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Study of Simulated Temperature of Butt Joint during Friction Stir Welding Of Aluminium Alloy by Using Hyperworks

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Abstract
Friction stir welding (FSW) is one of the latest welding technology that utilizes a special tool for generation of frictional heat in the work piece by its rotation due to which joining occurs without melting of metal. For this reason friction stir welding lies under the category of solid state joining. A part from experimental work, there is large space to work on simulation of FSW by using simulation tools. In the present paper, simulation of friction stir welding of aluminium alloy AA-6061 is done by using HyperWeld module of Altair HyperWorks. The virtual experiment of friction stir welding is conducted for variable tool rotational speeds with constant travelling speed and study of simulation results of variation in temperature distribution along the weld line of butt joint is done. The results of simulation shows that the temperature is symmetrically distributed along the weld line. It is observed that the maximum temperature along the weld line increases with the increase in rotational speed. It is also observed that the temperature at advancing side is greater that retreating side.
Keywords—Friction stir welding, Temperature distribution, HyperWeld.

I. INTRODUCTION

In case of FSW, a cylindrical shouldered tool with a pin is rotated and plunged into the joint edges of metal plates which are clamped to prevent vibrations and separation. Frictional heat between the tool and the work pieces causes softening without melting which allows the tool to traverse along the weld line. The stirring action is performed by tool pin. On cooling, a solid state joint is created between the work pieces. FSW is considered to be the most significant invention in metal joining and it is considered as green technology because it is energy efficient, environment friendly, and versatile. As compared to the conventional welding methods, FSW consumes comparatively less energy [2].

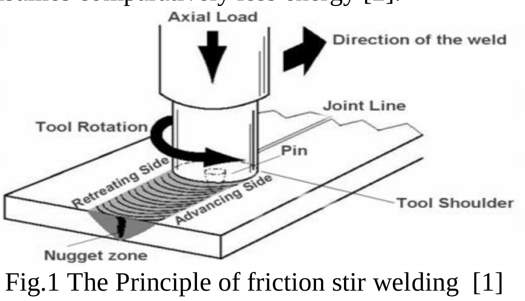

Fig.1 The Principle of friction stir welding [1]

Many experiment based researches has been carried out in this technique for joining of similar and dissimilar aluminium alloys. Welding of steel and other similar alloys is still a challenge in this area. A part from experimental work for study of friction stir welding, there is large space to work on simulation and virtual experimentation of friction stir welding process by finite element method with utilization of available simulation tools such as Ansys, LS-Dyna, Abaqus, Forge, Comsol and HyperWorks. Generally this technique is adopted by scholars before experiment because it saves both cost and time as simulation tools creates a virtual environment for experiment. HyperWeld FSW module of Manufacturing Solutions, Altair HyperWorks provides an interface for performing virtual welding that contains options to create finite element model which is solved by HyperXtrude solver [10].

II. LITERATURE REVIEW

R.S.Mishra & Z.Y.Ma [2] studied mechanisms involved in formation of friction stir welds including microstructural refinement and effects of different parameters on resultant microstructure & mechanical properties. They provided information regarding friction stir welding of aluminium alloys. Prasanna et.al. [3] worked on finite element modeling for maximum temperature in friction stir welding and its validation. They studied maximum temperature developed in 304L stainless steel by using ansys. Santhosh and Mahamad [4] worked on thermo mechanical modeling and experimental evaluation of friction stir welds of aluminium AA6061 alloy. They used altair hyperworks to evaluate the important physical aspects of FSW and compared their simulation with experimental results. Abdul Arif, et.al, [5] worked on finite element modelling for validation of maximum temperature in friction stir welding of aluminium alloy. The developed finite element model and validated it by comparing the results with obtained by Feng et al. aluminium alloy. K.D. Bhatt et.al., [6] worked on effect of size of tool on peak temperature & viscosity during friction stir welding of AA6061-T6 aluminium alloy using hyperworks. They found that variations in dimensions of tools along with tool rotational speed, tool traverse speed by keeping the geometry same have effects on temperature history & viscosity developed during friction stir welding of the aluminium alloy. Jaimin B. Patel & H. S. Patil, [7] worked on simulation of peak temperature & flow stress during FSW of aluminium alloy AA6061 for various tool pin profiles. They modeled FSW tool with four pin profiles and found that hexagonal profiled pin gives better flow of material with least resistance as compared to other pin profiles. Armansyah et.al. [8] worked on temperature distribution in friction stir welding using finite element method by using hyperworks. They analysed heat affected zone and found that the peak temperature of FSW appeared in rear of the advancing side. Binnur Gören Kiral et.al. [9] worked on finite element modeling of friction stir welding in aluminum alloys joint. They performed transient thermal finite element analyses are in order to obtain the temperature distribution in the welded aluminium plate during FSW. They analysed temperature distribution by using ansys and hyperxtrude.

