PRE-EXPERIMENTAL SIMULATION FOR PREDICTION OF ROTATIONAL SPEEDS FOR REQUIRED RANGE OF TEMPERATURE IN FRICTION STIR WELDING OF BUTT JOINT OF ALUMINIUM ALLOY

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ABSTRACT

Friction stir welding is proved to be one of the recent process for joining aluminium alloys. The joining process is environment friendly because there are no consumables and no fumes during friction stir welding. Since there is no evidence of melting of metal during friction stir welding, this indicates that maximum temperature achieved is less than melting point of the working metal. The experiment can be performed by using vertical milling machine at low rotational speed. This can be done by using the FSW tool and base plate modifications. Before experimental work, it is required to have simulation of friction stir welding process in order to predict the range of suitable rotational speed for required range of temperature for the purpose of saving time and cost. For this prediction, finite element analysis is performed for several rotational speeds at two constant sets of transverse speeds. The selection of lower rotational and transverse speed is based on the suitability of machine from energy saving view point. The rotational speeds corresponding to the temperature value within the required temperature range are selected for observation in variation of maximum temperature with respect to rotational speeds and for further experimental work.

Keywords: Friction sir welding, Simulation, Aluminium Alloy, Rotational speed, Temperature

I. INTRODUCTION

Friction stir welding process is a solid state joining process invented by The Welding Institute (TWI). Friction stir welding is based upon the simple concept of heat generation due to friction. The heat generated results in plastic diffusion of the material at the edges. In this case a non-consumable rotating tool with a pin and shoulder is inserted into the abutting edges of plates to be joined and moves along the line of joint. Heat generation due to friction between the tool and the work pieces causes softening. On cooling, a solid state joint is created between the plates. FSW is proved to be one of the most significant invention in metal joining and it is considered as energy efficient, environment friendly, and versatile. [1]. Several researches based on experimentation work has been carried out in this technique for joining of similar and dissimilar aluminium alloys. There are several challenging aspects regarding welding of steel. Studies related to temperature distribution has been carried out by conducting 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.

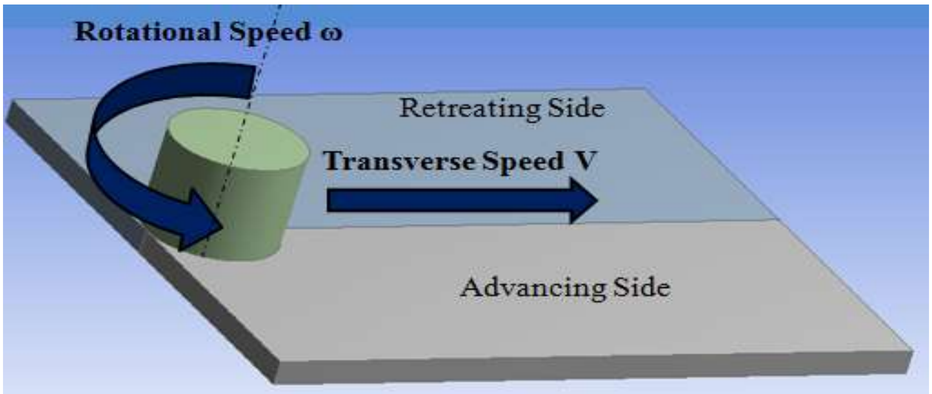

Fig.1 The Schematic Model of Friction Stir Welding

The objective of the present work is to perform pre-experiment simulation and predict rotational speeds for required temperature range in friction stir welding of butt joint of aluminium alloy AA-7075. The experiment can be performed by using conventional milling machine available in our workshop. Before going to experimental work, it will be beneficial to predict the range of rotational speed for the required range of temperature. Finite element analysis is performed for several rotational speeds from 300 rpm to 500 rpm with the step of 25rpm at two constant sets of transverse speed of 2.5mm/s and 5mm/s. The rotational speeds for temperature values within the required temperature range were selected for observation. The graphical representation for the variation of maximum temperature with respect to rotational speed is also generated.

