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Design of Fabricated Aluminum 6061-T6 by Friction Stir Processing and Analyze the Heat Distribution through Finite Element Method

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ABSTRACT

Friction stir processing technique to fabricate the Aluminum Matrix Composite (AMCs) enhances the mechanical properties. AMCs fabricated by reinforced with various ceramics particles such as silicon carbide, fly ash, and sodium diboride. The welded zone reveals the microstructures and mechanical properties had been investigated. The various reinforcement particles Change the welded area into fine size.

The main objective of this project is to instigate the thermal analyze of heat distribution in Al 6061material during friction stir welding which is evaluated by Finite element method. In Welded region it is difficult to take measurements on experimental data due to unpredictable nature of physics in stir zone of welds without Simulation. For that purpose, Abaqus simulation is used here to simulate the process of Welding, It is also easy to evaluate the effect of strain rate and temperature distribution by using Johnson Cook law. Addition to that, it is also studied the change of probe shapewhile at the time of heat distribution. It was found that spherical pins result in the highest temperatures at workpieces with respect to cylindrical and tapered pins.

KEYWORDS

Element Method,Numerical Modelling, Strain Rate.

Introduction

Friction Stir Welding Process was discovered in 1991. Workpieces are solidly connected in a joint during FSW by pressing a spinning tool. Therefore heat is produced in between tool and material which resultsin a very pliable surface near Friction Stir Welding tool. The spinning tool's forging force makes the material to bend plastically which results thestirof materialand joins to the workpiece. This process causes the material into plastically deform to experience large shear forces,which increases the temperature to about 0.5-0.6 Tm (melting point of material). As a result, the Friction stir process is the thermomechanical solidity that requires close consideration of both mechanical and thermal aspects. Rudd’s, who discovered a dissolve of significant precipitation and re-precipitation in welding corecomes to the conclusion that the max temperatures are between 400 and 480 degrees Celsius. The results of micro-structure and mechanical properties of stirred region in stainless steel was investigated by Saeid and proves it by increasing the speed ofweld and decreasing the size in the stirred zone. Hwengshowed the heat distributionof a workpiece with pure copperthrough butt joining. He usedK type thermal junction to measure the temperature background of the workpiece at various locations. Temperatures between 460°C and 530°C were found to be ideal for an effective FSW operation. Elangovan used a variety of tool profiles to investigate the tensile strength of awelded aluminum alloy joint. To analyze the temperature, Aesidi discovers a reliable friction model for simulations. Finally heconcludes that as the thickness of the material increases, the welding tool's stirring effect decreases. The heat distribution formed in 6061 aluminum alloy during Friction stir process, particularly in the weld area, was investigated using the FE-method and Abaqus software in the current study. Experiment findings corroborated the predictions. The impact of pin shape and angle form on heat distribution was also investigated.

Selection of Materials & Process Parameters

Numerical Modelling

Using Abaqus software, the Friction Stir Welding was simulated using the Finite Element method. The investigated material of Al 6061 series were presumed to have an plastic and elastic nature, while the spinningtool was assumed to be inflexible material. To mimic the conditions of experimental test, two cubic sections of thematerial were modelled and the gap between them be taken as zero. In order

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tosimulate the FSW method, Abaqus was used to create an arbitrary Lagrange Eulerian formulation (ALE). It can simulate flow while also accounting for heat generated by friction and deformation. It also prevents mesh regeneration and admits the deformation of free surfaces. For discretization of the components, brick C3D8RF elements of various sizes were used. While Meshing it closes the weld zone, and it was considered fine (0.9 mm), while another welded line were considered as coarse (2.5 mm). The Meshed part as well as the geometry of the probe are shown in Fig. 1. For simulation evaluations, a combined temperature-displacement analysis was used. Workpieces were set during the simulation, but the tool were free to spin around the x-axis and travel around the x and y-axes (Fig. 1(a)). For simulation Plunging, Pre-heating, and Traversing were defined with different time periods for each stage, and different speed of rotation and transverse of the probe are measured according to the experiment. Table 1 contains information about the steps, such as the time stage, boundary conditions, turning, and traversing speeds.On simulation, the probe was pushed down towards shoulder and make contact with workpiece at a depth of 0.2 mm. Coulomb friction rule has been applied between the touching surfaces of the tool and the workpiecesand the friction coefficient was set to 1.2. By using Johnson Cook law it is easy to identify the material behavior though it takes yield stress as a function of strain rate.

