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DESION OF WELDING PARAMETERS OF FRICTION STIR WELDING

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Abstract - Friction-based welding procedures are considered efficient solid-state metal joining processes due to the soundness of the welded junction and their low energy consumption. The aim underlying these techniques is to fuse materials by using elevated temperatures (or stress beyond elastic limits) induced by mechanical friction at touching surfaces. Contact between the surface causes friction in friction welding (FRW), whereas friction stir welding (FSW) uses a non-consumable rotating tool to fuse material at the junction. Based on the current research parameter such as rotational speed, welding speed, axial force, tool geometry, and flaws will influence friction stir welding (FSW). In our project, we are going to study the influence of these parameters using the finite element package, ABAQUS..

KEYWORDS : FSW, ABAQUS, WELDING, FRICTION.

I. INTRODUCTION

Friction Stir Welding is apparently quite a new welding process and is a good process for particularly welding aluminium parts. The conventional rotary friction welding process requires at least one of the parts being joined to be rotated and has the practical limitation of joining regularly shaped components, preferably circular in cross-section and limited in their length. Short tubes or round bars of the same diameter are good examples.

Friction stir welding (FSW) is a solid-state joining process that uses a non-consumable tool to join two-facing workpieces without melting the workpiece material. Heat is generated by friction between the rotating tool and the workpiece material, which leads to a softened region near the FSW tool. While the tool is traversed along the joint line, it mechanically intermixes the two pieces of metal, and forges the hot and softened metal by the mechanical pressure, which is applied by the tool, much like joining clay, or dough. It is primarily used on wrought or extruded aluminium and particularly for structures which need very high weld strength. FSW is capable of joining aluminium alloys, copper alloys, titanium alloys, mild steel, stainless steel and magnesium alloys. More recently, it was successfully used in the welding of polymers. In addition, the joining of dissimilar metals, such as aluminium to magnesium alloys, has been recently achieved by FSW. Application of FSW can be found in modern shipbuilding, trains, and aerospace applications

Close-up view of a friction stir weld tack tool. The bulkhead and nosecone of the Orion spacecraft are joined using friction stir welding. It is a joint design. it was invented and experimentally proven at The Welding Institute (TWI) in the UK in December 1991. TWI held patents on the process, the first being the most descriptive. Friction stir welding (FSW) is a solid-state joining process developed at TWI Ltd in 1991. FSW works by using a non-consumable tool, which is rotated and plunged into the interface of two workpieces. The tool is then moved through the interface and the frictional heat causes the material to heat and soften.

The parts are clamped rigidly onto a backing bar in a manner that prevents the plates from being forced apart. The length of the pin is slightly less than the weld depth required and the tool shoulder is in full contact with the work surface

II. LITERATURE REVIEW

This chapter describes the literature review of design on welding parameters on friction stir welding is analysis and performance based on different temperatures using ANSYS software. In this we considered 20 journals to analyse the welding parameter on friction stir with different temperatures, the 20 journals are explained as follows:
M. El-Sayed et.al [1] discussed The temperature distribution and the residual thermal stresses generated from the friction stir welding process were predicted by using a finite element wringer (FEA)The predicted temperature was validated experimentally by using an infra-red thermal image camera, Variegated AA5083-0 joints were friction stir welded using cylindrical threaded pin profile and tapered smooth one at variegated rotational and welding speeds.**B. Aziz Mohammad et.al [2]** say the objective of this paper was to develop a numerical thermomechanical model for FSW of aluminium-copper transfuse AA2219 and unriddle heat generation during the welding process. The thermomechanical model has been ripened utilizing ANSYS APDL. The model was verified by comparing the simulated temperature profile of three variegated weld schedules (i.e., variegated combinations of weld parameters in real weld situations) from simulation with experimental results. **MD. PARWEZ ALAM et.al [3]** Says Friction Stir Welding (FSW) is a solid-state joining process. Heat generation and heat distribution of friction stir welding is a fundamental miracle and Sound welding is dependent on unobjectionable heat generation. Numerical simulation of the temperature distribution of friction stir welding of aluminium transfuse has been investigated in the present research. **Ramesh. et.al [4**] Proposed the present work is mainly carried out to study the distribution