II. LITERATURE REVIEW

Z. Zhang & H. W. Zhang [2] worked on a fully coupled thermo-mechanical model for friction stir welding. They reported that acceleration of material flow near the top surface depends upon the rotation of shoulder. They showed that temperature distribution in the friction stir welding process is symmetrical along the weld line. Hongjun Li and Di Liu [3] worked on simplified thermo-mechanical modeling of friction stir welding with a sequential FE method. They presented a methodology for modeling the transient thermal and mechanical responses without computing the heat generated by friction or plastic deformation. Through this thermal model, they showed temperature history and they found it good agreement with experimentally measured results. Z Feng et. al.,[4] used an integrated thermal-metallurgical-mechanical model to study the formation of the residual stress in Al6061-T6 friction stir welds. K. N. Salloomi et. al., [5] worked on 3-Dimensional nonlinear finite element analysis of both thermal and mechanical response of friction stir welded 2024-T3 aluminium plates. They used Ansys to predict thermal behaviour and thermal stresses. They found considered the effects of various heat transfer conditions at the bottom surface of the workpiece, thermal contact conductances at the work-piece and the backing plate interface on the thermal profile. Abdul Arif, et.al, [6] worked on FEM 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. Armansyah et.al. [7] 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 friction stir welding appeared in rear of the advancing side. Binnur Gören Kiral et.al. [8] 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 hyperworks. Zhang, Z., and H. W. Zhang [9] studied numerically the effect of transverse speed in friction stir welding. They analysed the effect of transverse speed on friction stir welding by using a fully coupled thermo-mechanical model. They observed that when the transverse speed was higher, the stirring effect of the welding tool became weaker which is also the reason for the occurrence of weld flaw.

III. MATERIAL AND ACCEPTED TEMPERATURE LIMIT

C.G.Rhodes et. al. [10] investigated the microstructural evaluation during friction stir welding of aluminium alloy 7075 and showed that maximum temperature of 480 ºC is achieved during the process. Mahoney et al. [11] performed experiment on friction stir welding of aluminium alloy 7075 reported the maximum temperature of 475 ºC. Since there is no evidence of melting of metal during friction stir welding, this indicates that maximum temperature achieved is less than melting point. In this context Abdul Arif, et.al. [6] mentioned the fact in their discussion that the maximum temperature during FSW process is below the solidus temperature of the workpiece. As far as Aluminium alloy AA-7075 is concerned, it is generally used in transport applications, including marine, automotive and aviation, due to their high strength-to-density ratio. The properties of AA-7075 are shown in Table I.

TABLE 1. Physical & Thermal Properties of AA-7075

Property	Values
Density	2.81g/cm3
Melting Point	477-635ºC
Modulus of Elasticity	71.7GPa
Poisons Ratio	0.33
Thermal Conductivity	130 W/m-k
Specific Heat Capacity	0.96 J/g ºC

IV. PRE-EXPERIMENTAL SIMULATION BY FINITE ELEMENT ANALYSIS OF FSW PROCESS

Finite element analysis was performed by using of Hyperworks simulation tool. A three dimensional finite element model for butt joint of aluminium plates was developed as shown in figure 2. Two plates of aluminium alloy 7075 size 300mm×200mm×3.1mm is considered with steel tool H-13 of shoulder diameter, shoulder length, pin diameter and pin length 16mm, 150mm, 4mm & 2.79mm respectively. The dimensions are selected with reference to the available literature for valid combinations. The steps for finite element analysis of friction stir welding process are as below.

