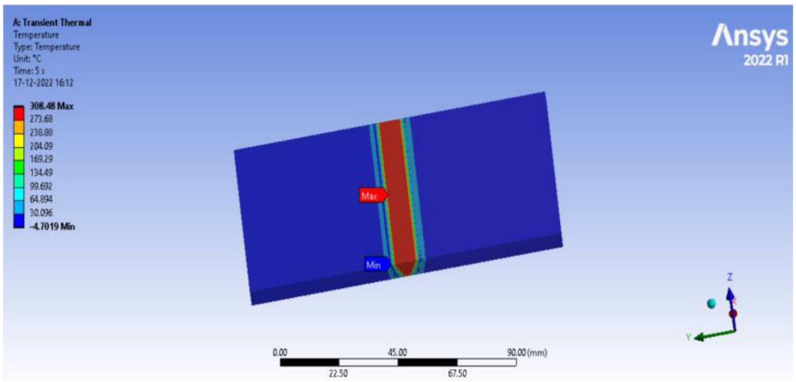

Figure 19: Temperature distribution to HAZ in 300^{0}C

A maximum temperature obtained at weld middle zone of 308.48 ^{0}C and temperature at HAZ maintained as 169.29 as shown in figure.

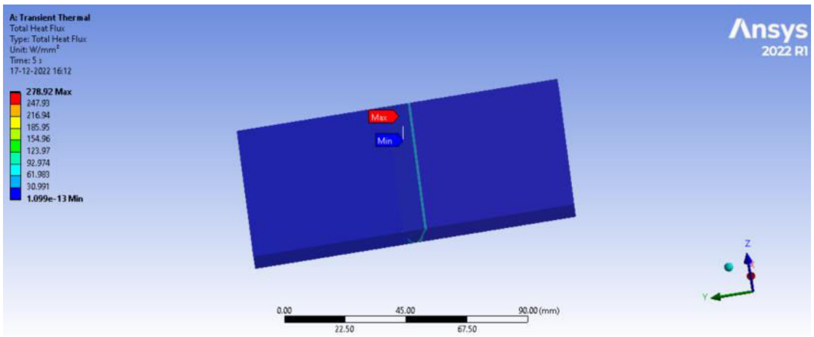

Figure 20: Total heat flux at 300^{0}C

Heat flux formed at the edge of shoulder in this case with heat particle rubbing and maintained 61^0 C at corner edges of mated zone as well as HAZ.

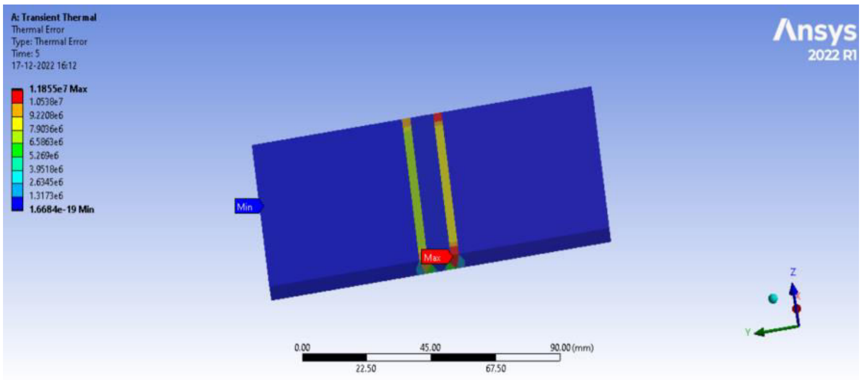

Figure 21: Thermal error at 300^{0}C

Error increase with increase in temperature at heat affected zone with a diverse increment of 4 % compared with before case study of 250^{0}C.

