DESIGN AND ANALYSIS OF AL ALLOY COMPOSITE WELDING USING FSW (FRICTION STIR WELDING)

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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. The matrix material is AA 6065, and the reinforcing is Cu**.** friction stir welding (FSW) modeling with a special focus on the heat generation due to the contact conditions between the FSW Conical tool and the workpiece. The physical process is described and the main process parameters that are relevant to its modeling are highlighted. The contact conditions (sliding/sticking) are presented as well as an analytical model that allows estimating the associated heat generation. Thermal 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,) 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

Friction stir welding (FSW) is a solid-state joining process that uses a non-consumable tool to join two facing workpieces without melting the workpiece material. Heat is generated by friction between the rotating tool and the workpiece material, which leads to a softened region near the FSW tool.

Introduction of friction stirs 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 work piece and the instrument, the heat generated by the friction causes the atoms in the material to diffuse together, joining the ends of the work piece. 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.

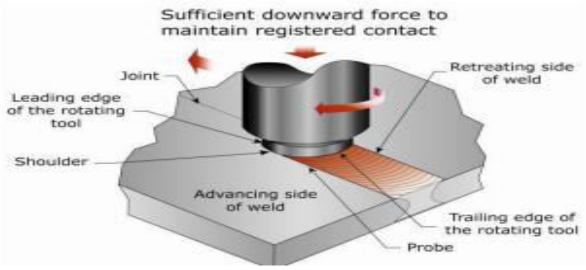

Figure 1: Friction stirs welding

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, aluminium to copper, connections, and other electronic equipment's.
- When the weld is performed, the welding tool will continue to rotate in an unlit state. When it's time to combine the two pieces of metal, the tool is taken away. The tool pin hole in the welding plate remains.

Advantages of friction stir welding (FSW):

- Solid-state welding uses no flux, filler metal, etc.
- FSW can weld similar and dissimilar metals.
- This method produces high-quality, fine-grain weld.
- Lower power usage due to no external heating.
- Highly automated.

Friction Stir Welding (FSW) Tool Geometry

The FSW methods have a tool shoulder and a tool pin, for example. The pin of the tool is inserted into the material, and the shoulder keeps the tool in place. The frictional heat produced by the pin as it "stirs" the material to be welded is transferred through the shoulder contact. You can find tool pins in a variety of geometric forms, including triangles, cylinders, squares, and cones. Weld flaws can be avoided and better material flow obtained by developing threads on the pin.

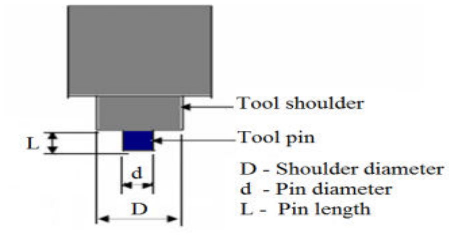

Figure 2: Basic FSW tool nomenclatures

Materials such as tungsten, molybdenum, and tungsten carbide are used to manufacture FSW tools (WC). High forces and rotation speeds do not distort or wear these materials, making them ideal for tools. Welds made with steel welding rods have a low wear rate and high strength, making them the preferred material for welding aluminium alloys.

Problem Statement

Aluminum doesn't act the way other metals do during welding, so it can be difficult to determine weld progress and quality. Simply put, aluminum is difficult to weld because it is a soft, highly sensitive metal insulated by a tougher oxidized layer. Because of the potential of advantages over arc welding in some applications associated with these processes, FSW has received interest from many areas of industry working with aluminum. The advantages include the ability to produce long lengths of welds in aluminum without any melting of the base material.

Objectives

- To Study the FSW weld joints
- To weld joints design was done by using NX 12.0
- The analysis was done by using ANSYS 2024 R1 with different materials
- To validate the transient thermal analysis with various parameters (Temperature, heat flux thermal error)

