Numerical Investigation of Temperature Distribution in Friction Stir Welding of Aluminum Alloys

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***Abstract*—Friction Stir Welding (FSW) is a solid state joining process that uses a non-consumable tool to join two facing work pieces by plastic deformation. In this work, the Numerical thermal analysis of Aluminum Alloy plates of different grades AA5083, AA6063, AA7075 of size 100mm×100mm×6mm is carried out by using ANSYS Workbench. Based on different types of tool profiles, the Bobbin tool is considered and is investigated in this present work. Due to the stirring of materials it is difficult to measure the temperature in stir zone. Numerical simulation helps in finding temperature at stir zone. By considering the transient thermal module, the analysis of temperature distribution of the FSW is carried out. The temperature at stir zone of grade AA5083 is relatively low which is 365.88˚C at 12sec when compared with grade AA6063 and AA7075 having temperature of 1107.6˚C at 11sec and 589.23˚C at 11 sec respectively. It is also found asymmetric temperature distribution exist on both the plates. The numerical simulation results are compared with the experimental results and observed the results of the simulation are in good agreement with that of experimental results.**

***Index Terms*— Friction stir welding, Aluminum alloys plates, Temperature distribution, Numerical simulation.**

I. INTRODUCTION

Friction Stir Welding (FSW) is a new welding process which was developed at The Welding Institute (TWI), Cambridge, UK. In this method a non-consumable rotating tool is used for make frictional heat and distortion at the welding position. The principle advantage of FSW is that we can join the alloys that do not join by using conventional welding process[1]. The FSW process can be occur in four different phases, namely: Tool Rotation, Plunge, Dwell, and Feed[2].

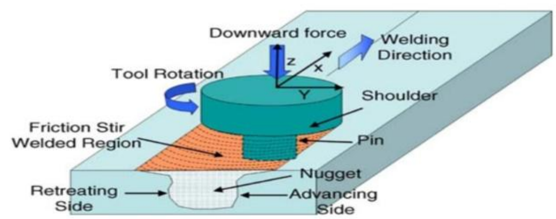


Figure1. Friction Stir Welding Process

The generated heat during the welding process, the effects of friction and plastic deformation is transferred to both the tool and work piece. The heat transfer ratio between these two components depends on the thermal properties of materials[3].

[1] During the FSW process, the temperature remains below the melting point of the material (80% of its melting point). The heat transfer in the material allows the rotating tool to stir mechanically and the softened material flows to the backside of the pin where it is more solid to form a metallic bond at specified zones i.e., the heat affected zone (HAZ) and the thermo mechanically affected zone (TMAZ). [2] FSW process gives sound weld joint along with high ductility and it is high energy efficient and a less harmful effect for the atmosphere. Finite element method is an appropriate tool for thermo-mechanical investigation of this welding process. [3] In this research work, finite element (FE) analysis is carried out to investigate the thermal distribution, deformation and stress in weld joints. Studies on temperature distribution and thermal histories have been done on different combinations of materials.

[4] Many researchers have resorted to numerical methods and simulation techniques in order to predict the thermal behaviour during FSW. [5] Objective of this study is to analyze the structural and transient temperature distribution for AA5083, AA6063, and AA7075 plates numerically that were welded by