The objective of the present work is to simulate and study temperature distribution during the FSW of Aluminium alloy AA-6061. The HyperWeld (FSW) module of Altair HyperWorks is used for conducting simulation and results are obtained for different rotational speeds of tool. The virtual experiment of FSW is conducted for seven different tool rotational speeds from 600 rpm to 900 rpm with step of 50 rpm keeping transverse speed of tool constant at 2.5mm/s and temperature distribution is analysed.

III. MATERIAL SELECTION

The material for workpiece and tool are selected with reference to the available literature for valid combinations. In the present work, two plates of aluminium alloy AA-6061 size 300mm×200mm×3. 1mm is selected. The properties of AA-6061 are shown in Table I. Friction stir welding tool is considered of hot die steel H-13. The shoulder diameter, shoulder length, pin diameter and pin length 16mm, 150mm, 4mm & 2.79mm respectively are shown in figure 2.

TABLE I. PHYSICAL & THERMAL PROPERTIES OF AA-6061

Property	Values
Density	2.7g/cm3
Melting Point	582-652ºC
Modulus of Elasticity	68.9GPa
Poisons Ratio	0.33
Thermal Conductivity	167 W/m-k
Specific Heat Capacity	0.869J/g ºC

IV. FINITE ELEMENT MODELING

Finite element modelling is performed by HyperWeld (FSW) friction stir welding module of Altair HyperWorks. A three dimensional finite element model for butt joint of aluminium plates was developed and solved using HyperXtrude solver [8].

A. Modelling inputs

Modelling input includes geometric, process, material parameters that are provided for the analysis during the friction stir welding.

B. Geometric input parameter

Details of workpiece & tool are required to input during butt joint modelling which includes length, width and thickness of the plate and pin diameter, pin height, shoulder diameter, shoulder height for the tool geometry.

C. Process input parameter

Process input parameter to be considered in a friction stir welding are as follows :

- Temperature of workpiece (Degree Celsius)
- Tool feed rate (mm/s)
- Tool rotational speed (RPM)
- Coefficient of friction between tool and work piece
- Top and bottom surface heat losses

D. Workpiece and tool properties

For the purpose of accurate prediction and simulation of temperature distribution, it is required to input correct and reliable data with reference to previous published literature. Material properties related to heat transfer and deformation are defined. The material properties commonly used for heat transfer modelling are the thermal conductivity, heat capacity, and emissivity of the work piece and tool materials which are defined as a function of temperature.

E. Boundary Conditions

The thermal and mechanical boundary conditions that are applied are as follows:

- Tool and work piece interface conditions
- Coefficient friction (μ)
- Thermal boundary conditions

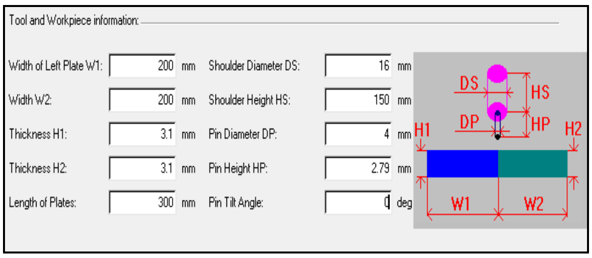

Fig.2 Tool & workpiece information input in HyperWeld.