Table 1. Simulation Details for Analysis

Step	**Time Step**	**Boundary Condition for Tool**	**Rotating Speed/ rpm**	**Transverse Speed [mm/min]**
Plunging	1.2	Rotation of x axis and Movement around x axis	1200	15
Pre-heating	1.4	Rotation ofx axis	1200	0
Transversing	3	Rotation ofx axis Movement aroundy axis	1200	30

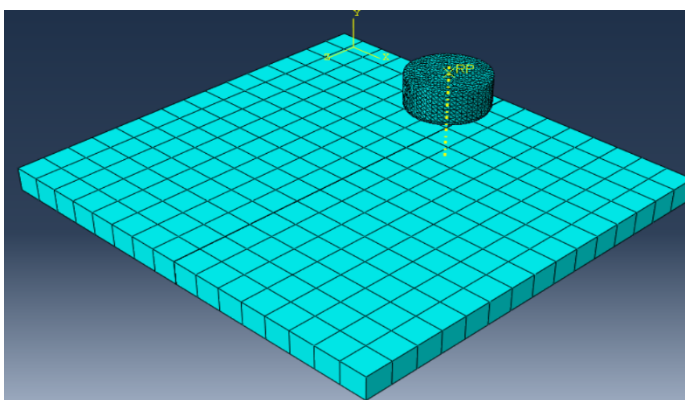

Fig. 1(a). Geometry of Meshed Parts with a Probe

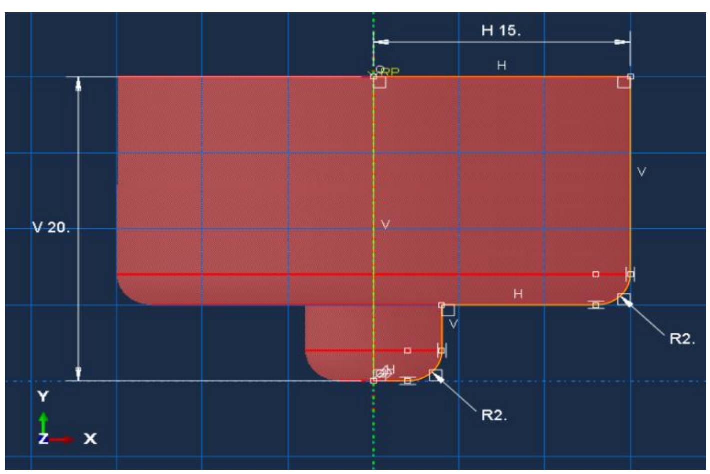

Fig. 1(b). Detailed measurement of Probe

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Materials

Table 2. Johnson Cook Co-efficient of Al-6061

A [MPa]	B [MPa]	C	D	E	ε_0	Θ_m [K]	Θ_t [K]
279.5	212.3	0.021	2.35	2.33	10	935.33	300.25

Table 2. mentions the Johnson Cook Coefficient Values, addition to that thermal and thermo mechanical Properties of Al-6061 alloy were obtained

Chemical Composition of Al-6061

Base metal	Density [Kg/m^3]	Melting Temp [^0C]	Modulus of Elasticity[Gpa]	PoissonRatio
6061	2794	600	60	0.33

Physical Composition of Al-6061

Elements	Mg	Mn	Fe	Si	Cu	Cr	Al
6061	1.5	0.15	0.29	0.60	0.25	0.24	Bal

Mechanical Properties of Al-6061

Base Metal	Yield stress (M pa)	Ultimate Tensile Stress (M pa)	Hardness number, BHN	Elongation(%)
6061	234	283	95	10-15%

Measurement of Temperature

To test the temperature distribution inside the aluminum parts during FSW, three different types of K (General purpose Thermo couple) were used. Figure 2 depicts these different layouts. In Fig 2(a) all type of thermo couples are being placed in one particular side where as fig 2(b) it is placed in two sides of the weld line. In Fig. 2(c) thermo couples are not been placed at the same distance from the weld line as they are in Figs. 2(a) and (b), but rather at different distances.

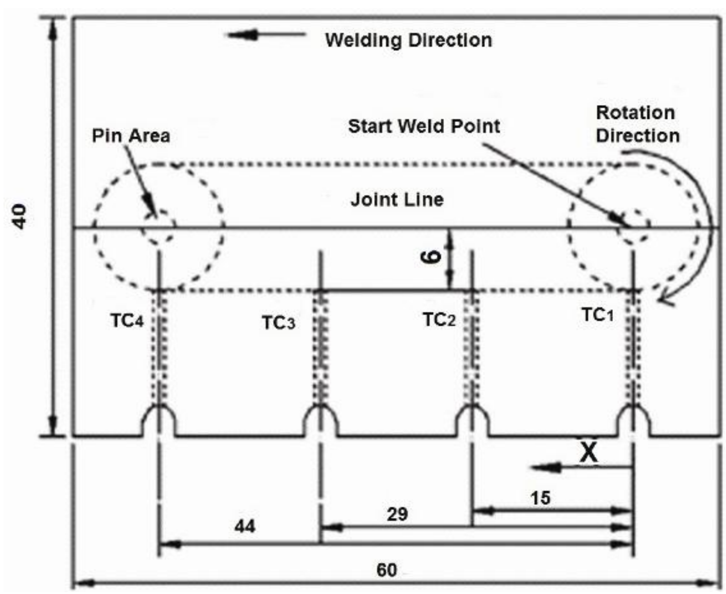

Fig. 2(a)