of temperature in friction stir welded plate of Aluminium alloy. The maximum temperature ripened in friction stirs welded plated increases with the increase of rotational speed of the tool and midmost load where as it decreases with an increase in welding speed. **Kareem N et.al [5**] Discussed the current paper develops the FSW model finance for all process Stages such as plunging dwelling, traversing, pulling out and finally cooling off the workpiece to simulate the real situation of heat transfer during FSW as closely as possible, the effects of variegated heat transfer conditions such as heat losses due to convection and radiation surrounding workpiece and thermal contact conductance between work-piece and the valuables plate interface on the thermal history of the weld material were considered.**Noureddine Zina Samir et.al [6]** Says Important welding techniques to join materials that are difficult to weld by traditional fusion welding technology. The model used in this study is a simplified version of the thermo-mechanical model ripened by zhu and chao for fsw with aluminium transfuse a6061-t6. Zhu and chao presented nonlinear thermal and thermo-mechanical simulations using the finite element wringer law making Ansys and 16.2. They initially formulated a heat transfer**Vijayabaskar et.al [7]** Says The project is the study of the thermal drilling process. The main wholesomeness of the process over the conventional drilling process is that the holes worked using this process do not need any valuables arrangements such as weld nuts, rivet nuts etc. Because the extruded small-time itself acts as a supporting structure for the fasteners This eliminates the need for the wangle to the heinie of the work material for fastening operations: The major factors contributing to the thermal drilling operation are the spindle speed and the thrust gravity required for forming a hole.**Kumaraswamy Dhas et.al [8]** Proposed To understand the dynamics of the friction Stir Welding thermal and residual effects, the thermal history and the incubation of longitudinal, lateral residual stresses in the friction stirred weld are simulated using ANSYS. It is found that the proposed model is correlated with the experimental result, Application/ Improvements: The ripened FEM model can be used as one of the tools for correlating the temperature and residual stresses on the weld zone.**Pierpaolo Carlone Roberto Citarella et.al [9]** Says This paper deals with a numerical investigation of the influence of FSW process parameters on fatigue one-liner growth in AA2024-T3 stump joints. The residual stress field has then been superimposed in a DBEM environment to the stress field induced by a remote fatigue traction load. **Abdul Wahab H. Khuder et.al [10]** proposedFriction stir spot welding (FSSW) is a type of solid-state joining process, which was derived from the linear friction stir welding (FSW) as a volitional method for single-point joining processes like resistance spot welding and fastening. Two types of tool pin geometry (straight cylindrical & triangular) and an unvarying tool rotational speed of (535 rpm) were used to evaluate the temperature distribution during the welding process.**JRB. B. GRIMMETT et.al [11]** demonstrated the feasibility of friction stir welding (FSW).Defect-free welds were produced on 0.25-plates (6.3 mm) of hot-rolled AISI 1018 summery steel at travel speeds ranging from 1 to 4 in./min (0.42 to 1.65 mm) molybdenum-based and tungsten based transfuse tools. Extrapolation of measured temperatures and microstructural evidence suggest peak temperatures of the stir zone creedal 1100°C (2012°F) and likely surpassed 1200°C (219°F) Transverse temple properties of the welds were evaluated at room temperature. **M. Chen et.al [12]** Discussed friction stir welding (FSW) as a relatively new welding process that may have significant advantages compared to the fusion processes as follow: joining of conventionally non-fusion weldable alloys, reduced distortion and improved mechanical properties of weldable alloys joints due to the pure solid-state joining of metals. To provide a quantitative framework for understanding the dynamics of the FSW thermomechanical process, the thermal history and the incubation of longitudinal, lateral, and through-thickness stress in the friction-stirred weld are simulated numerically.