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Experimental Analysis of Two Dissimilar Metal Alloy by Friction Stir Welding

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Abstract— Existing manufacturing technologies are continually improving as a result of the diversity and never-ending quest for a higher level of living. Demand for increasingly complex materials is growing in lockstep with developments in conventional manufacturing methods, resulting in new metal manufacturing breakthroughs including revolutionary welding technologies. Welding is a typical method of connecting metals and other materials. A number of welding procedures are employed in a range of sectors in today's globe. Friction stir welding is a cutting-edge welding process that outperforms standard welding procedures in a variety of ways. Because it eliminates the obstacles associated with traditional welding techniques, friction stir welding is employed as a solid state joining solution for materials like aluminium, magnesium, and other alloys, as well as hard materials like steels. This study paper explains the FSW concept and technique. It goes through some of the technological elements that influence the process and output of the FSW joint. Friction stir welding (FSW) of aluminium has advanced substantially in the recent decade in every element of tool manufacture, including microstructure property estimate [2]. Thanks to the progress of efficient welding equipment and particular control systems, FSW of aluminium has reached a new level of technological competence, and the influence on butt joint arrangement is being explored. Ansys CFD Mechanical is a full-featured FE (finite element) structural analysis tool that can do linear, nonlinear, and dynamic analysis.

Keywords : Friction stir welding, CFD, Aluminium alloys, Welding tool.

I. INTRODUCTION

Welding is a one-of-a-kind manufacturing technique that permits complicated objects to be made out of difficult-to-form materials. Individual components are often manufactured separately and then linked using an appropriate joining method [1, 12]. After all, welding technology is a supplement to, not a replacement for, other industrial processes. As a result, one of the most essential aspects deciding the utilization of innovative materials is weldability. With the advancement of technology, there has been a surge in demand for sophisticated things that are impossible to construct in one piece or are just too expensive to manufacture. Such items include high-speed trains, which use a lot of fuel [4].

1.1 Friction stir welding

Friction stir welding (FSW), a solid-state joining method, was pioneered by the Welding Institute (Thomas W. N., 1991). It was originally intended to work with aluminium alloys, but it has now been broadened to include magnesium alloys, low-carbon steel, chrome steel, and titanium alloys (TWI) (Thomas C. D., 1995). A.P. Gerlicha, 2009. NASA's spaceship outer tanks, super liners such as the Ogasawara, Shinkansen fast trains, and Ford's magnesium prototype spare wheel, to mention a few, have all used FSW. Because friction stir welding does not cause the bottom plate material to freeze, it is classified as a solid-state process. Friction stir welding uses a pin and shoulder, which is a non-consumable tool [3, 5]. The purpose of the instrument is to create enough heat to soften the bottom material. As the tool travels through the softened base plate, friction, pressure, and localized plastic deformation of the substrate create heat [15]. By joining the fabric at the pin and shoulder, this will also aid in the formation of a joint. A butt weld is a common FSW arrangement in which the FSW tool is placed between the sides of two sheets and travels along the joint [6].

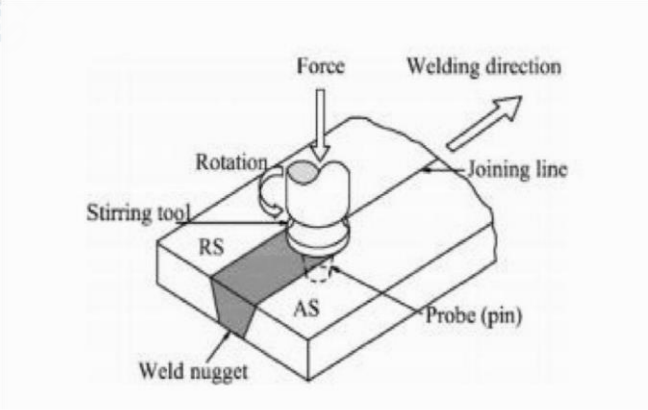

Figure 1: Friction Stir Welding is depicted in a diagram.