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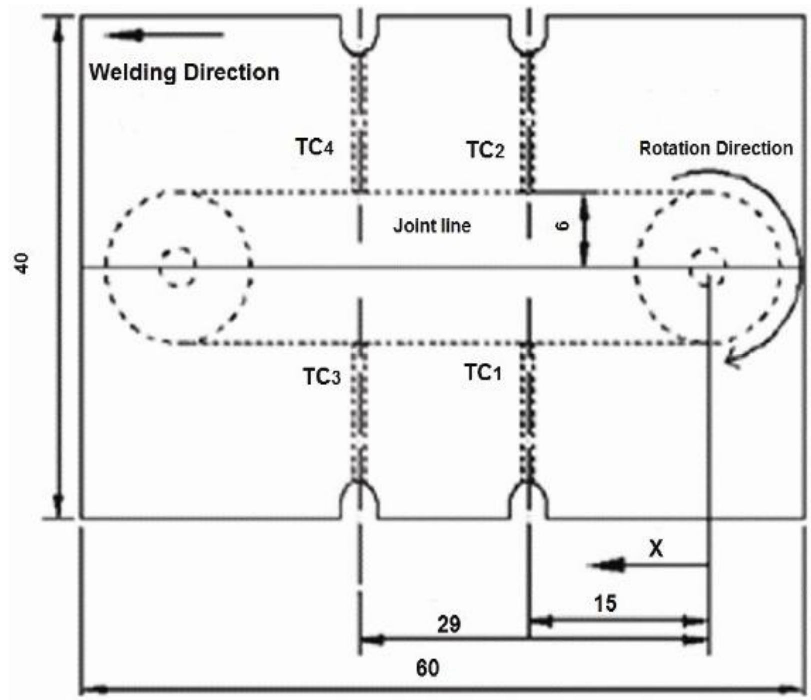

Fig. 2(b)

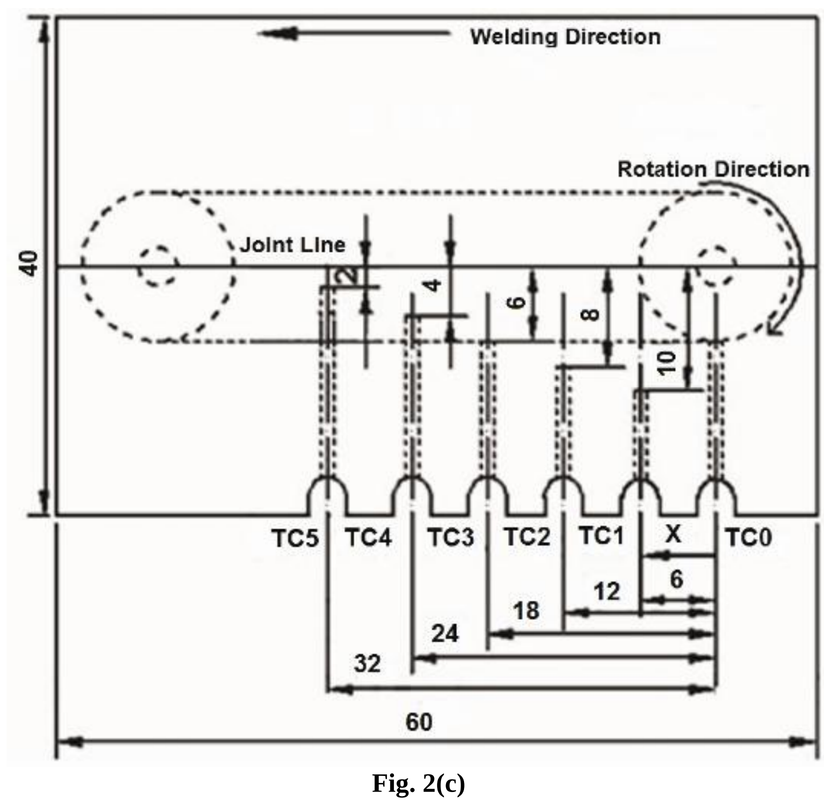

Fig. 2(c)

Fig. 2. Position of thermocouples which is placed in work-pieces, (a) all Thermo-couples are beenplaced at one side; (b) Thermo-couples are placed at different layouts; (c) Thermo-couples are placed in one side but welding line are located at different places.