2.0 LITERATURE REVIEW

D.M. Nikam et al. (2017) used taguchi and the particle swarm optimization approach to try to maximize the impact of FSW process parameters on AA6082-T6. It was found via the use of ANOVA and PSO modeling that the tilt angle is a linear function of rotation speed and has a large impact on the tensile strength. Prashant Chauhan et al. (2018) A friction stir welded JC material was investigated, and a 3D thermo-mechanical model based on a coupled Eulerian Lagrangian approach was developed to forecast the generated flaws. It was determined that a 2.5 mm pin at a tilt angle of 20 provides a sound weld based on the model's predictions of spindle torque and axial force. Experimental flaws were found using X-ray CT scanning. Correlations between effective plastic strain and welding efficiency were analyzed qualitatively, and some predictions were reached. Akshansh Mishra et al. (2018) The FSW (friction stir welding) method and its settings were analyzed. Scientific research has shown that this method successfully welds together a wide variety of metals, including aluminum alloys, copper, magnesium, zinc, steels, and titanium, with no harmful byproducts or fillers required. Chintamani Mahananda et al. (2018) The preferred approach for joining these materials is friction stir welding, a solid-state forge welding procedure that might solve problems typically encountered while welding them. All of the steps take place in a solid state via plastic deformation and mass transfer between the various components; therefore, there is no melting involved. This paper summarizes previous studies on friction stir welding and explains how it is used in the workplace. Md Perwej Iqbal et al. (2019) using verified experimentally acquired axial force, we constructed a Lagrangian based viscoelastic model for FSW of pipes. Experts recommended a minimum plunge depth of 0.3 mm. It was discovered that there was asymmetry in the distribution of temperature and strain along the weld line. C. RAJENDRAN et al. (2019) investigated the results of FSW on lap-joined AA2014-T6 aluminium alloy by adjusting the parameters. The highest lap shear strength of the joint was 14.42 KN, and the efficiency was 84% when the weld was performed at a tilt angle of 20. This generated finer grains, greater hardness (HV 132), and a stronger weld in the stir zone. OLATUNJI P et al. (2019) study of the mechanism of wear and corrosion in aluminum alloys produced by friction stir welding. Weld parameters should be tuned to create a sound weld with a long life and the necessary qualities. Results showed that process factors and mechanical qualities had significant effects on corrosion and wear. It was determined from this assessment that more research into the interplay between wear and corrosion as they relate to FSW is necessary. D.G. Andrade et al. (2020) .To analyze the impact of certain factors on Friction stir welded aluminum alloys. Analysis of the experimental data involved a thermo mechanical interaction. Analytical coefficients (CM and CT) were established as a means of expressing torque and peak temperature in terms of welding parameters. Abdulaziz et al. (2020) friction stir welding was analyzed (FSW). Since it can join materials that are both similar and different, this solid-state welding technique is widely used in industry. Alloys like aluminum, copper, and magnesium, which have a high strength-to-weight ratio, may be fused using this method, even though they are notoriously difficult to join using standard fusion welding techniques. Getachew Gebreamlak Yeshitla et al. (2020) studied In friction stir welding (FSW), a method of connecting solids, coalescence occurs as a result of thermal-mechanical deformation of the work pieces, with the resultant temperature exceeding the solidus temperature of the work pieces.

3.0 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

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

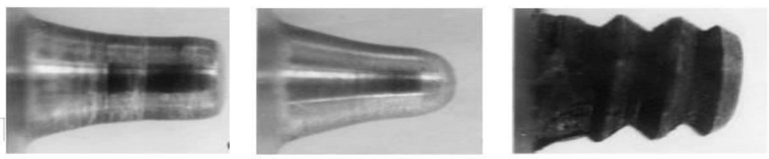

Figure 3: Tool Geometries (a) Cylindrical (b) Conical (c) Threaded

Figure 4: Friction Stir Welding Setup

Friction stir welding is one of the prominent fastening processes for Al alloys when compared with other fastening techniques.

Design of FSW WELD Joint:

The NX software supports the full product development and manufacturing process, from the initial idea through the completed product being packaged. Design aids "straight to market, first time" success by favoring digital product models over assess the condition prototypes. Sales go up, distribution costs go down, and product quality goes up as a result.