**G. Buffa et.al [13**] proposed in friction stir welding (FSW) the welding tool geometry plays a fundamental role in obtaining desirable micro structures in the weld and the heat-affected zones and consequently improving the strength and fatigue resistance of the joint. In this paper, an FSW process with varying pin geometries (cylindrical and conical) and up-and-coming speeds is numerically modelled, and a thermo-mechanically coupled, rigid visco-plastic, fully 3D FEM wringer worldly-wise to predict the process variables, as well as the material spritz pattern and the grain size in the welded joints, is performed. **M. Song et.al [14]** presented a mathematical model to describe the detailed three-dimensional transient heat transfer process in friction stir welding (FSW). The heat input from the tool shoulder is modelled as frictional heat and the heat from the tool pin is modelled as uniform volumetric heat generated by the plastic deformation near the pin.**G. Buffa et.al [15]** mentioned that in friction stir welding (FSW)the welding tool geometry plays a fundamental role in obtaining desirable microstructures in the weld and the heat-affected zones, and consequently improving the strength and fatigue resistance of the joint. In this paper, an FSW process with varying pin geometries (cylindrical and conical) and up-and-coming speeds is numerically modelled, and a thermo-mechanically coupled, rigid-viscoelastic, fully 3D FEM wringer worldly-wise to predict the process variables as well as the material spritz pattern and the grain size in the welded joints is performed. The obtained results indulge in finding optimal tool geometry and up-and-coming speed for improving the nugget integrity of aluminium alloys **M. Song et.al [16]** presented a three-dimensional heat transfer model for friction stir welding (FSW) and a moving coordinate is introduced to reduce the difficulty of modelling the moving tool. The calculated results are in good try-on with the experimental results. **C.M. Chen et.al [17]** proposed friction stir welding (FSW) is a relatively new welding process that may have significant advantages compared to the fusion processes as follow: joining of conventionally non-fusion weldable alloys, reduced distortion and improved mechanical properties of weldable alloys joints due to the pure solid-state joining of metals. To provide a quantitative framework for understanding the dynamics of the FSW thermomechanical process, the thermal history and the incubation of longitudinal, lateral, and through-thickness stress in the friction-stirred weld are simulated numerically.**H.J. Liu et.al [18]** demonstratedIn their study, a 2219 aluminium transfuse was underwater friction stir welded at a stock-still rotation speed of 800 rpm and various welding speeds ranging from 50 to 200 mm/min to sieve the effect of welding speed on the performance of underwater friction stir welded joint. Tensile strength firstly increases with the welding speed but dramatically decreases at the welding speed of 200 mm/min owing to the occurrence of groove defect. **Mir Zahedul H. Khandkar Jamil AKhan et.al [19]** utilized a sequentially coupled finite element model of the friction stir welding process to study the residual stresses caused by the thermal cycles during friction stir welding of metals. The temperature history generated by the thermal model is then sequentially coupled to a mechanical model that predicts the residual thermal stresses. **P.B Prangnell et.al [20]** carried out to 'freeze the friction stir welding process by stopping the tool and immediately quenching the workpiece in an Al-2195 plate welded under typical conditions Sectioning through the frozen weld keyhole with the tool in place has unviable the microstructure development leading to the insemination of the ultrafine-grained nugget material to be directly observed as fresh material encounters the deformation field surrounding the rotating pin.