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Experiments & Results

History of Thermal Distribution

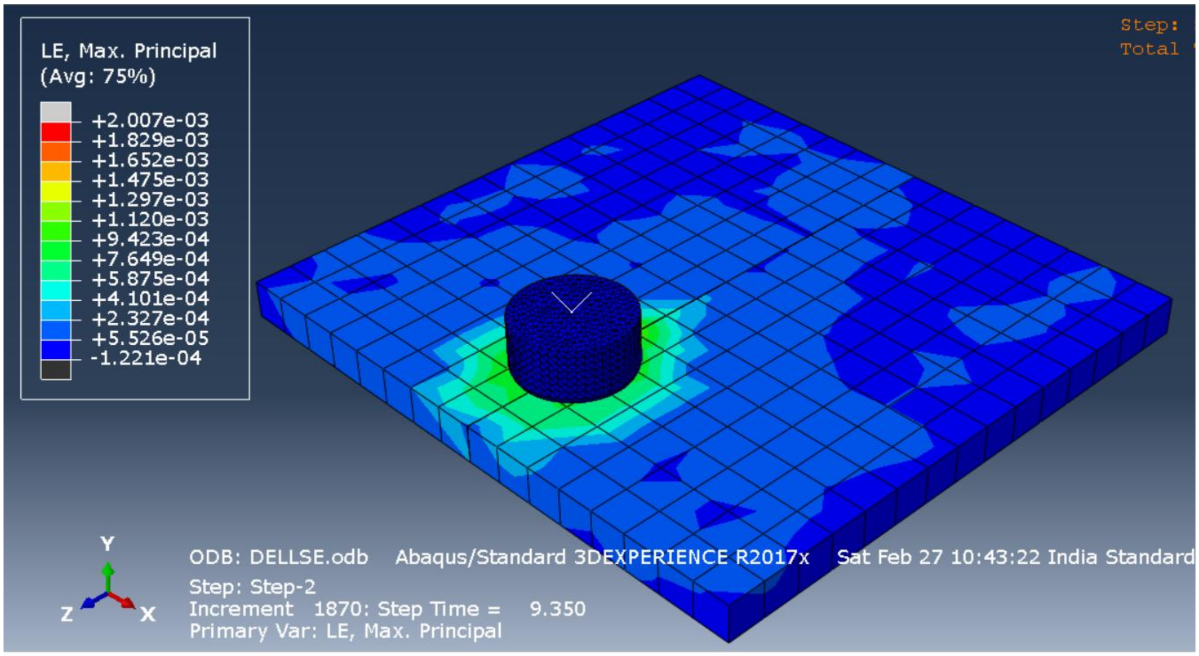

Fig.3. Temperature Distribution around FSW Tool

Figure 3 depicts the temperature distribution across the workpieces as a result of the FSW operation. The heat distribution around the tool is higher than the surrounding environment, as shown in Fig. 3. This is due to the result of heat produced by friction and plastic deformation. The temperature around the tool is highest due to localized heating, and it gets decreased due to the increase of pin distance. Figure 4 shows the experimental measurement of heat distribution which was measured in abaqus at various nodes.Layout of thermocouples (Fig. 2(a)) is depicted in Fig. 4(a), while layout-b [Fig. 2(b)] and layout-c [Fig. 2(c)] are depicted in Figs. 4(b) and (c), respectively. The heat distribution reported by the four thermocouples are fixed according to the layout of Fig. 2(b) are shown in Fig. 4(b). Thermo-couples TC1 and TC3 were inserted on the workpiece's advancing side, while TC2 and TC4 were inserted on the workpiece's retreating side.The temperature distribution on the advancing side areslightly higher than the retreatment side, as shown in Figure4(b). This has something to do with the influence of therotation**.** The temperature distribution on the advancing side is higher than retreatment side, due to fact that it is heavily deformed behind the probe. In Fig. 4, one significant feature is the strong agreement between experimental data &numerical results; nevertheless, numerical results were virtually identical to experimental data. While simplifying the data considered during the simulation process may be one explanation for these differences, another reason may be the zero distance between the modelled pieces. The presence of a minor distance between the parts in fact, even though they are in touch, is unavoidable.Due to the presence of Surrounding air with a lower heat transitivity coefficient than metal parts brings about less warmth conduction away from the weld field, bringing about a higher temperature. The highest temperatures obtained through measurement and simulation (Fig. 4) fit well with the relationship proposed by Arbegeest and Hardley, who investigated the results of FSW parameter of a particular temperature.While experimental methods for measuring temperature can be used at a distance from the tool and shoulder, they cannot be used to evaluate temperature directly beneath the tool, where plastic disfigurement and thermo-couples could be obliterated by the device pin when it navigates through the joint line. The Finite Element-strategy defeats the deficiency and can look at warm and mechanical qualities of the weld field. As demonstrated in Fig. The temperature history of a hub in the weld area is appeared in Figure 5. The assessed heat distribution of the TC5 thermo-couple (Fig. 2(c)) as a component of welding time is appeared in Figure 5. The thermocouple TC5 is 2 mm away from the weld line. The highest temperature is 480°C, as demonstrated in Figure 4.