friction stir welding. Recently, many studies on friction stir welding have been published. Those studies are either experimental or numerical. [9] Vishwanath *et al.* in their analysis Ansys tool is used for analyzing the weld induced stresses and temperature distribution. 3D finite element analysis has been proved to be more efficient than 2D in predicting the weld induced stresses. [10] Eisazadeh *et al.* in their work the metal joining takes place in the solid state as it is reaches about 80% to 90% of its melting point. All classes of Aluminium alloys can be joined without any filler material. The variation of peak temperature is based upon the thermal conductivity and specific heat of the material. A moving heat source technique is proved to be a reliable method for the simulate friction stir welding process. Recently, many new studies on friction stir welding have been published. These studies are either experimental or numerical. As discussed, the tool geometry plays an important role to determine the amount of heat generation during FSW process. [11] There are very few studies have been made to indentify the thermo mechanical features at various positions of FSW. [12] Chen *et al.* in their study a coupled thermo mechanical modelling of finite element method for temperature distribution and stress variation at the weld. [13] Muhsin *et al.* they developed a numerical model for the main thermo mechanical features in the FSW process. For validation, numerical analysis data is compared with experimental data at the location of mid position along welding path. [14] Mohammad *et al.* they investigated the effect of tool pin and tool shoulder of AA5083 by using 3D FEM analysis of thermo mechanically coupled. [15] Mudavath *et al.* they experimentally say that the tool Running with speed more than 700rpm and below 1500rpm gives better results for Aluminium Alloy's in FSW. [6] A numerical study has conducted to find the temperature variation, stress distributions along the weld joints.

II. MATERIALS AND METHODOLOGY

In the present work, three aluminium alloy grades are considered with dimensions of 100mm ×100mm×6mm. The following table shows the material properties of three grades i.e. AA5083, AA6063, AA7075, and H13 tool steel. The Figure 2 shows the flow of work used.

Table1. List of material properties

Properties	AA5083	AA6063	AA7075	H13 tool steel
Density (kg/m^3)	2650	2700	3000	7800
Thermal conductivity (W/mK)	121	218	150	28.6
Specific heat capacity (J/kgK)	900	900	714.8	460
Thermal expansion (10^{-6}/K)	23.6	23.5	23	3.8
Poisson's ratio	0.33	0.33	0.32	0.3
Tensile strength (MPa)	345	186	560	1200
Elastic modulus (GPa)	72	68.9	71.7	215
Bulk modulus (10^7Pa)	6.96	6.69	6.63	1.60
Shear modulus (10^7Pa)	2.66	2.56	2.71	8.17

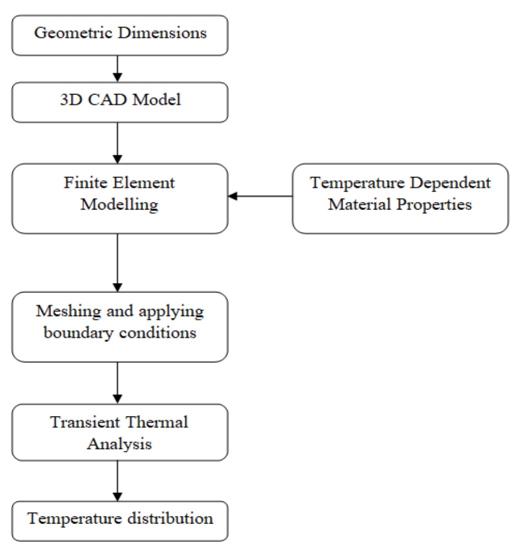


Figure2. Methodology for present work

III. FE MODELLING

To analyze the temperature distribution a 3D model is developed. During the analysis the tool position is considered at different positions. A moving heat source is considered and the tool position is fixed at a position. In this analysis the dimensions of plates and the tool dimensions are same.

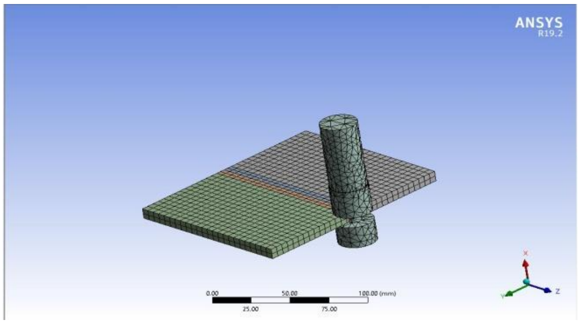


Figure3. FE model of FSW after mesh

During meshing, 3D quadrilateral elements are used with the mesh size of 3mm in the analysis. The temperature distribution observed in the weld components are depends on the material properties.