Conical tool Design:

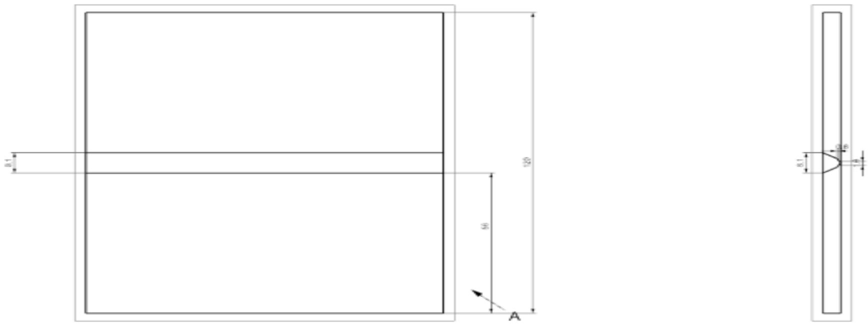

Figure 5: Geometry Model Conical tool

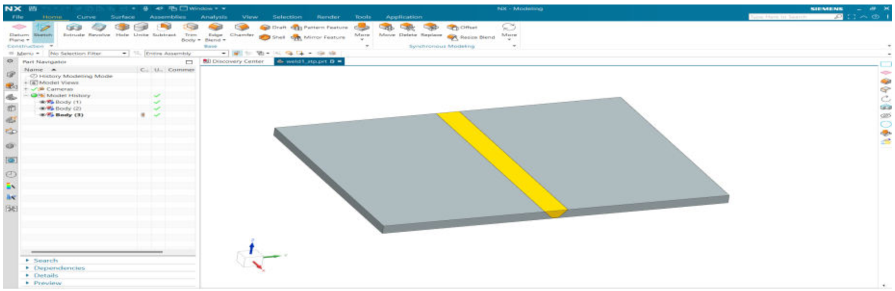

Figure 6: Design File Using NX 12.0

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

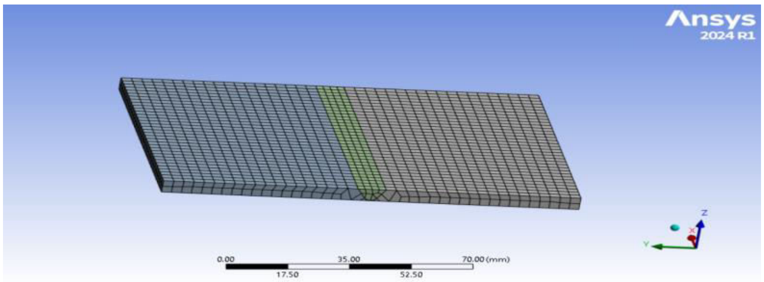

Figure 7: Meshed model

4.0 RESULTS AND DISCUSSIONS

In ANSYS analysis, Transient thermal analysis for steady state is formed with uniform initial temperature of 22^{0}C. The design and analysis of welding fixtures based on transient thermal analysis. Welding fixtures is designed to hold and support the workpiece securely during the welding process. The heat transformation from the workpiece could lead the temperature rises and impacts to the welding fixtures using (250^{0}C,300^{0}C, 350^{0}C,) temperature to validate.

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

Simulation Approach (Weld Structure Analysis)

Simulation study on weld with temperature and power in put given in Ansys workbench 2024R1 used 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.