Summary:

After studying all these research articles, we found that for different materials different parameters are required and there is no unique set of parameters exist for the friction stir welding.

III METHODOLOGY

This section gives step by step process of analysis of FSW of two plates in ABAQUS software. The flow chat is as follows:

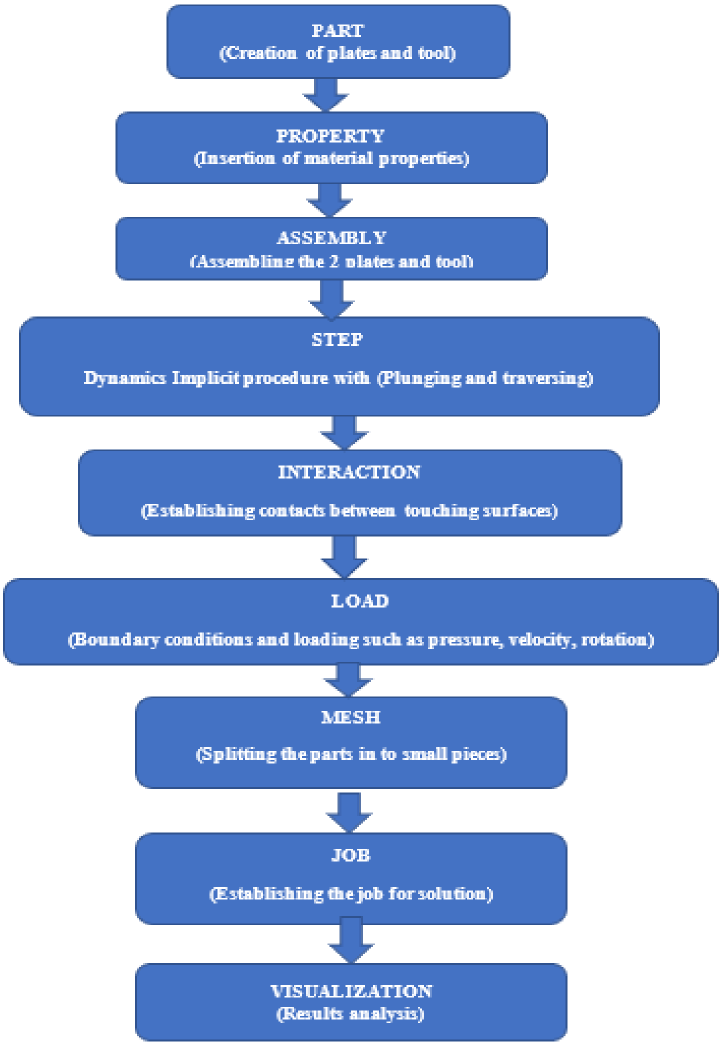


Figure 3.1 Methodology

In this present study ABAQUS standard procedure is considered based on the table 3.1.

Table- 3.1: Usages of ABAQUS Analysis

ABAQUS STANDARD (Implicit)	ABAQUS EXPLICIT
BEST FOR:	**BEST FOR:**
Linear/Non-Linear Static	High speed dynamics
Linear dynamic	Example. drop test, crashing.
Low speed nonlinear dynamic	Large deformations
Mass diffusion	Example. moulding, drawing.
Coupled temp-dips (quasi static)	Damage modelling
Heat transfer	Contact Problems

IV MODELLING AND ANALYSIS :

4.1 MODELLING

Part modelling: Two metal plates of aluminium alloy are created (deformableand extrusion type feature in ABAQUS). Here we are using sketch 1 and sketch 2for the two plates with dimensions of 80mm width, 10 mm thick and extrusion depth of 150 mm as shown in figure4.1.

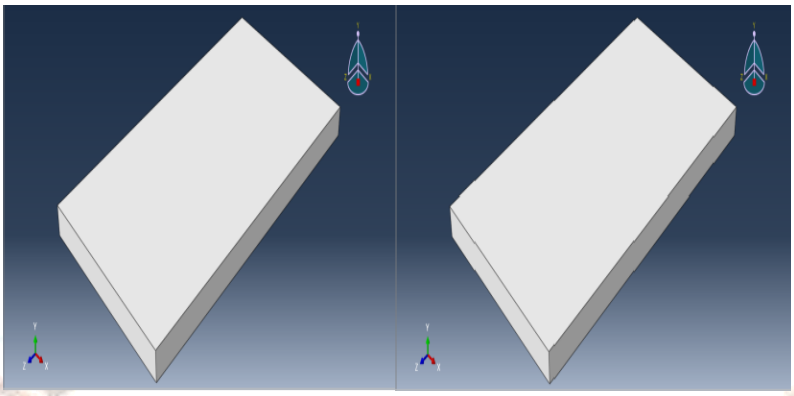


Fig- 4.1: plates 1 and plate 2

A steel tool is created with a pin of 3 mm, a radius of 10mm and height of 10mmand shoulder radius of 15 mm, and a radius of 20mm height of 20 mm having a reference point (RP) at the centre as show in figure 4.2.

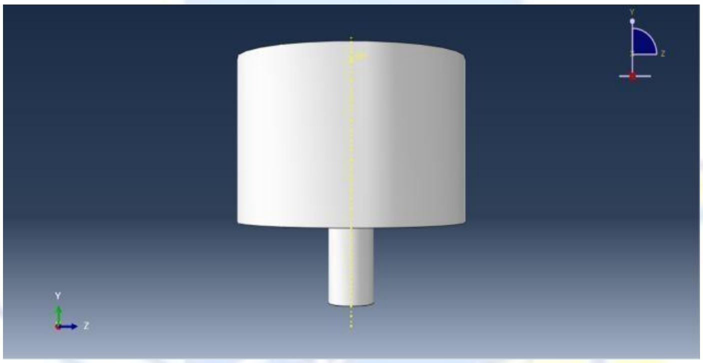


Fig-4.2: Steel Tool

Material manager

The material properties of the plates are shown in Tables 4.1 and 4.2. Plates 1 and 2are made of the same material AA5083-O.