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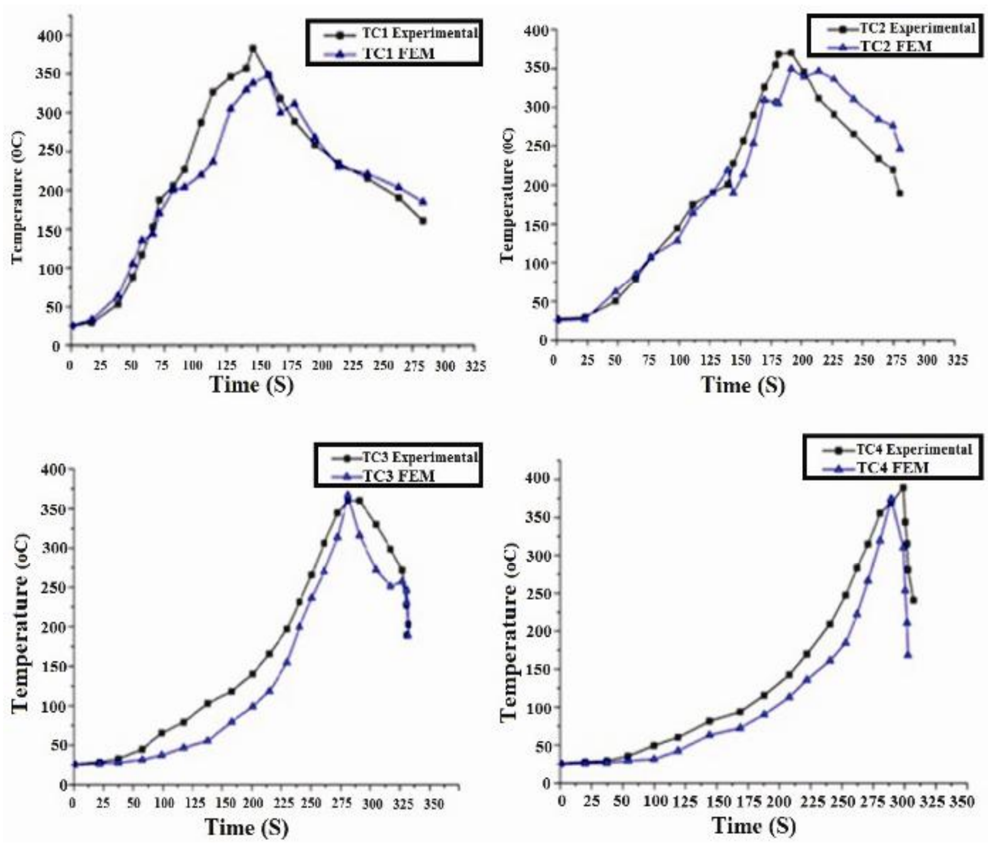

Fig. 4(a)

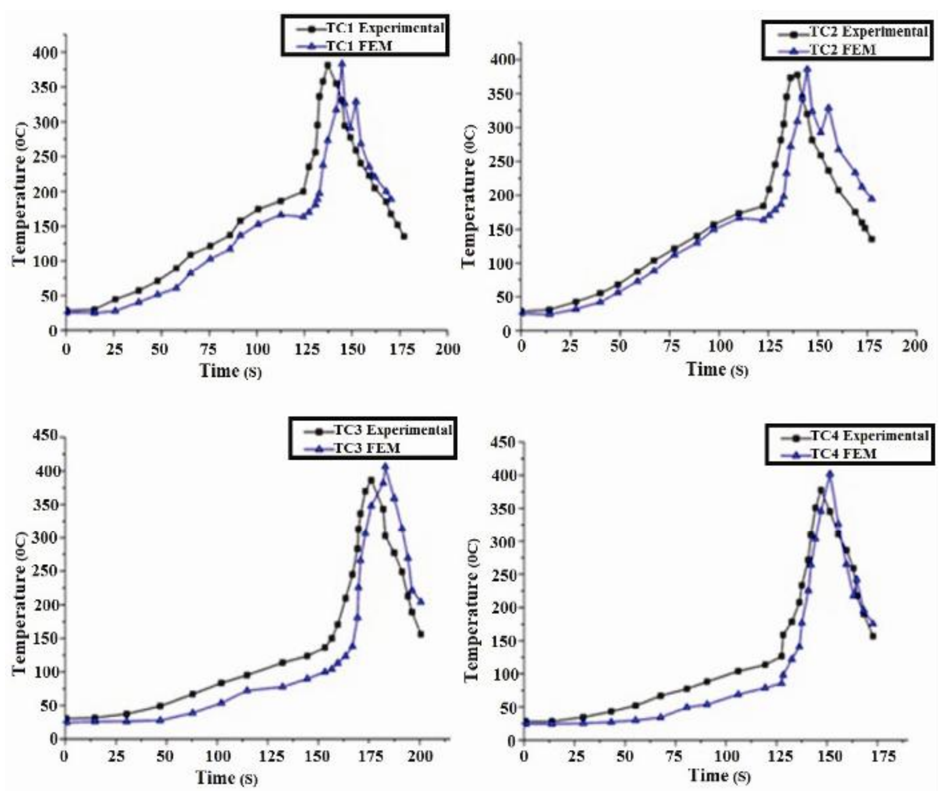

Fig. 4(b)