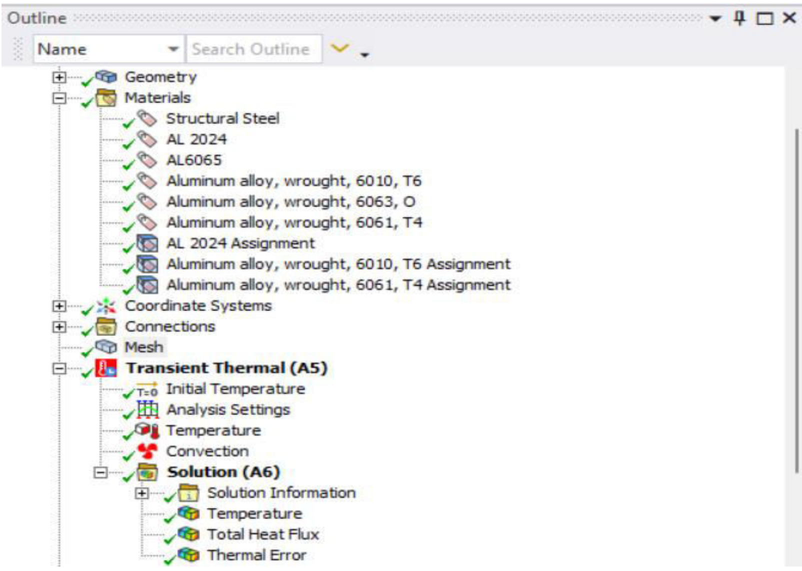

Figure 8: Weld structure Analysis

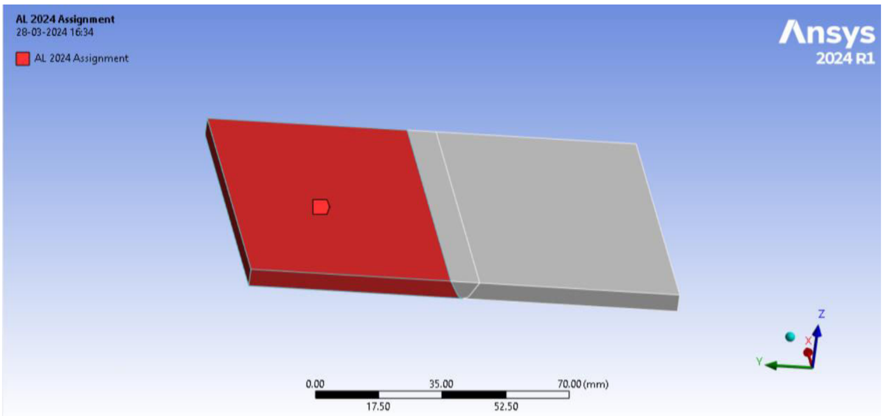

Figure 9: Material Assignment for clamping work piece

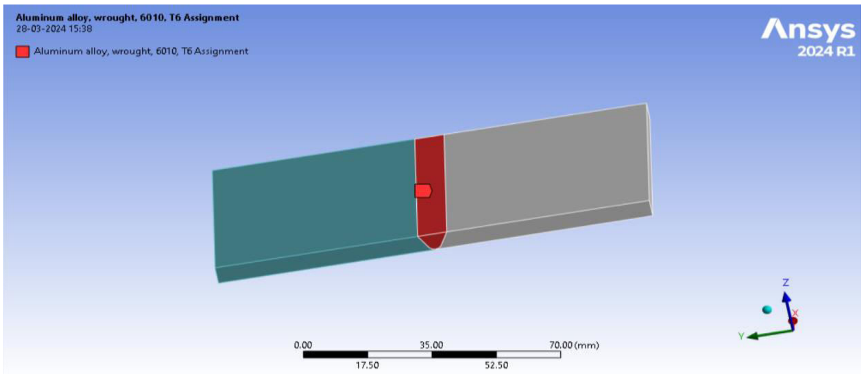

Figure 10: Material Assignment for clamping work piece Aluminum 6061

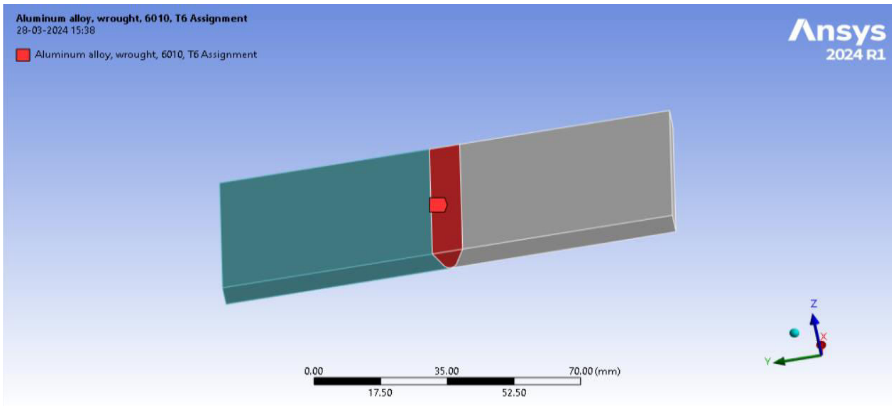

Figure 11: nugget zone assignment Al 6010

Transient thermal Analysis Applied Nuggle zone temperature 250^{0}C