Table -4.1: Strength of AA5083-O material

Ultimate tensile strength (σ_u) [MPa]	Yield strength (σ_y) [MPa]	Brinell hardness(HV)
275	176	75

Table -4.2 : Mechanical properties of AA5083-O plates

Conductivity (w/m^{0}C)	Secific heat (J/kg C)	Density (kg/m^3)	Young's modulus (GPa)	Poisson's ratio
112.5	924.1	2673.9	72000	0.33

The material properties of the steel tool are shown in the table 4.3. These propertiesare assigned inthe material manage section.

Table -4.3: Tool property

Pin diameter (mm)	Shoulder Diameter (mm)	Youngs modulus (Gpa)	Poison's ration	Thermal conductivity (w/m^{0}C)	Specific heat (J/kg^{0}C)	Density (kg/m$^{3)}$
6	30	210	0.3	24.4	460	7750

Section manager

In the section manager select section-1 (solid, homogeneous) for the tool, section-2(solid, homogeneous) and section-3 (solid, homogeneous) for plates 1 and 2. After assigning these sections the parts are shown in figure 4.3.

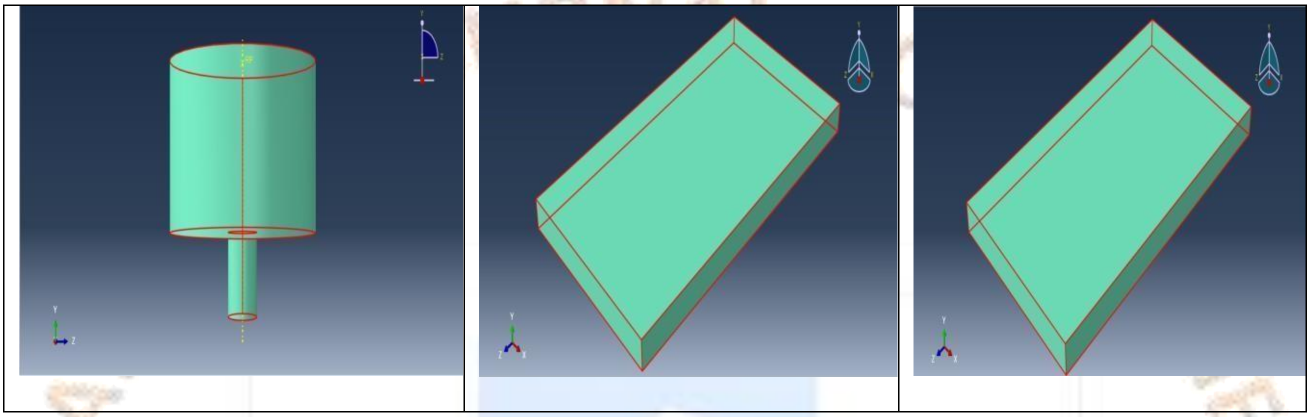


Fig- 4.3: Section manager

Assembly:

Create instances from parts and select the two plates and place them side by side nowselect the tool and place it and the centre of the two plates as shown in figure 4.4.

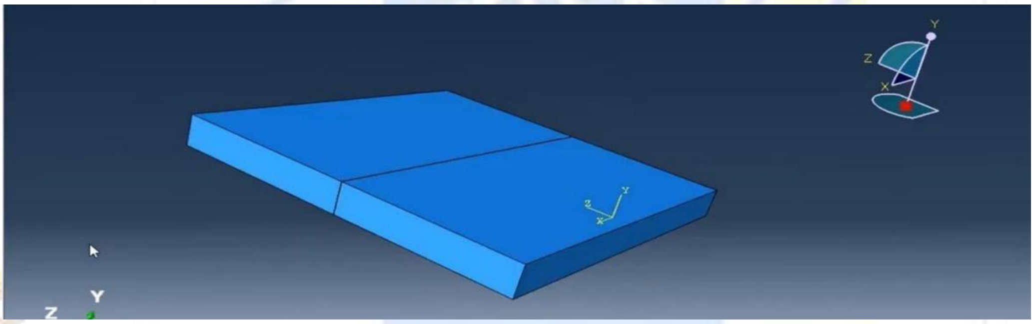


Fig- 4.4: Joining the two plates

Now place the tool and place it at the centre of the two plates as shown infigure 4.5.