- Loading of FSW User profile
- Selection of Units
- Creation of butt weld model

- Loading of model to solver
- Inspection of materials and process parameters
- Running the analysis
- Post process results obtained in hyperview [12]

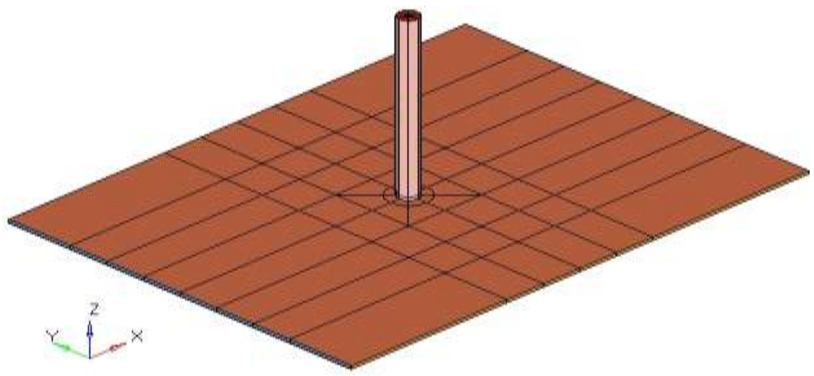

Fig.2 Isometric View of Finite Element Model of Friction Stir Welding Process Showing Tool and Workpiece

V. RESULT & DISCUSSION

In order to predict suitable rotational speeds for required temperature range in friction stir welding of butt joint of aluminium alloy AA-7075, finite element analysis is performed for several rotational speeds from 300 rpm to 500 rpm with the step of 25rpm for two set of transverse speed i.e 2.5mm/s and 5mm/s. The rotational speeds corresponding to the temperature value lying within the accepted temperature limits were selected with reference to solidus temperature of 477 ºC which are shown in Table II.

Table 2. Rotational Speed (In Rpm) For Maximum Temperature Values within Accepted Limit

S.No	RPM	Max Temp (ºC)at V=2.5 mm/s	Max Temp (ºC)at V=5 mm/s
1	300	403.43	391.78
2	325	417.02	404.06
3	350	429.94	415.83
4	375	442.27	427.13
5	400	454.24	438.00
6	425	465.71	448.50
7	450	476.72	458.43

5.1. Simulation Results of Temperature Distribution for Different Rotational Speeds with Constant Travelling Speed of 2.5 Mm/S.

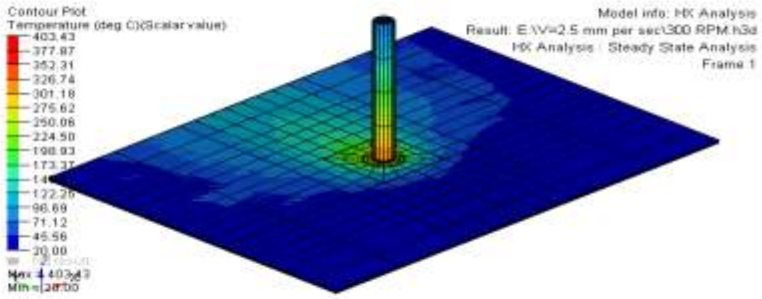

Fig.3 Temperature Distribution With Maximum Value of 403.43 °c For Rotational Speed of 300 Rpm

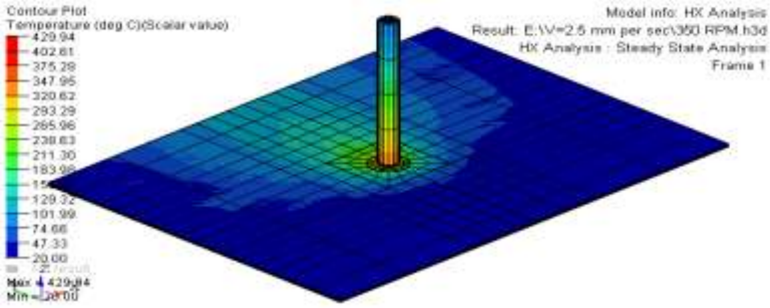

Fig.4 Temperature Distribution With Maximum Value of 429.94°c For Rotational Speed of 350 Rpm