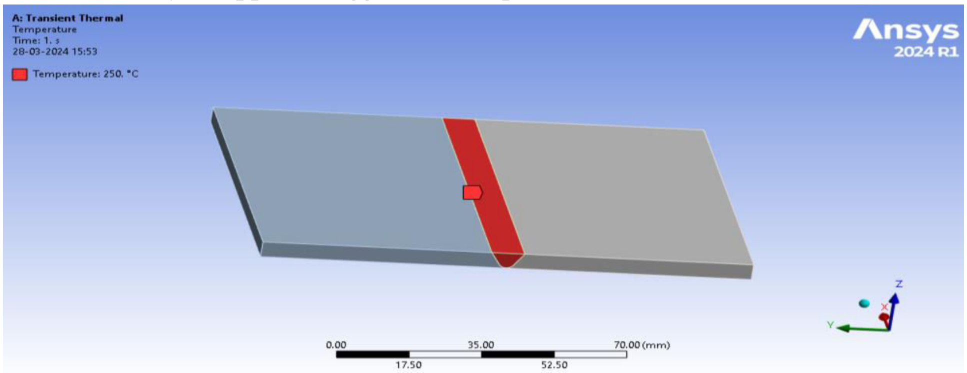

Figure 12: Temperature assignment for thermal distribution at 250^{0}C

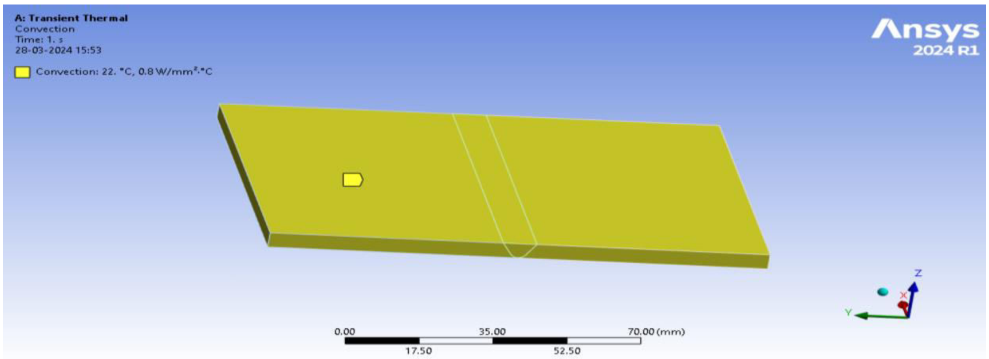

Figure 13: Convection to room temperature

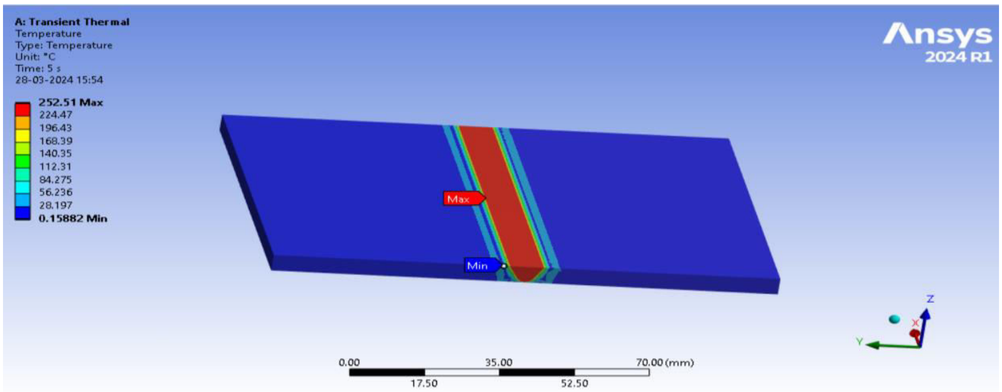

Figure 14: Temperature distribution to HAZ with 250^{0}C

From figure it is shown that the temperature elevated with tool momentum and the distribution to HAZ is up to 252^{0}C.