Friction stir welding is influenced by the following factors: [7]

1. Rotational Speed
2. Welding Speed
3. Pressure on Tool (Down Force)
4. Tilting Angle

The effects of each parameter are indicated in Table 1 below,

Table 1: FSW Parameters for Mechanized Welding

Sr. No.	Parameters	Effect of parameters
1.	Rotational Speed	Frictional heat, Stirring, oxide layer breaking and mixing of material
2.	Welding Speed	Appearance, heat control.
3.	Pressure on Tool (Down Force)	Frictional heat, maintaining contact conditions
4.	Tilting Angle	The appearance of the weld, thinning

II. METHODOLOGY

2.1 Principle of operation of FWS

Welding the components in FSW is done with a cylindrical rotating tool with a concentric threaded pin and gear shoulder. A non-consumable rotating tool, coupled with a specifically constructed pin and shoulder, is positioned at the faying edges of the plates to be joined and traversed along the welded connection [13]. Clamps are utilised to secure the two sheets on the bed, and vertical force is employed to secure the tool on the vertical miller's collect. Friction between the welding tool, especially the spinning tool, and the workpiece is caused by the revolving tool on the metal to be welded, resulting in plastic deformation of the workpiece [8]. Due to the generation of localised heat from friction, the plates soften at the round of the pin, and the combination of tool rotation and translation causes the softened material to travel from the front to the rear of the pin. The fabric is deformed at temperatures below the freezing point of the parent material to generate the welded connection [16,22]. The advancing side is when the direction of tool rotation and welding tool translation are in the same direction; the retreating side is when both motions are in the opposite direction. The tool geometry is crucial in the FSW process because it determines the standard levels of joint formed [9].

2.2 Tool Used:

By modelling friction stir welding transient analysis in Ansys 19.2, the temperature of the system is estimated; von misses stress and static deflection are missed. ANSYS Design Modeler (DM), which is included in the ANSYS application, is used for CAD modelling [14].

Ansys 19.2: ANSYS Mechanical software may be used as a full FE (finite element) analysis tool for structural analysis, including linear, nonlinear, and dynamic investigations. For a wide range of mechanical design problems, the engineering simulation application includes a complete collection of element behaviour, material models, and equation solvers. ANSYS Mechanical now includes thermal analysis and coupled-physics capabilities for acoustic, piezoelectric, thermal–structural, and thermoelectric analysis. ANSYS structural analysis software offers a variety of sophisticated modelling methodologies based on solid element and material technologies for a variety of applications [10, 21].

2.3 FE Analysis involves following major steps:

1) Pre-Processing
    - Geometry Modelling
    - Meshing
    - Material Properties
    - Contact Definition
    - Loading and boundary condition
2) Solution &
3) Post-Processing
    - Deformation
    - Stresses [18,19]

2.4 Friction Stir Welding (FSW) Simulation:

In most cases, the FSW process necessitates the use of a tool made of a tougher material than the workpiece to be welded. FSW was formerly only utilised for soft workpiece materials like aluminium. FSW is now achievable with high-temperature materials like stainless steel, because to the development of tools constructed of super-abrasive materials such polycrystalline cubic boron nitride (PCBN). In this example [17], a cylindrical PCBN tool is modelled. To mimic the clamping ends, the workpiece sides parallel to the weld line are limited in all directions. To imitate support at the bottom, the workpiece's bottom side is limited in the perpendicular (z) direction. Heat losses are taken into account on all of the model's surfaces [20]. Across the weld centre line, all boundary conditions are symmetric. In the simulation, three load stages are employed, each reflecting a different aspect of the FSW process (plunge, dwell, and traverse) [11].