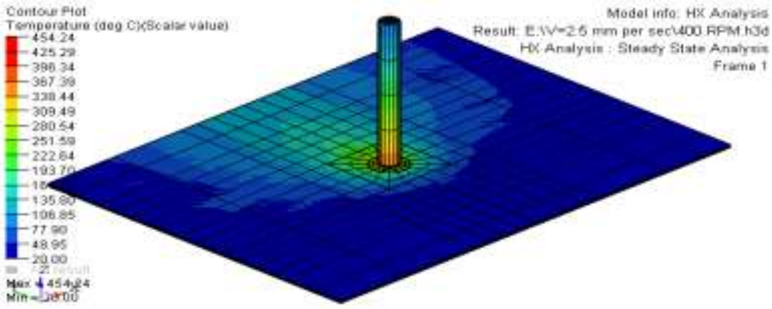

Fig.5 Temperature Distribution with Maximum Value of 454.24°c For Rotational Speed of 400 Rpm

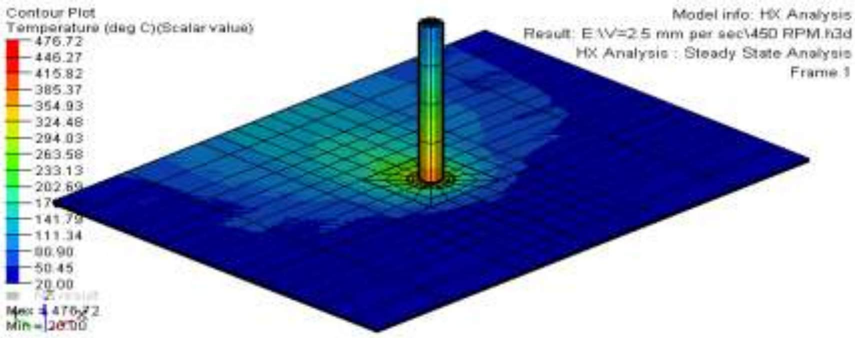

FIG.6 Temperature Distribution With Maximum Value of 476.72°c For Rotational Speed of 450 Rpm

5.2 Simulation Results of Temperature Distribution for Different Rotational Speeds With Constant Travelling Speed of 5 Mm/S.

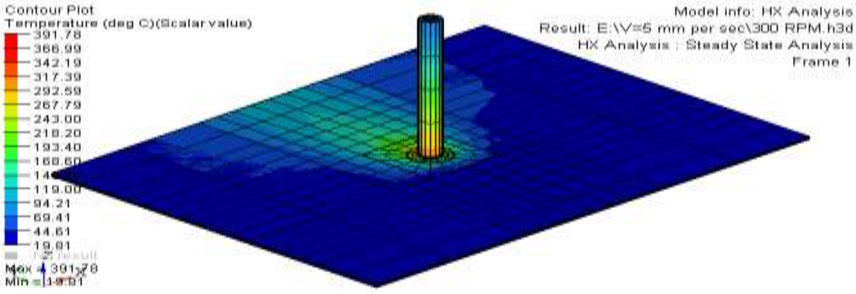

Fig.7 Temperature Distribution with Maximum Value of 391.78 ºc For Rotational Speed of 300 Rpm

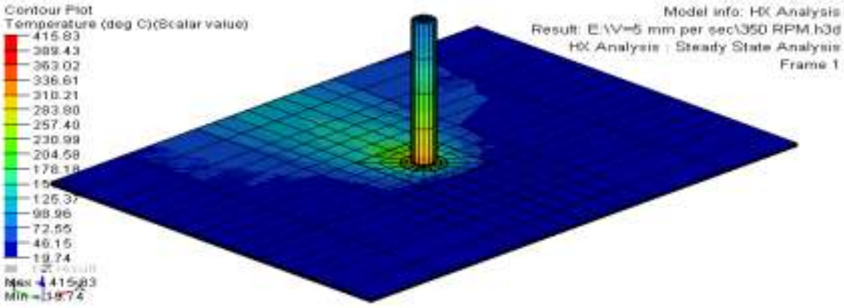

Fig.8 Temperature Distribution with Maximum Value of 415.83 ºc For Rotational Speed of 350 Rpm