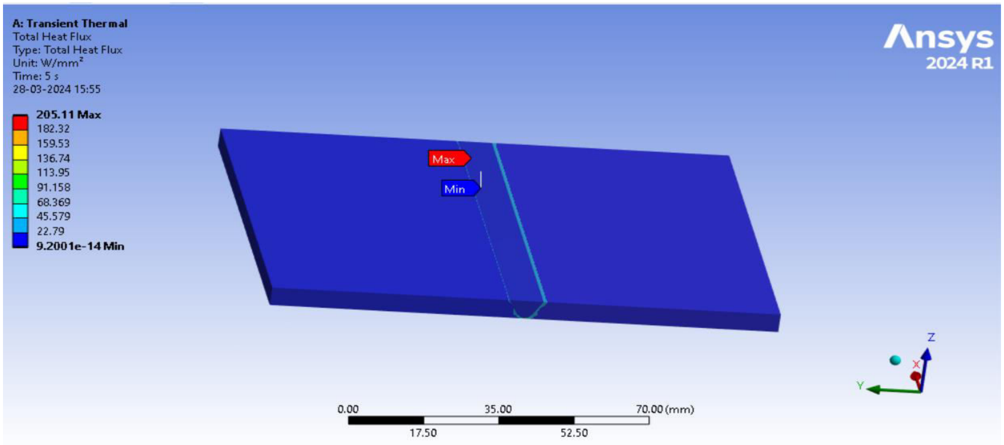

Figure 15: Total heat flux

Heat flux has been formed at the bottom of mated plate and the temperature and the thermal flux temperature is 205.11^{0}C

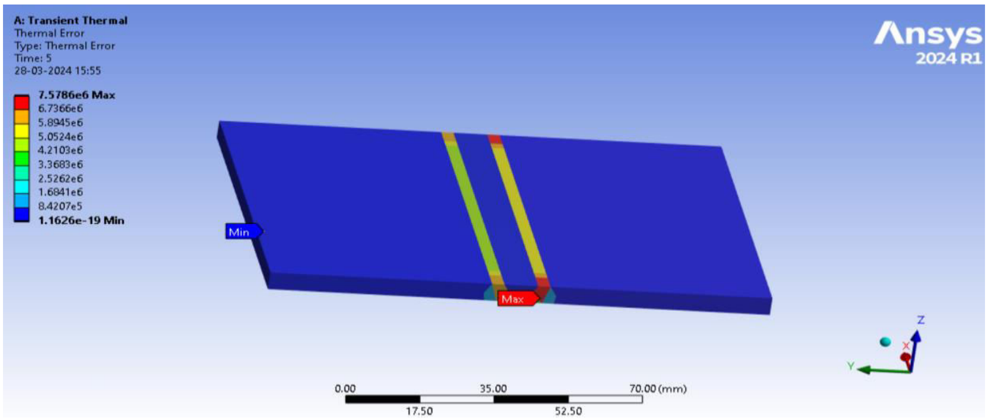

Figure 16: Thermal error

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

Transient thermal Analysis Applied Nuggle zone temperature 300^{0}C

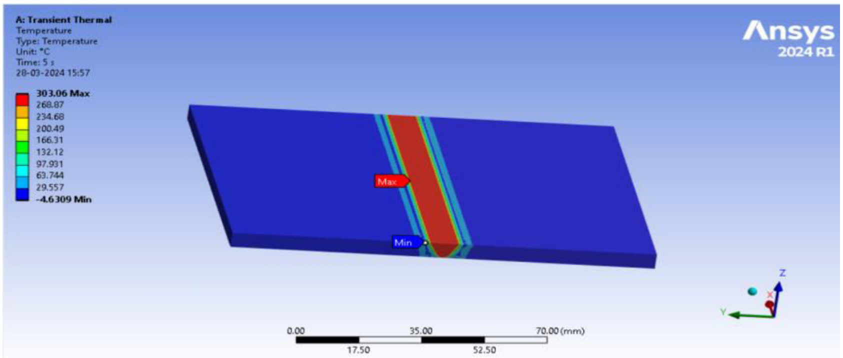

Figure 17: Temperature distribution to HAZ in 300^{0}C

A maximum temperature obtained at weld middle zone of 303.06 ^{0}C and temperature at HAZ maintained as 46.309 as shown in figure.