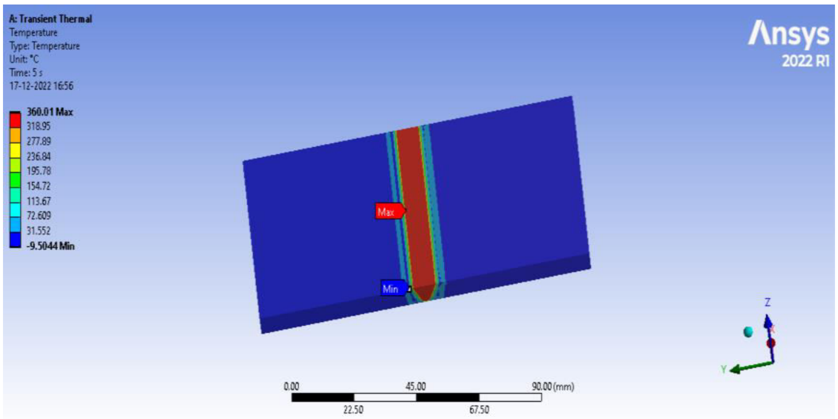

Figure 22: Temperature distribution 350^{0}C

Temperature distribution increases with increase in temperature a near friction temperature increased by 2^{0}C with the increment of 50^{0}C.

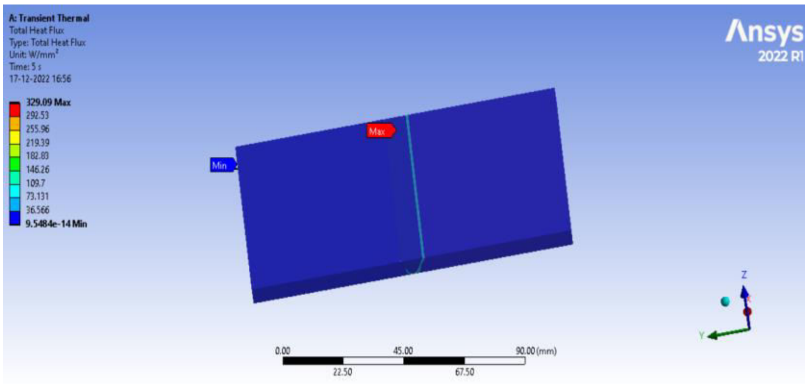

Figure 23: Heat flux at 350^{0}C

Fluxes formed at the bottom line of the shoulder and bottom of the mating plates, the value found to be 329 at weld zone and 109^{0}C at the bottom

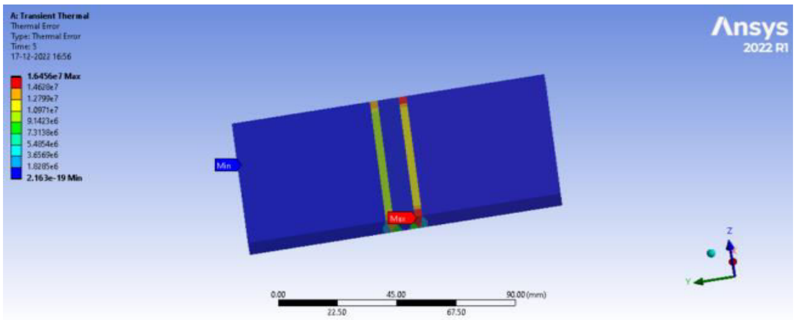

Figure 24: Thermal error at temperature 350^{0}C

An increment of 5% varied error found by the repeated conditions at HAZ when compared with 300^{0}C. Mostly the error at initial stage of plunging noted in the simulation.