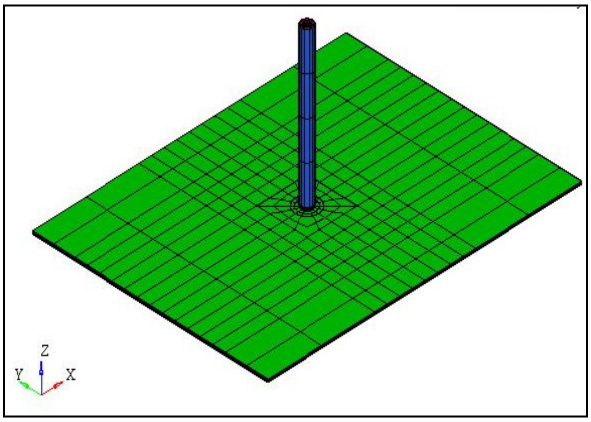

Fig.3 Isometric view of finite element model for FSW process displayed in main graphic area.

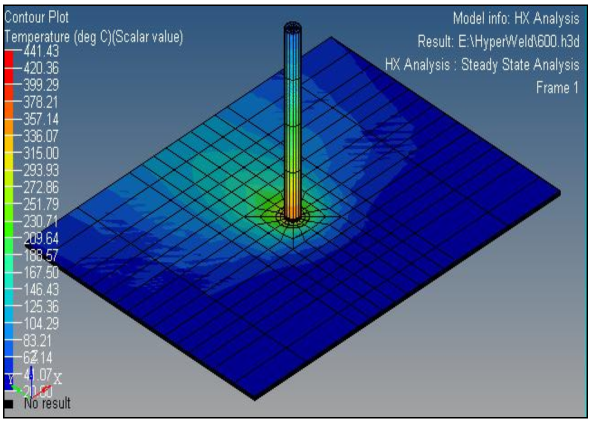

Fig.4 Isometric view of finite element model for FSW process with loaded simulation results of temperature distribution along the weld line displayed in main graphic area.

V. RESULTS & DISCUSSIONS

In case of friction stir welding FSW, joining occurs due to frictional heating effect between rotating tool and work piece. In the present work, simulation of finite element model is performed to study the effect of different tool rotation speeds on maximum temperature along the weld line in friction stir welding of AA-6061 aluminium alloy plates. The virtual experiment is carried out for tool rotational speeds from 600 rpm to 900 rpm with step of 50 rpm keeping the transverse speed of tool constant at 2.5mm/s. The contour plot of temperature distribution along the weld line for different rotational speeds are shown in figure 5-11.