IV. THERMAL MODEL

The transient thermal analysis is conducted to measure the temperature distribution of the welding process. Here the moving heat source is considered to measure the temperature at the weld zone. As it is a new technique, which is proved that it is reliable for the simulation of friction stir welding. Here the boundary conditions which are considered the velocity and the source power intensity i.e. 5mm/sec and 100W/mm^2 respectively. The material properties are temperature dependent. Here the time of weld is also considered which is based upon the velocity and the length of the plates welded and is taken 20sec.

V. RESULTS

THERMAL ANALYSIS

The thermal analysis mainly focuses on temperature distribution during the Friction stir welding process for different grades i.e., AA5083, AA6063, AA7075. For performing the simulation, transient thermal analysis was carried in order to simulate the temperature distribution curves at the weld zone.

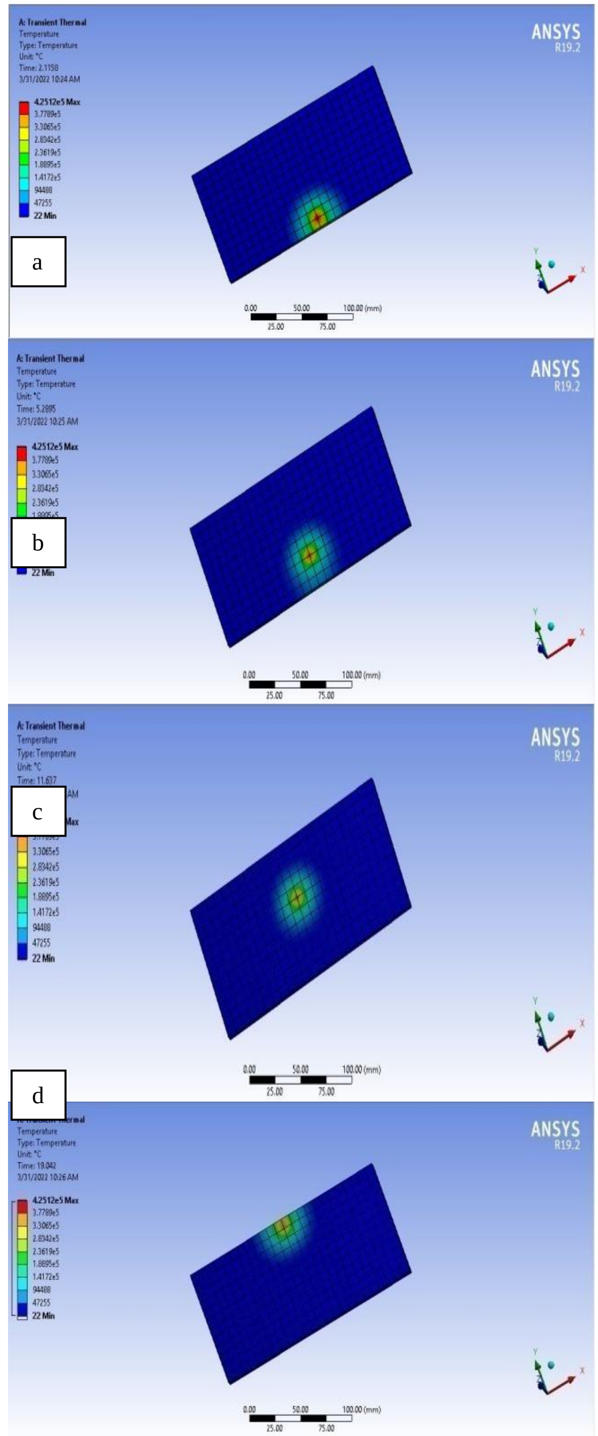


Figure4. Numerical simulation of temperature distribution in AA5083 plates at different time steps (a) 5s (b) 10s (c) 15s and (d) 20s during FSW welding

The peak temperature of AA5083 is recorded during the welding process is 603.18˚C at 13sec.