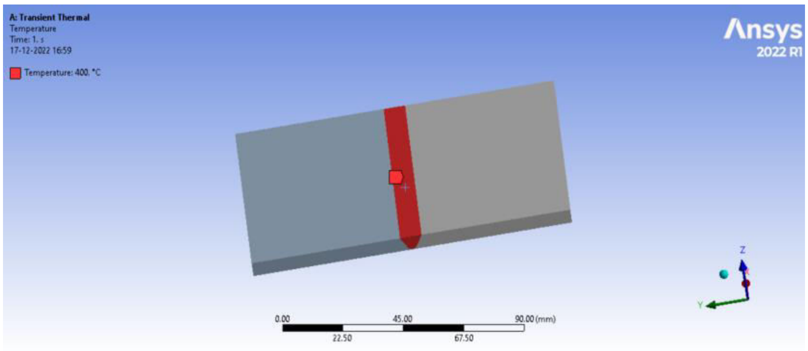

Figure 25: Temperature 400^{0}C assignment to friction welded zone

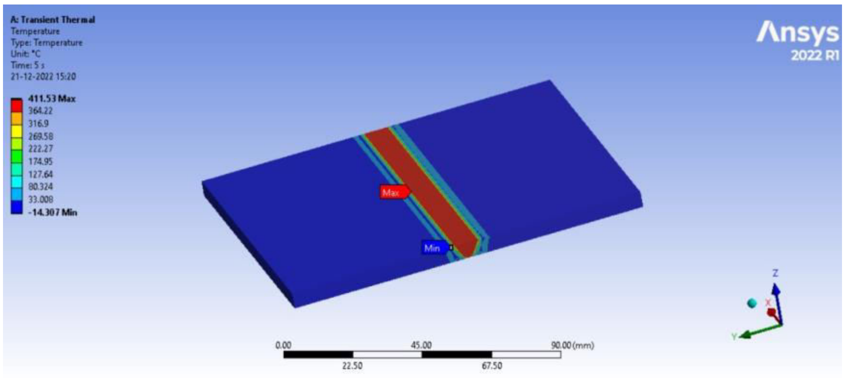

Figure 26: Temperature distribution 400^{0}C

Temperature distribution increases with increase in temperature a near friction temperature increased by 1^{0}C with the increment of 350^{0}C to 400^{0}C.

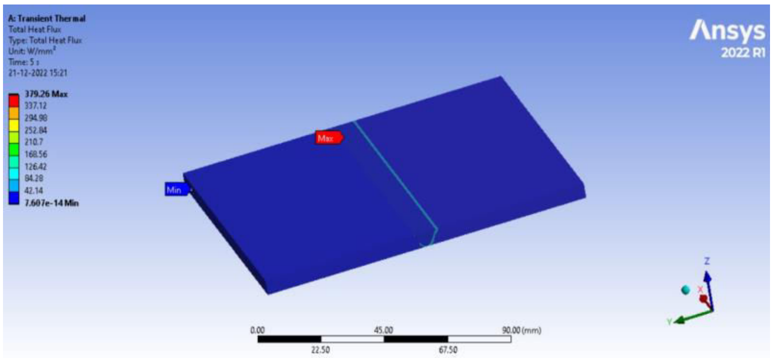

Figure 27: Total heat flux

Difference in heat flux found at higher temperature a nearby hat deposition of 4^0 found from the before with an increased temperature of 50^{0}C.

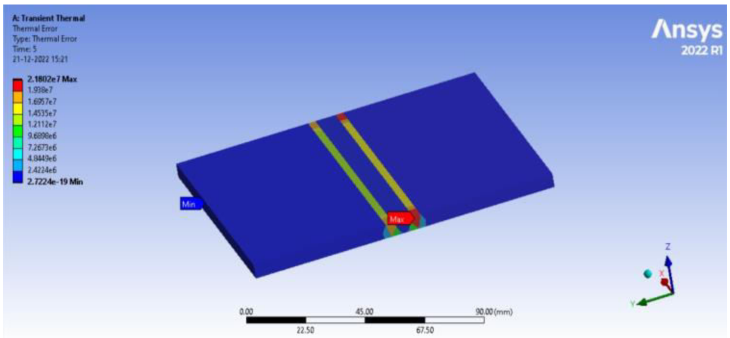

Figure 28: Thermal error at temperature 400^{0}C

An increment of 5-6% varied error found by the repeated conditions at HAZ when compared with 350^{0}C. Mostly the error at initial stage of plunging noted in the simulation.

Table 3: Transient thermal of conical tool maximum deformation

Tool Design	Temperature	Temperature (^{0}C) Distributed	Total Heat Flux(W/mm^2)	Thermal Error
	Input	Max	Max	Max
Conical Tool	250^{0}C	256.96	223.81	7.9994e+006
	300^{0}C	308.48	278.92	1.1855e+007
	350^{0}C	360.01	329.09	1.6456e+007
	400^{0}C	411.53	379.26	2.1802e+007