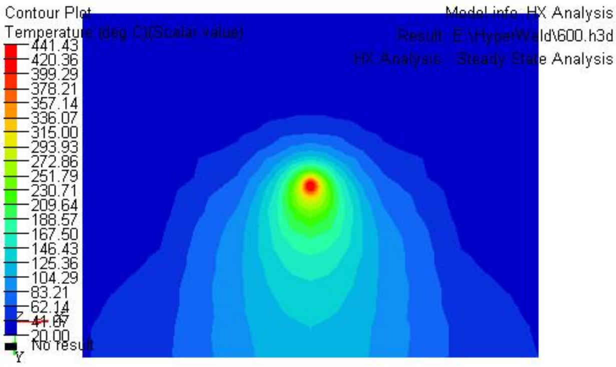

Fig.5 Temperature distribution for rotational speed 600rpm

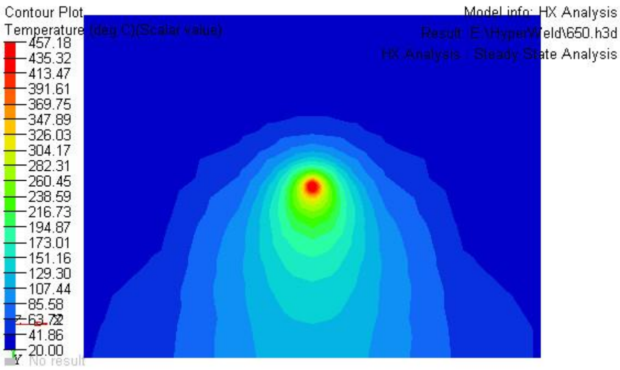

Fig.6 Temperature distribution for rotational speed 650rpm

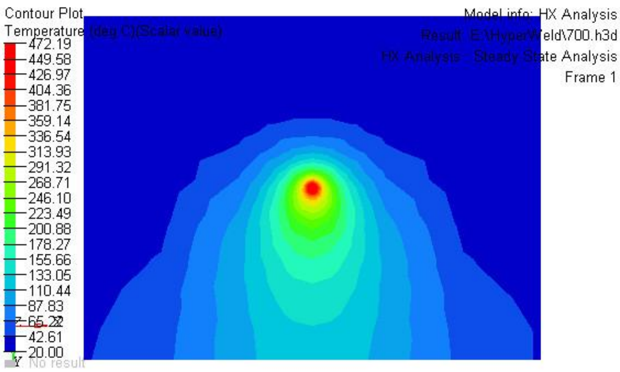

Fig.7 Temperature distribution for rotational speed 700rpm

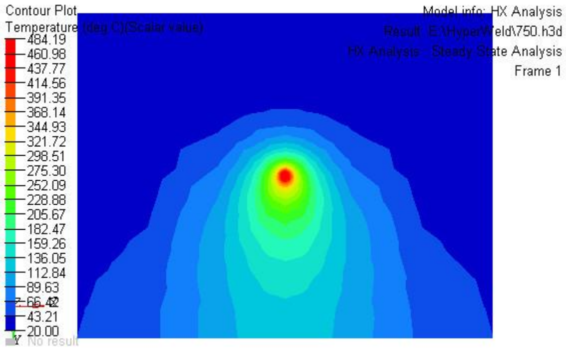

Fig.8 Temperature distribution for rotational speed 750rpm

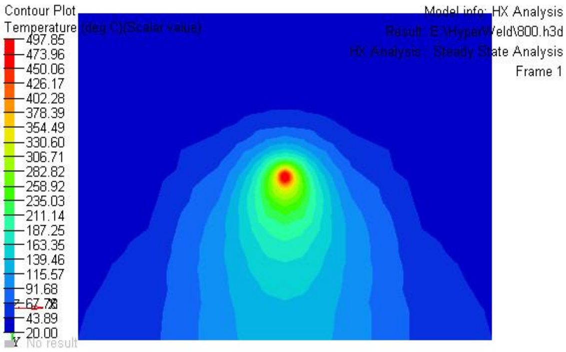

Fig.9 Temperature distribution for rotational speed 800rpm

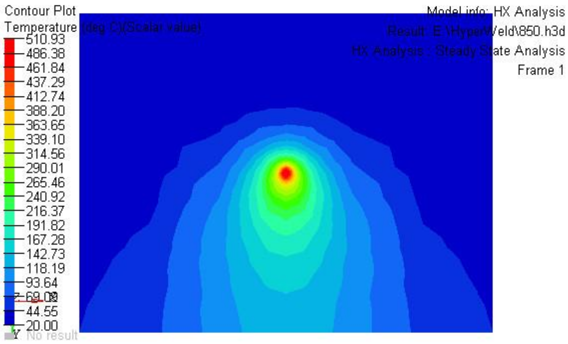

Fig.10 Temperature distribution for rotational speed 850rpm

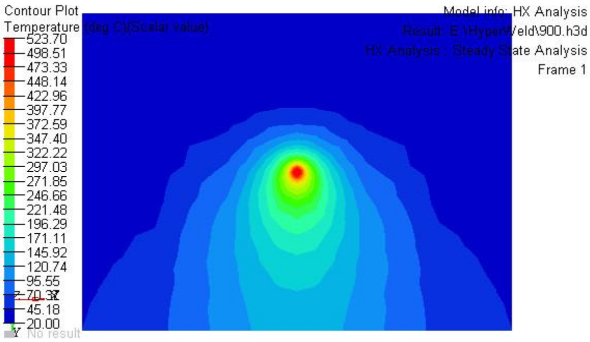

Fig.11 Temperature distribution for rotational speed 900rpm

TABLE II. MAXIMUM TEMPERATURE VALUES FOR DIFFERENT TOOL ROTATIONAL SPEEDS AT CONSTANT TRANSVERSE SPEED OF TOOL (2.5mm/s)