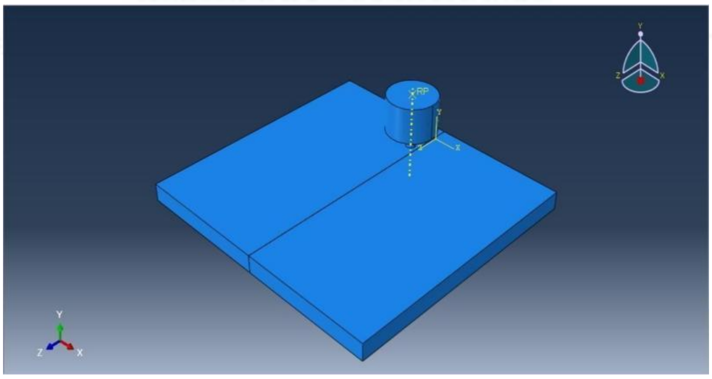


Fig- 4.5: placing the tool at the centre.

4.2 ANALYSIS

In step we are going to step manager and step-1 is dynamic, implicit and the timeperiod is 2 sec,and step-2 is dynamic, implicit and the time period is 15 sec.

Edit field output

Here the product is dynamic, implicit and the domain is the whole model is exterioronly and frequency is every n increment (i.e., n =10) and the output variables stress,strain displacement/velocity/ acceleration, force/reactions, contact, and energy are shown in outputs.

Interaction management

Here is the surface-to-surface contact (standard) and the step is stepping -1 is (dynamic, implicit)and the first surface is the plate and second surface is a tool and master surface is mas and the slave surface is suf-1 and 1st step is plunging (i.e., rotation) 2nd step is traversing (i.e., velocity and rotation) as shown in figure 4.6.

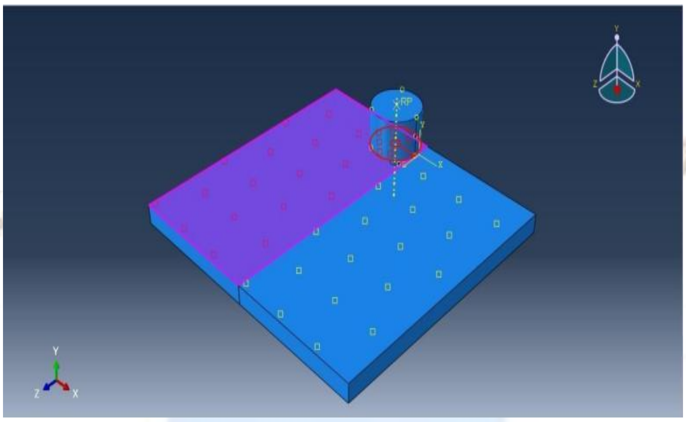


Fig- 4.6: Plate and Surface Contact

Constraint manager

Here is the surface-to-surface contact (standard) and step stepping -1 is (dynamic, implicit) and the first surface is the plate and second surface is the tool and the master surface is mas and the slave surface is suf-2 as shown in figure 4.7.