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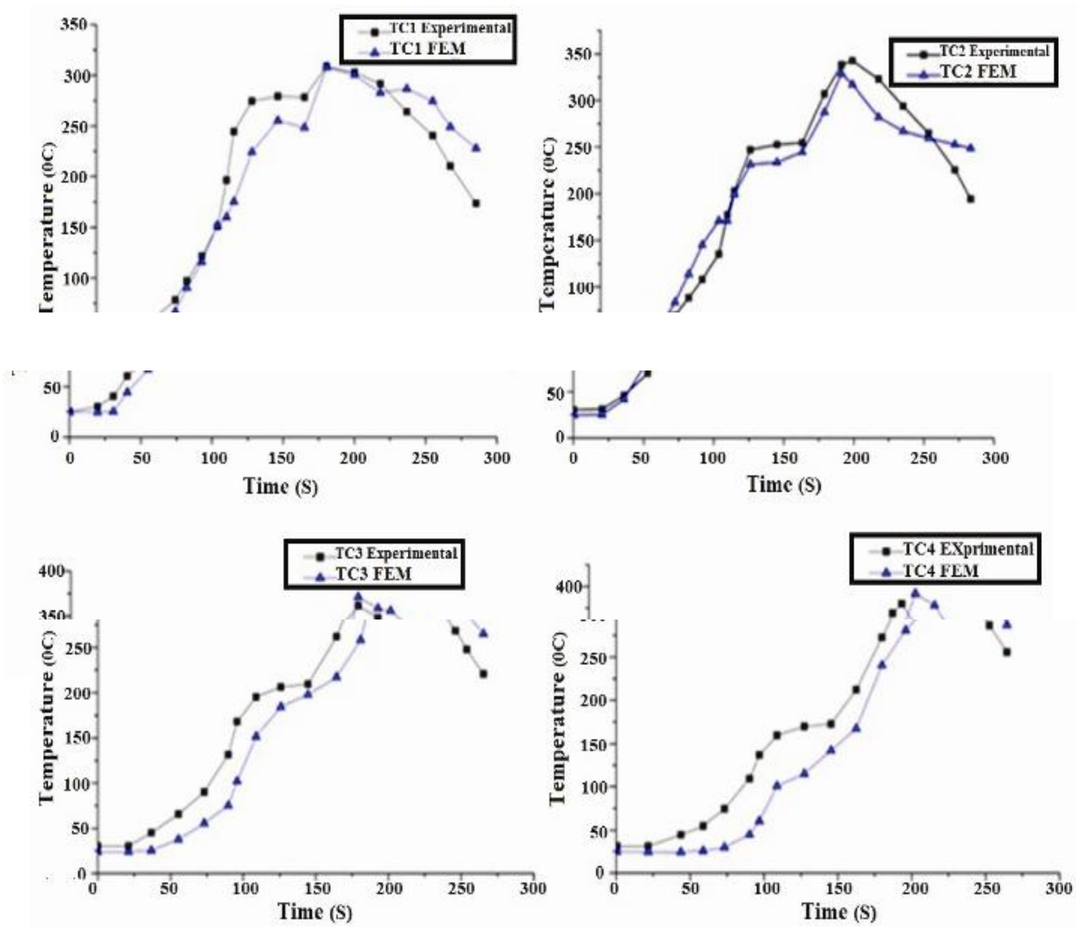

Fig. 4(c)

Fig. 4. Comparison data of Temperature distribution at different Thermo couples which was measured through Experimental and simulation on that (a) denotes layout of TC to Fig 3(a) and (b) denoteslayout of TC to Fig 3(b) and (c) denotesTC layout to Fig 3(c)