III. RESULTS AND DISCUSSION

3.1 Results

Workpiece and Tool modelling of the model

Two rectangular-shaped plates make up the work piece (identical to those used in the reference model). The dimensions have been reduced to save simulation time. The dimensions of the plate is 80x 40x 4mm. The shoulder of the tool is 10 mm in diameter.

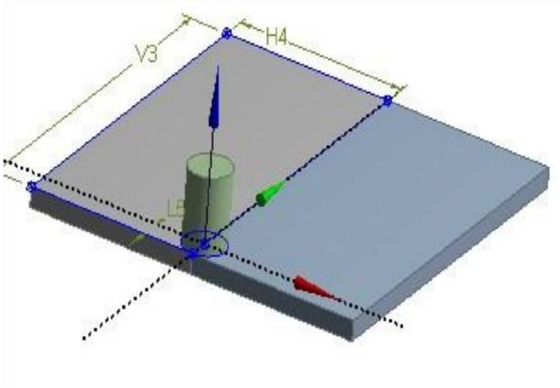

Figure 2: Dimensions of Work piece

Dimensions of workpiece and tool for FWS:

Table 2: Dimensions of workpiece and tool for FWS

H4	40 mm
L5	5 mm`
V3	80 mm
D6	10 mm

The tool's height is the same as the shoulder diameter. The coupled-field element SOLID226 with the structural-thermal option (KEYOPT (1) = 11) is used to represent both the workpiece (steel plates) and the tool.

Material Properties

Because the stresses and strains formed in the weld are temperature-dependent, the FSW approach relies on an accurate temperature calculation. Temperature affects the thermal conductivity, specific heat, and density of 304L steel plates. Due to a lack of data in the literature, mechanical characteristics of the plates, such as Young's modulus and coefficient of thermal expansion, are assumed to remain constant.

Table 3: Calculated Material properties of the workpiece

Young's modulus	193 GPa
Poisson's ratio	0.3
Coefficient of thermal expansion	18.7 μm/m °C

Table 4: Material properties of the BCBN Tool

Young modulus	680 GPa
Poisson's ratio	0.22
Thermal Conductivity	100 W/m °C
Specific Heat	750 J/Kg °C
Density	4280 Kg/m3

Loading

The following table shows the details for each load step.

Table 5: Load steps

Load Step	Time Period (sec)	Loadings on Pilot Node	Boundary Condition
1	1	Displacement boundary condition	UZ = -7.95E-07 m
2	6.5	Rotational boundary condition	ROTZ = 60 RPM
3	29	Displacement and rotational boundary conditions together on the pilot node	ROTZ = 60 RPM UY = 60.96E-03 m

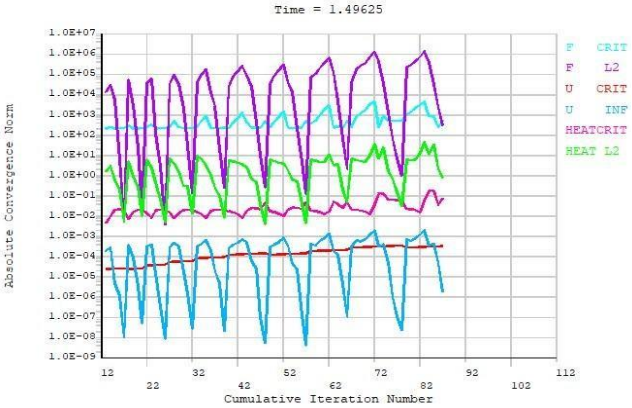

Figure 3: Solution convergence of loading

Deformation Plot: The following diagram depicts the workpiece deflection induced by the tool sinking in the first load:

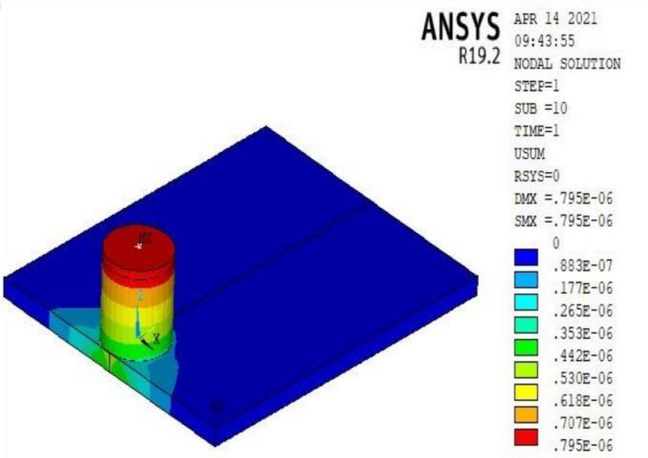

Figure 4: Deflection of the workpiece due to plugging of the tool

Stresses Plot: As seen in this diagram, the deflection causes significant stresses to build on the workpiece beneath the tool.

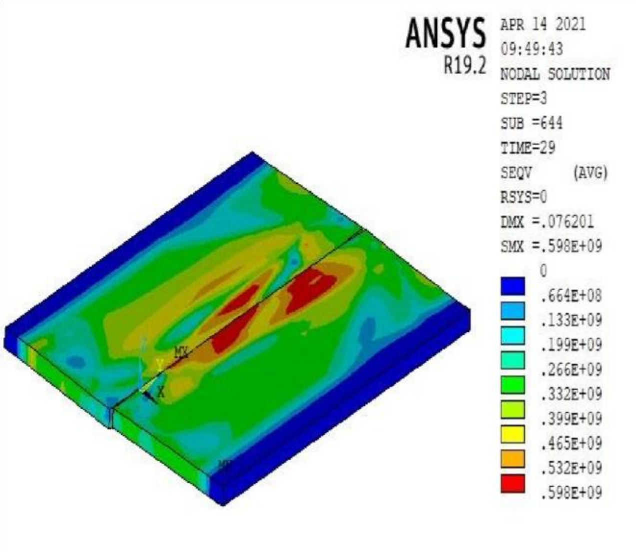

Figure 5: The deflection causes high stresses to develop on the workpiece beneath the tool

Temperature plot: The workpiece deflection caused by a change in tool temperature in the first load is shown in the picture below:

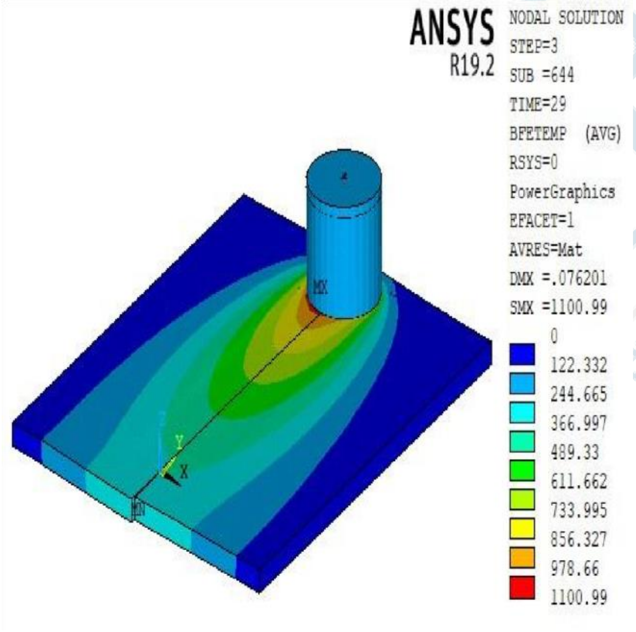

Figure 6: Deflection due to change in temperature

The melting point of tool metal is 1450 degrees Celsius. The temperature range at the weld line area on the workpiece beneath the tool during the second and third load phases is substantially below the melting temperature of the workpiece material, but exceeds 70% of the melting temperature during the fourth load step, as shown in the diagram:

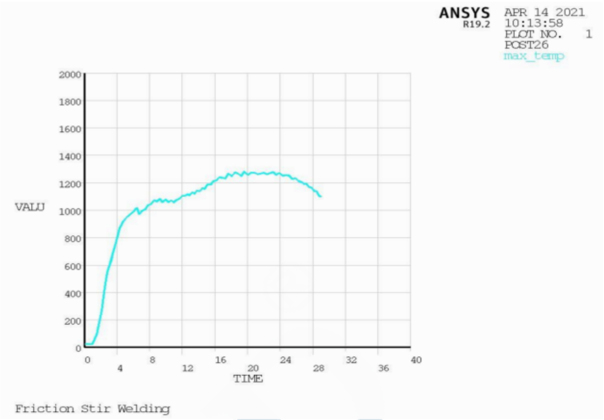

Figure 7: Maximum Temperature (on Workpiece beneath the Tool) Variation with Time.

Heat Generation:

Heat is produced by friction and plastic deformation. Frictional and polymeric heat production are both taken into account. As a result of friction, heat is generated during the second load stage. The FDDIS (SMISC item) output option of the CONTA174 element is used to calculate frictional heat production on the workpiece. This feature determines a component's frictional energy dissipation per unit area.

The friction heat-generation rate for a component is calculated by multiplying this amount by the corresponding element area. The overall frictional heat production rate is estimated at any given time by adding the data from each CONTA174 workpiece element. It is feasible to calculate the overall frictional heat generation rate at each time step by summing the figures from each CONTA174 element of the workpiece (ETABLE). The graph below shows the rate of total frictional heat production on the workpiece as a function of time: Frictional heat appears to begin during the second load level, according to the graph (after 1 second).

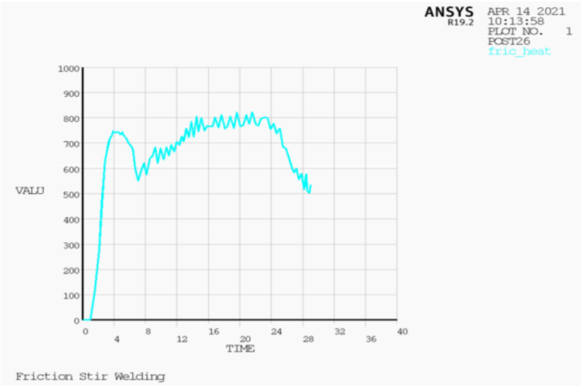

Figure 8: Total Frictional Heat Rate Variation with Time

3.2 Discussion

During the last two load phases, the workpiece reaches its maximum temperature beneath the tool. Mechanical loads cause heat to be generated. There are no external heat sources employed. The material softens and the coefficient of friction lowers as the temperature rises.

Heat generation during the second and third load phases is induced by friction between the tool shoulder and workpiece, as well as plastic deformation of the workpiece material, as demonstrated by the observed temperature rise in the model.

IV. CONCLUSION

A significant amount of research has been conducted in the direction of improving process parameters such as tool rotation speed, tool traverse speed, and gear shape in order to boost FWS joint efficiency. This study's findings also lead to the following conclusions:

1. The presence of defects (voids) and regions of deformed non-recrystallized grains characterise the microstructure of the stir zone created with a low tool rotation speed to tool traverse speed.
2. The micro hardness of the connected material rose from 86 HV0.1 to around 110–125 HV0.1 inside the stir zone as a result of dynamic recrystallization, depending on the welding conditions utilised.
3. The heat-affected zone is difficult to distinguish due to the lack of a strengthening phase and the alloy's poor strain hardening. The fractured samples were examined, and there was no evidence of a much softer zone.
4. In the majority of welding connections, lateral flash was seen. The majority of lateral flash occurred at rock bottom tool rotation and travel speeds.
5. It's also worth noting that temperature is connected to tool rotation and traversal speeds, just as tensile strength.

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