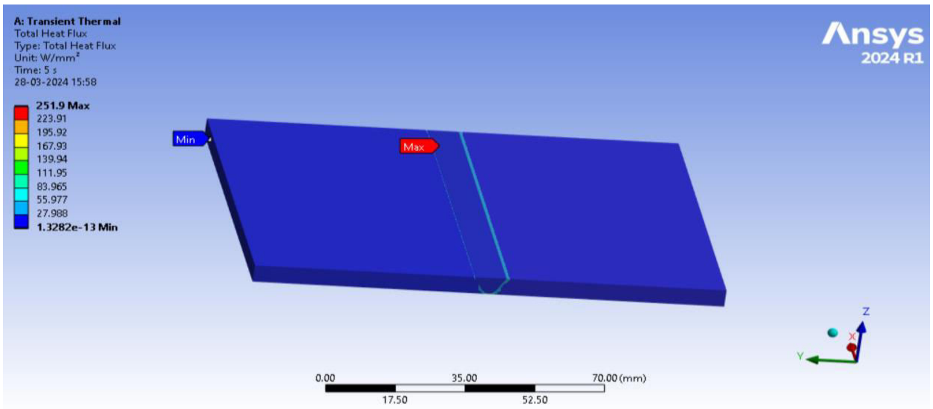

Figure 18: Total heat flux at 300^{0}C

Heat flux formed at the edge of shoulder in this case with heat particle rubbing and maintained 55^0 C at corner edges of mated zone as well as HAZ.

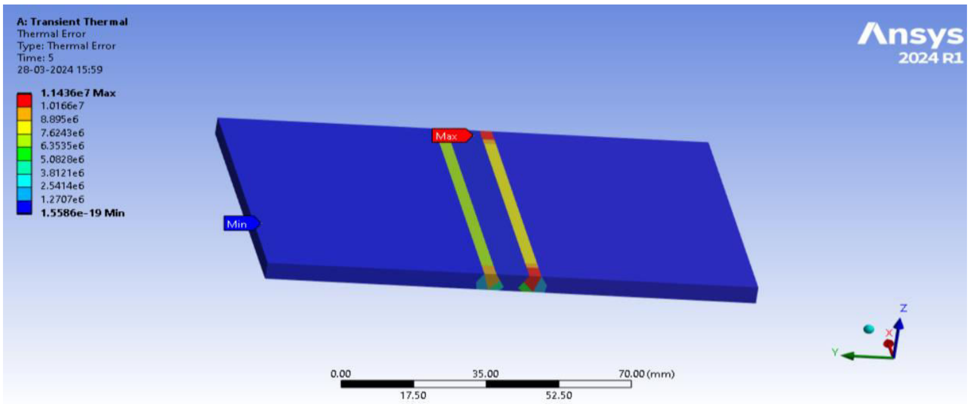

Figure 19: Thermal error at 300^{0}C

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.

Transient thermal Analysis Applied Nuggle zone temperature 350^{0}C

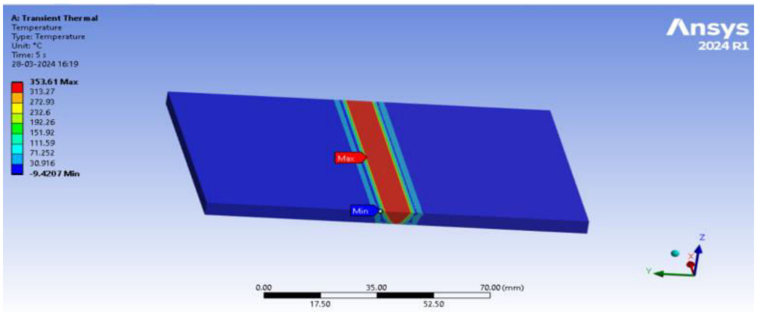

Figure 20: Temperature distribution 350^{0}C

Temperature distribution increases with increase in temperature a near friction temperature increased by 2^{0}C with the increment of 353^{0}C.