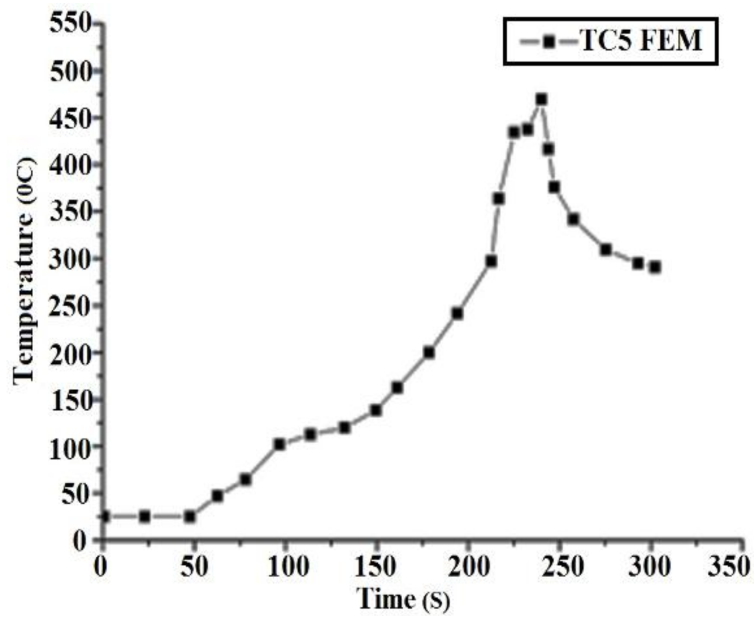

Fig. 5. Declared temperature distributionfor TC5 layout

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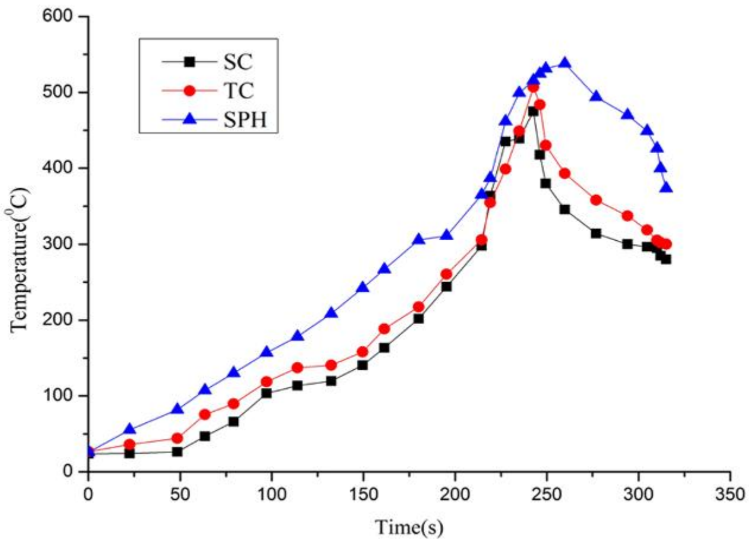
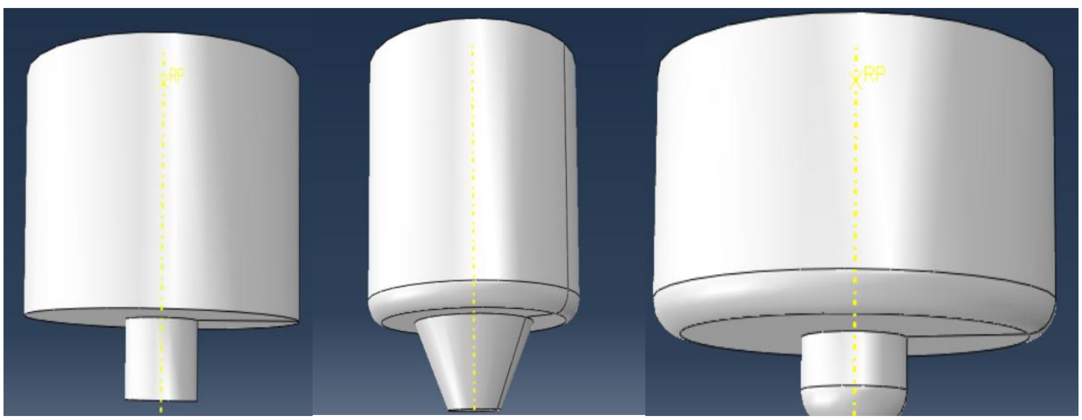


Fig.6. Temperature varieties of an unmistakable place of weld line when various pins are utilized individually for straight cylindrical Tapered Cylindrical and semi spherical



Straight cylindrical Tapered Cylindrical Semi Spherical

Fig.7. Three Kinds of Pin used in this Simulation

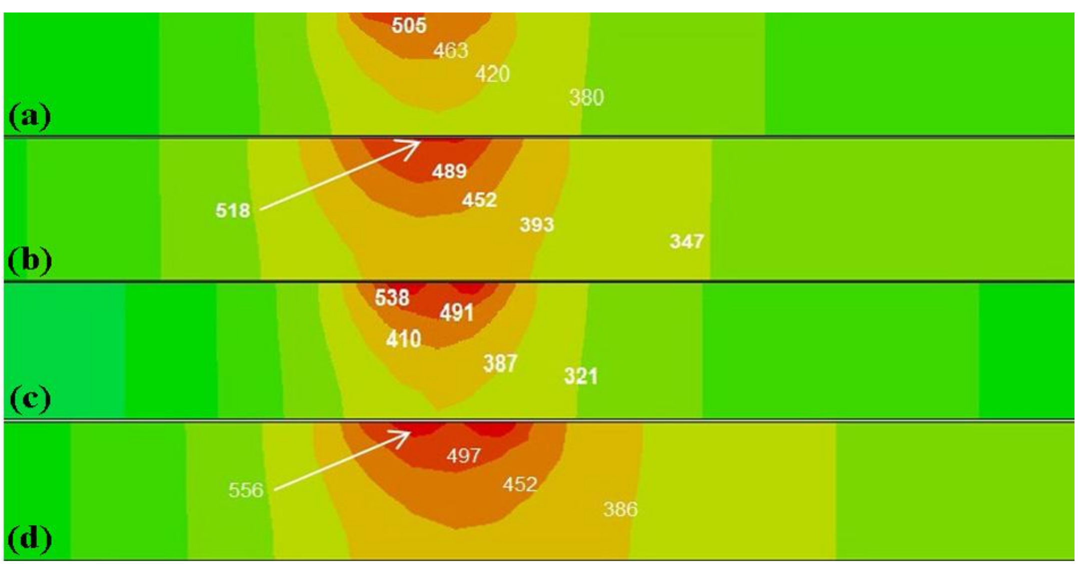


Fig.8. Different Types of pin angle around the weld line(a) 0º;(b)10º; (c)15º;(d)20º