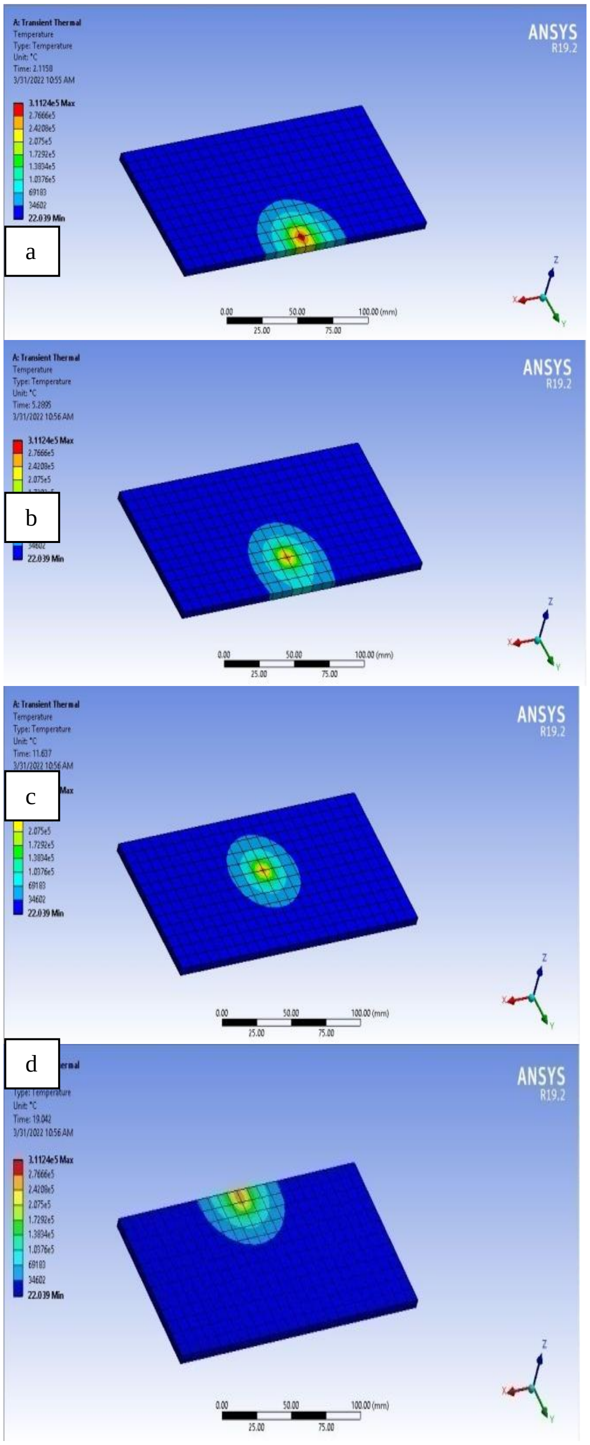


Figure5. Numerically simulated temperature distribution in AA6063 plates at different time steps (a) 5s (b) 10s (c) 15s and (d) 20s during FSW welding

The recorded peak temperature of AA6063 during the welding process is 1107.6˚C at 11sec.