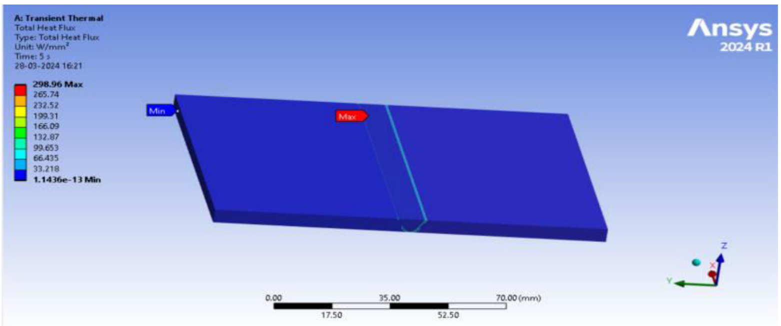

Figure 21: Heat flux at 350^{0}C

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

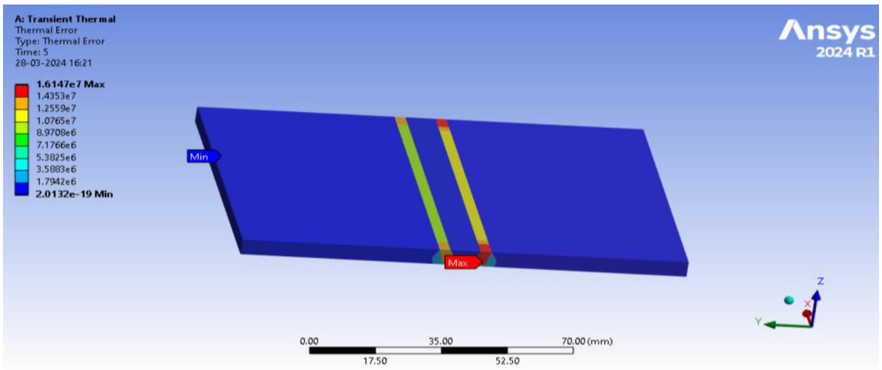

Figure 22: Thermal error at temperature 350^{0}C

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.

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

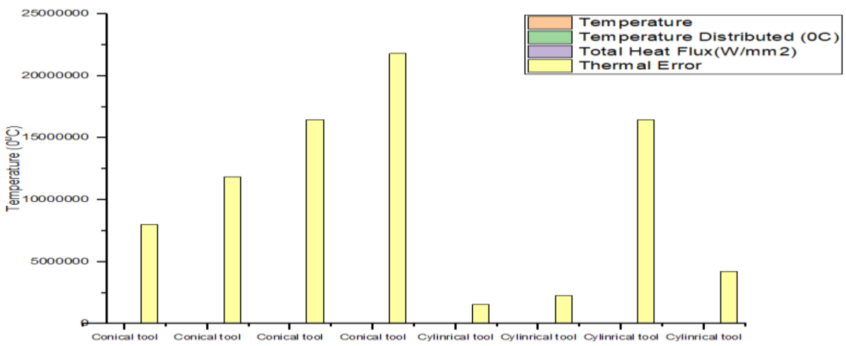

Figure 23: Transient thermal Analysis FSW process using different tools maximum variations

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

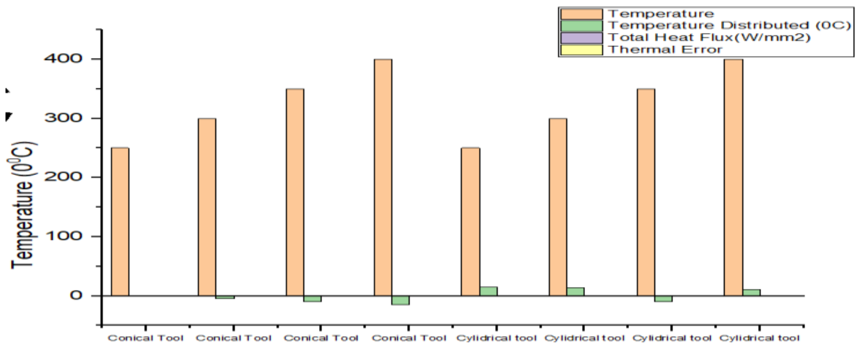

Figure 24: Transient thermal Analysis FSW process using different tools minimum variations

CONCLUSIONS:

FSW process is an eco-friendly solid state joining technique compared to the conventional welding techniques 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,) 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). 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.

OBSERVATIONS

- Composite aluminium alloys are recommended to enhance the quality of weld in industries and commercial applications.
- It is concluded that impeller blade angle at 30^0 gives optimal value, which will provide suitable combination axial flow and shearing action.
- The mould was preheated 250^{0}C to 350^{0}C, to reduce the porosity in the composites which results in increase in density of the composites.
- In terms of hardness, the manufactured composites and their hardness values increased as the reinforcement of weight percent increased.
- From the study it can be concluded that the appropriate temperature for a defect free friction stir weld of Al 6065 and Al 6065 composite can be within the range of 350 to 400^{0}C.
- By observing 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 with static structural analysis the total deformation noted 0.18mm 0.25mm and 0.06mm, 0.08mm as maximum and minimum for conical and cylindrical 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 with regular six series alloys. Considering the above research, a computational model has been prepared for further clarifications in an economical way, artificial neural network based optimised algorithm has been proposed.

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