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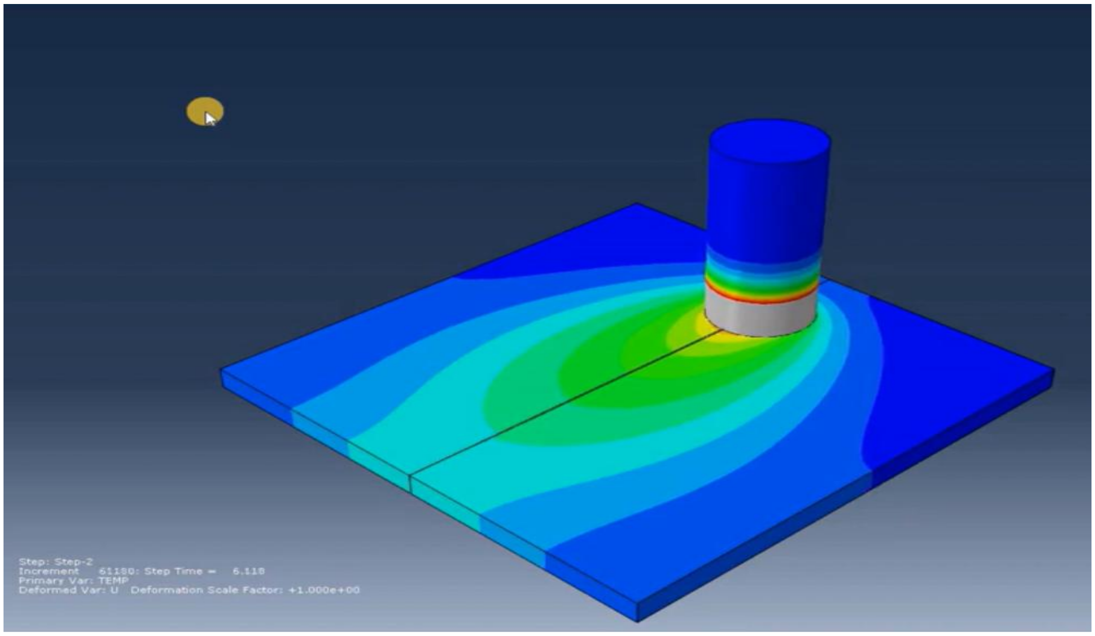

Fig.9. Model of Heat transfer in Al – 6061alloy

Result of Pin Shape

Mathematical examination of the impact of test shape on temperature dissemination was likewise performed. Straight Cylindrical, Tapered, and Semi Spherical tests were thought of, which are all portrayed in Fig. 7. The discoveries (Fig. 6) show that when SPH and SC tests are utilized, the greatest and most minimal temperatures are experienced for a particular point around the weld line, aside from when the pin is made touch with the thought about point. The TC test created temperature that were like than of the SPH and SC tests. Thomas found that pin profiles were connected to flightiness and concocted a proportion to mirror the connection among static and dynamic volumes. This proportion is 1 for a straight cylindrical test (SC), 2.3 for a Tapered Probe (TC), and 3.1 for a semi-spherical tool, as indicated by the portrayed point (SPH). These volumes are conformed by the Simulation performance. If the above ratio rises, more material deforms plastically, energy dissipation from heat generation rises and temperature rises.

Resultof Pin-angle

In FSW process, the point of spindle or tool tilt regarding the workpiece surface is a significant interaction boundary. The shoulder ofdevice conveys the stir material by the strung pin and pushes material proficiently from the front to the rear of the pin while the shaft is shifted the following way. Besides, the pin addition profundity (otherwise called target profundity) is significant in making sound welds with smooth apparatus shoulders. The result of four pin angles on temperature distribution was studied: 0, 10, 15, and 20 degrees. In Figure 8, the resulting distributions are compared. It has been discovered that increasing the pin angle causes the temperature to rise. This is may be due to a large distance of area between pin and work piece, resulting in higher heat output from friction. Another cause for temperature increase may be an increase in redundant work as the pin angle increases. During the metalworking process, various researchers have referred to heat output due to friction and redundant work.

Conclusion

In this investigation, the FSW interaction of the aluminum alloy Al6061 was thermo-precisely tried utilizing the Finite element and Abaqus Software. The test results were contrasted with the temperature conveyances acquired through reproduction. There was a ton of arrangement between the discoveries. The impact of the shape of pin and point on heat dispersion wereconsidered, and accompanying ends were arrived at that

1. Simulation takes into account the examination of temperature underneath the pin when thermocouples are

not free.

2. During the FSW activity, straight round and hollow pins produce less warmth and, therefore, lower temperature, than tightened barrel shaped pins are lower comparing withsemicircular pins.
3. Thoughthe pin point builds, the temperature of the workpieces ascends because of frictional warmth.

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