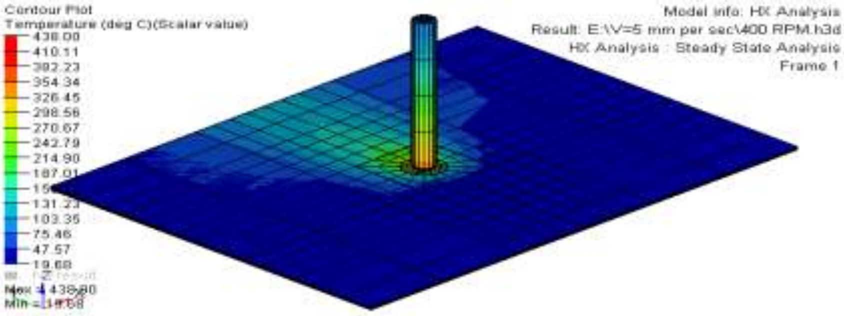

Fig.9 Temperature Distribution with Maximum Value of 438.00 ºc For Rotational Speed of 400 Rpm

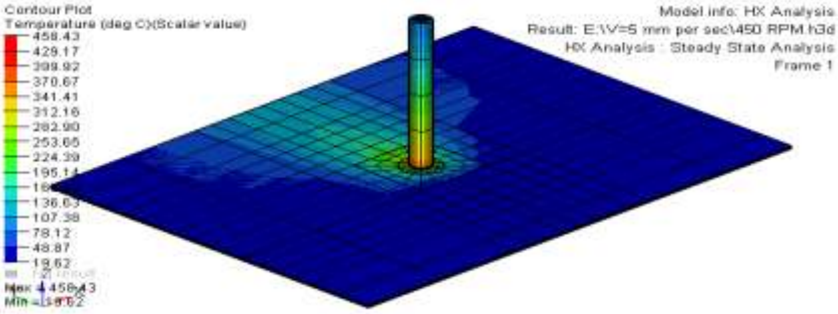

Fig.10 Temperature Distribution with Maximum Value of 458.43 ºc For Rotational Speed of 450 Rpm

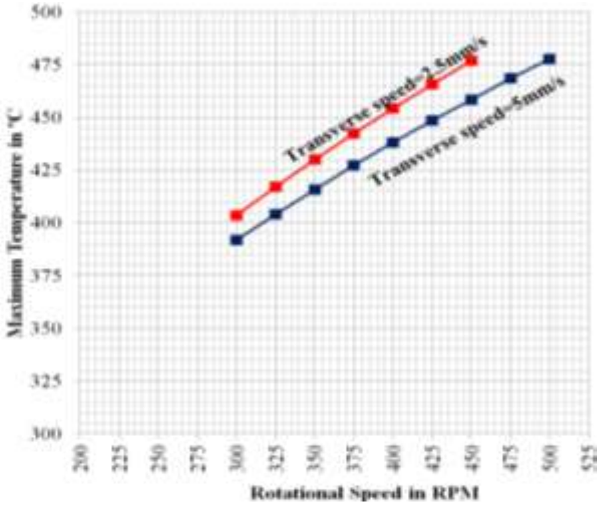

Fig.12 Graphical Representation of Variation of Maximum Temperature With Respect to Increase in Tool Rotational Speed

VI. CONCLUSION

In the present work, pre-experimental simulation has been carried out for the prediction of appropriate rotational speed range for required temperature range in friction stir welding of butt joint of aluminium alloy 7075. Finite element analysis of friction stir welding process is performed for prediction and selection of rotational speeds for required temperature values within accepted limits. This will provide an ease during experimental work in consideration with cost and time saving. The rotational speeds corresponding to the temperature value lying within the accepted temperature limits were selected with reference to solidus temperature of selected aluminium alloy. It is observed that the temperature distribution pattern is decreased in case of lesser transverse speed with constant rotational speed. It is also observed that the maximum temperature along the weld line increases with the increase in rotational speed at constant transverse speed. The graphical representation for the variation of maximum temperature with respect to rotational speed is generated showing two series of constant transverse speed. On the basis of the data obtained by simulation, It can be concluded that the experimental work of friction stir welding process can be performed on vertical milling machine at low rotational speeds from energy conservation point of view.

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