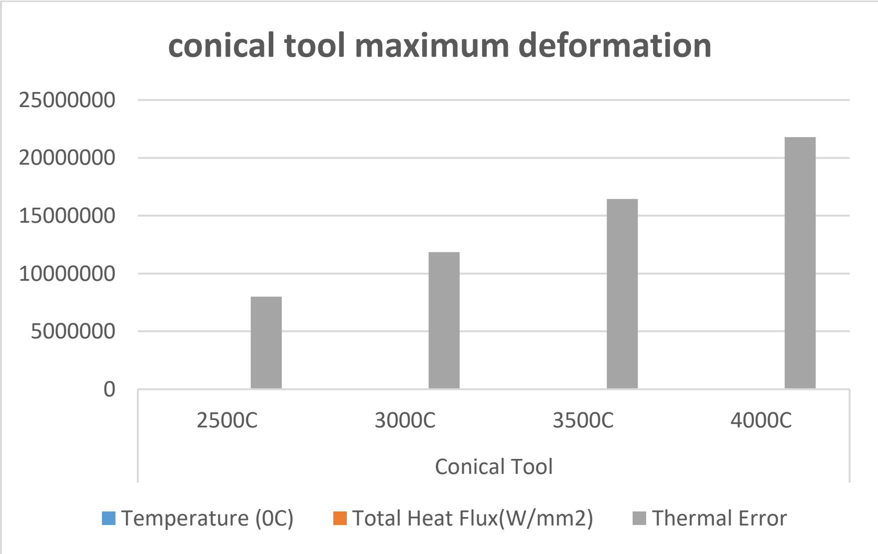

Figure 28: **Transient thermal of conical tool Maximum deformation**

Table 4: Transient thermal of conical tool minimum deformation

Tool Design	Temperature	Temperature (^{0}C) Distributed	Total Heat Flux(W/mm^2)	Thermal Error
	Input	Min	Min	Min
Conical Tool	250^{0}C	0.10063	8.6369e-014	1.2415e-019
	300^{0}C	-4.7019	1.099e-013	1.6684e-019
	350^{0}C	-9.5044	9.548e-014	2.163e-019
	400^{0}C	-14.307	7.607e-014	2.7224e-019

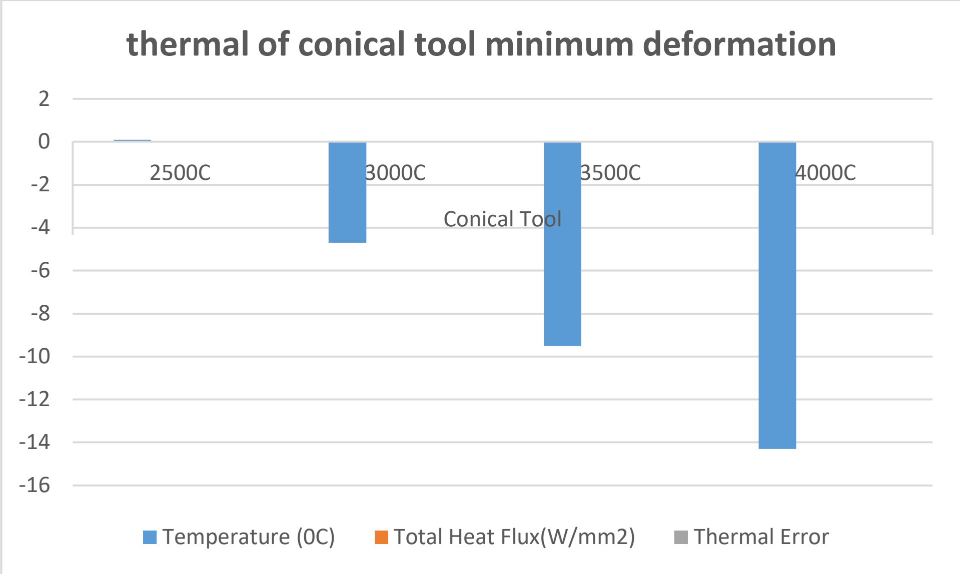

Figure 29: Transient thermal of conical tool minimum deformation

CONCLUSIONS

The design and analysis of welding fixtures based on transient thermal analysis. Welding fixtures is designed to hold and support the work piece securely during the welding process. The heat transformation from the work piece could lead the temperature rises and impacts to the welding fixtures using (250^0C,300^0C, 350^0C,400^0C) temperature to validate simulation results, it is noted that maximum heat flux was formed at bottom line of the plates, the values are 379.26, 329.0 (W/mm^2) as maximum for conical and cylindrical tools respectively. The transient thermal analysis linked the total temperature, heat flux as maximum and minimum for conical tools respectively. Total deformation was found more at the centre of welded joints. Ansys results is showing that very less heat fluxes and minimum deformations are formed for Al6065- Cu composite when compared.

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