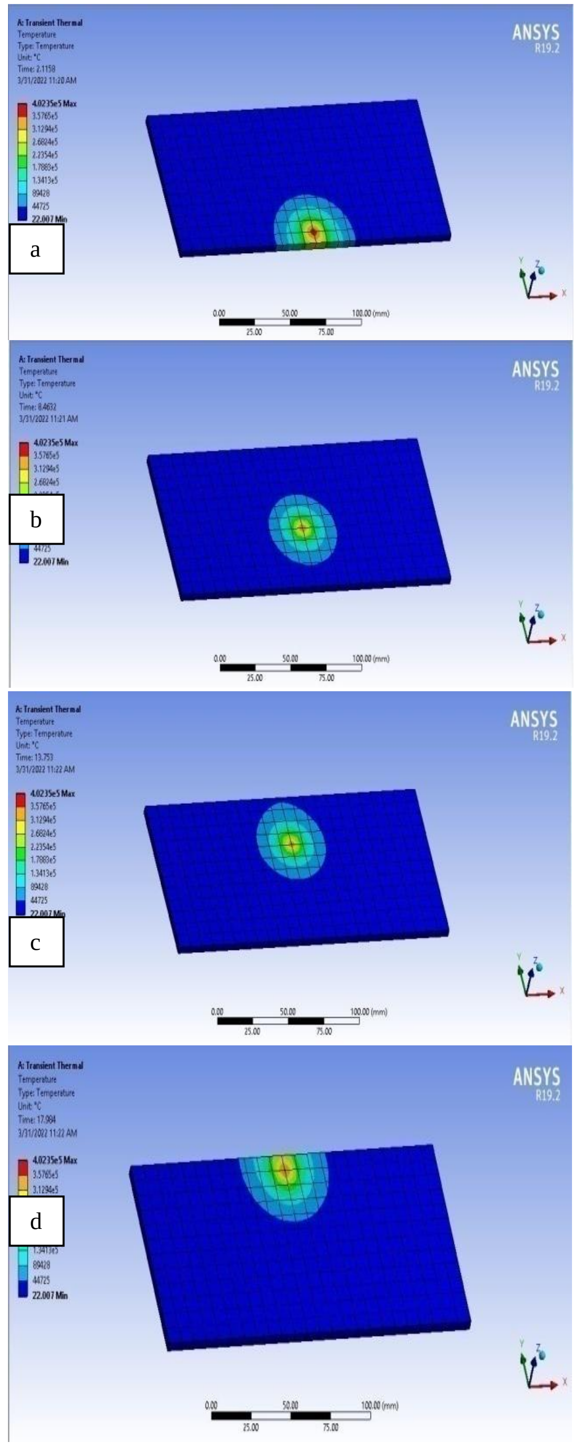


Figure6. Numerically simulated temperature distribution in AA7075 plates at different time steps (a) 5s (b) 10s (c) 15s and (d) 20s during FSW welding

The peak temperature of AA7075 recorded during the welding process is 589.2˚C at 11sec. The temperature variations of AA5083, AA6063, AA7073 are shown in Figures 4, 5 and 6 respectively at different time steps during welding process.

The temperature-time curves are plotted for all 3 grades and shown below. The curves shows the temperature distribution along the tool travel between the plates and varies from minimal to maximum and maximum to minimal.

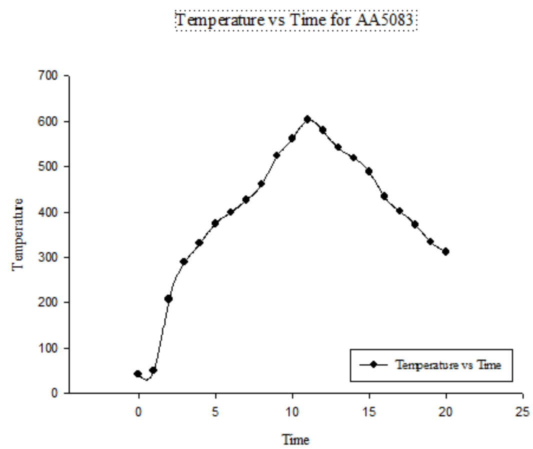


Figure7. Temperature distribution of AA5083

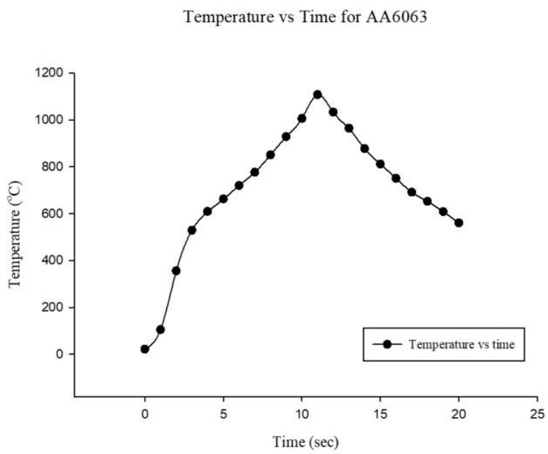
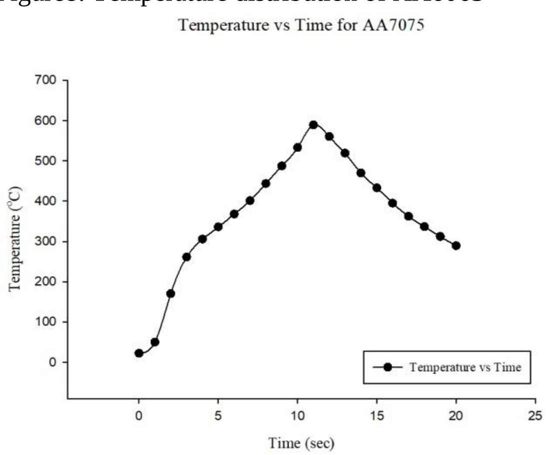