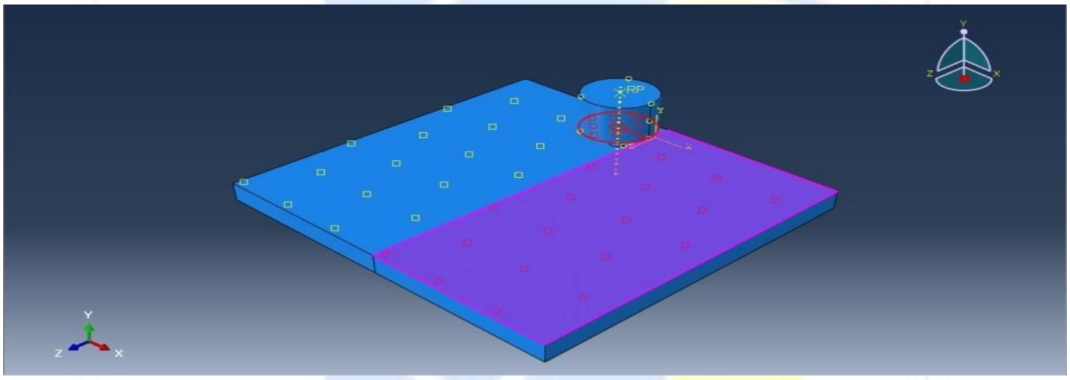


Fig- 4.7: Plate and Surface Contact Interaction

Interaction property manager

The contact conditions were established between the plates and shoulder areaseparately using a coefficient of friction of 0.3 as shown in figure 4.8.

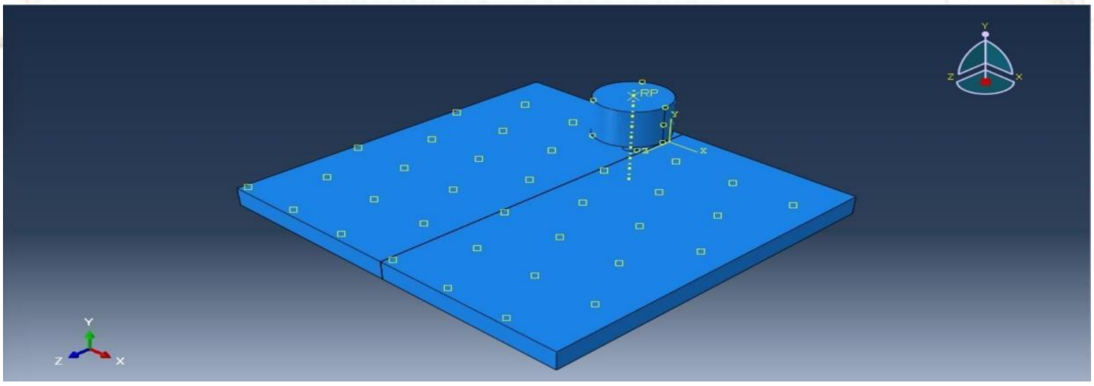


Fig- 4.8: CONTACT

Constraint manager

Here constraint 1 is the rigid body and the region type is body (element) as shown in the figure4.9

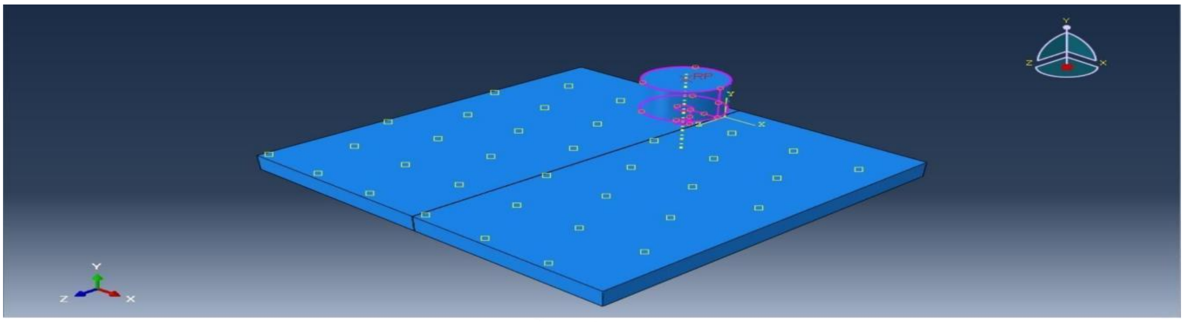


Fig- 4.9: Constraint

Boundary conditions

The model is completely fixed in all directions except along the welding line, whereit is partially fixed as half of the joint is simulated as shown in figure 4.10