S.No	Tool rotation speed RPM	Maximum Temperature ºC
1	600	441.43
2	650	457.18
3	700	472.19
4	750	484.19
5	800	497.85
6	850	510.93
7	900	523.70

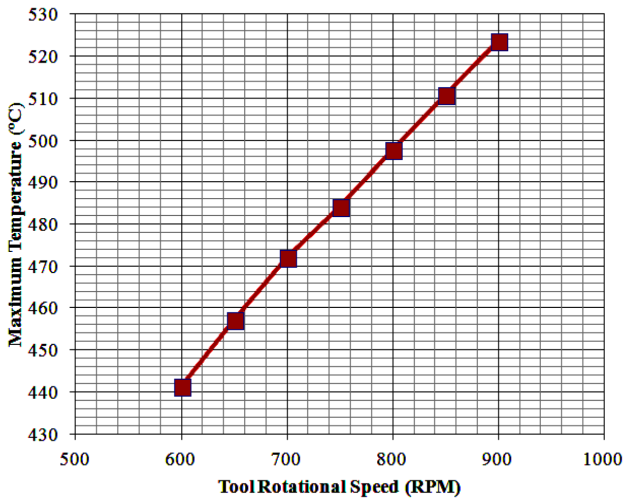

Fig.12 Graphical representation of variation of maximum temperature with respect to increase in tool rotational speed.

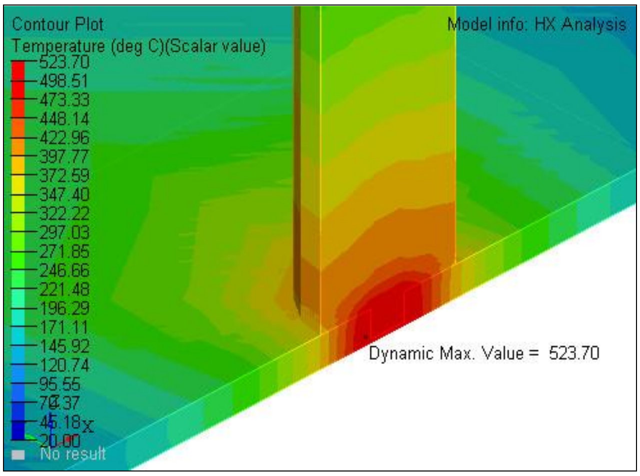

Fig. 13 Cross-sectional view of simulated finite element model showing maximum temperature at tool advancing side.

As shown in Fig.13 the temperature can be obtained for tool advancing side and tool retreating side. It is observed that the temperature at advancing side is more that retreating side. This fact is also revealed by several authors in previous literatures.

VI. CONCLUSION

Friction stir welding process conducted on HyperWeld module of Altair HyperWorks simulation tool creates a new platform for virtual experiments which can performed by providing appropriate data and several results can be obtained as per the need of research. This technique can be used for prediction of temperature distribution along the weld line where the tool moves with a rotational velocity. In the present study, simulated temperature of butt joint during friction stir welding of aluminium alloy AA-6061 is by using HyperWeld. The virtual experiment is performed for seven different tool rotational speeds from 600 rev/min to 900 rev/min with step of 50 rev/min keeping the transverse speed of tool constant at 2.5mm/s. It is observed that the maximum temperature along the weld line of the welding plates is symmetrical and it increases with the increase in rotational speed. It is also observed that the temperature at advancing side is more that retreating side.

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