Figure8. Temperature distribution of AA6063



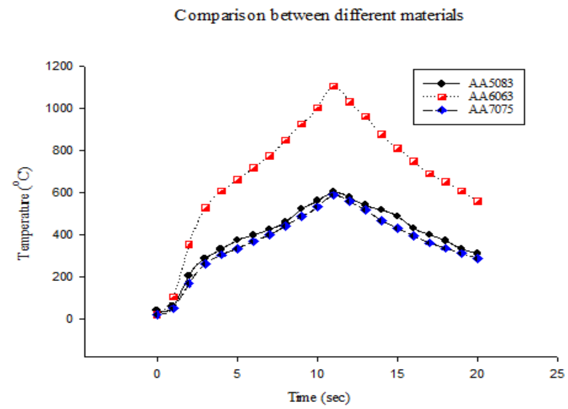


Figure9. Temperature distribution of AA7075

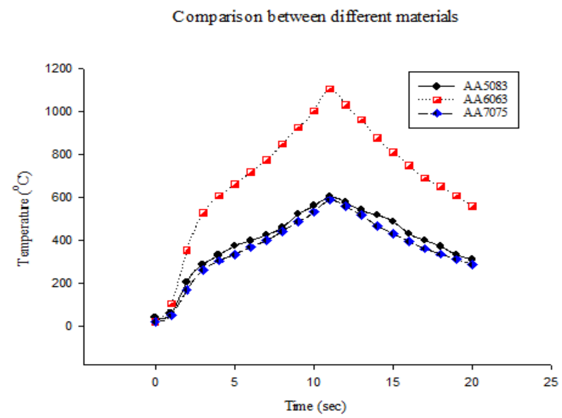


Figure10. comparison between three grades

The graphs explains the temparature variation it attains during the welding process. The Figs 7-9 shows the temperature distribution of gardes AA5083, AA6063, AA7075 is 603.18˚C, 1107.6˚C, 589.23˚C recpectively. The Fig. 10 shows the variation between all the three grades and the grade AA6063 has the highest peak temperature compared with the other two grades because of its higher thermal conductivity. The lowest temperature has grade AA7075. The variation of temperature is observed because of its chemical composition. There seen a reduction in the temperature after raeching the peak temperature, is because of the convection effect produced at the weld line.

VI. CONCLUSION AND FUTURE WORK

In the present work, numerical investigation of temperature distribution during friction stir welding process of aluminum alloys was performed. By observing the results obtained the following conclusions are drawn:

- The grade AA6063 having the higher

temperature which is 1107.60˚C at 11sec.

- The grade AA7075 having the low temperature at the weld zone which is 589.23 ˚C at 11sec.
- Due to its chemical composition difference the grade AA6063 having the higher temperature.
- It is observed from the results that the peak temperature reached sharply and steadily decreases due to the convection effect.
- It is also observed asymmetric temperature distribution on both the plates.
- The obtained results help to achieve a defect free and a good sound weld quality during the welding process.
- There is a possibility of doing the numerical investigation of dissimilar materials of friction stir welding.
- The simulation results are validated with the experimental results available in the literature survey and are observed the simulation results having a good agreement with experimental results at the welding line.

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