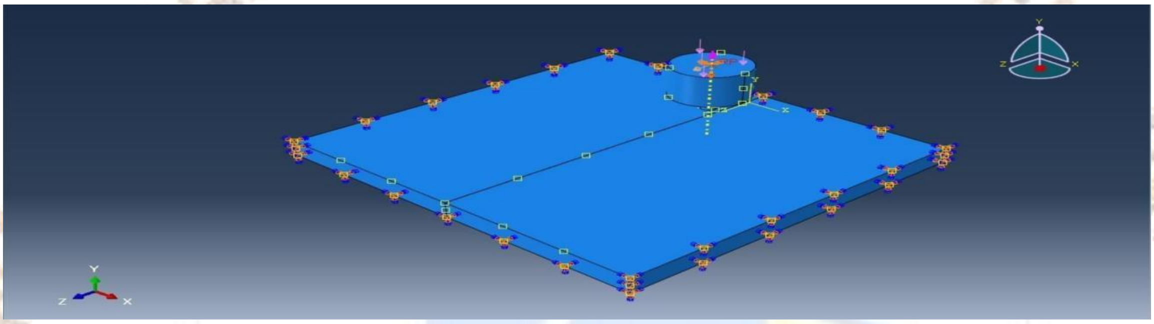


Fig- 4.10: Boundary Conditions

- Friction coefficient (μ) = 0.4
- Axial Pressure (P) = 50 MPa
- $A= \pi (R^2-r^2)$ mm^2
- Shoulder radius (R) = 15 mm
- Pin radius (r) = 3 mm

Meshing

The element size is 5 mm for all bodies except along the welding line and the thickness,where they are 2.5 mm and 1.5 mm respectively in order to get more accurate results asshown in Figure4.11. The element type is heat transfer C3D8T with an 8-node thermally coupled brick, trilinear displacement and temperature with an of the heat transfer model. While in the case of the thermomechanical model, the element type is coupled temperature C3D4T with an A 4-node thermally coupled tetrahedron, linear displacement and temperature. The total number of elements is 2080 elements and thetotal number of nodes is 2870 nodes.

The tools were fabricated from K720 tool steel which has good mechanical properties, good we a resistance, and good dimensional stability during heat treatment. The tools were subjected to a heat treatment to increase their hardness whose value is 57 HRC after heat treatment. The workpiece material is AA5083-O with dimensions of 80mm×10mm× 150 mm which is half of the welded joint.

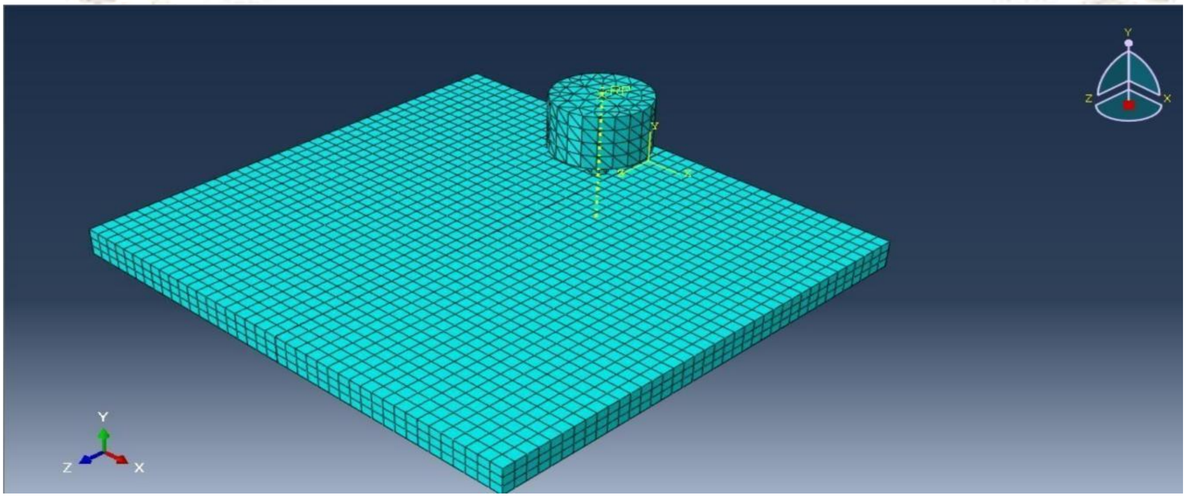


Fig- 4.11: Meshing

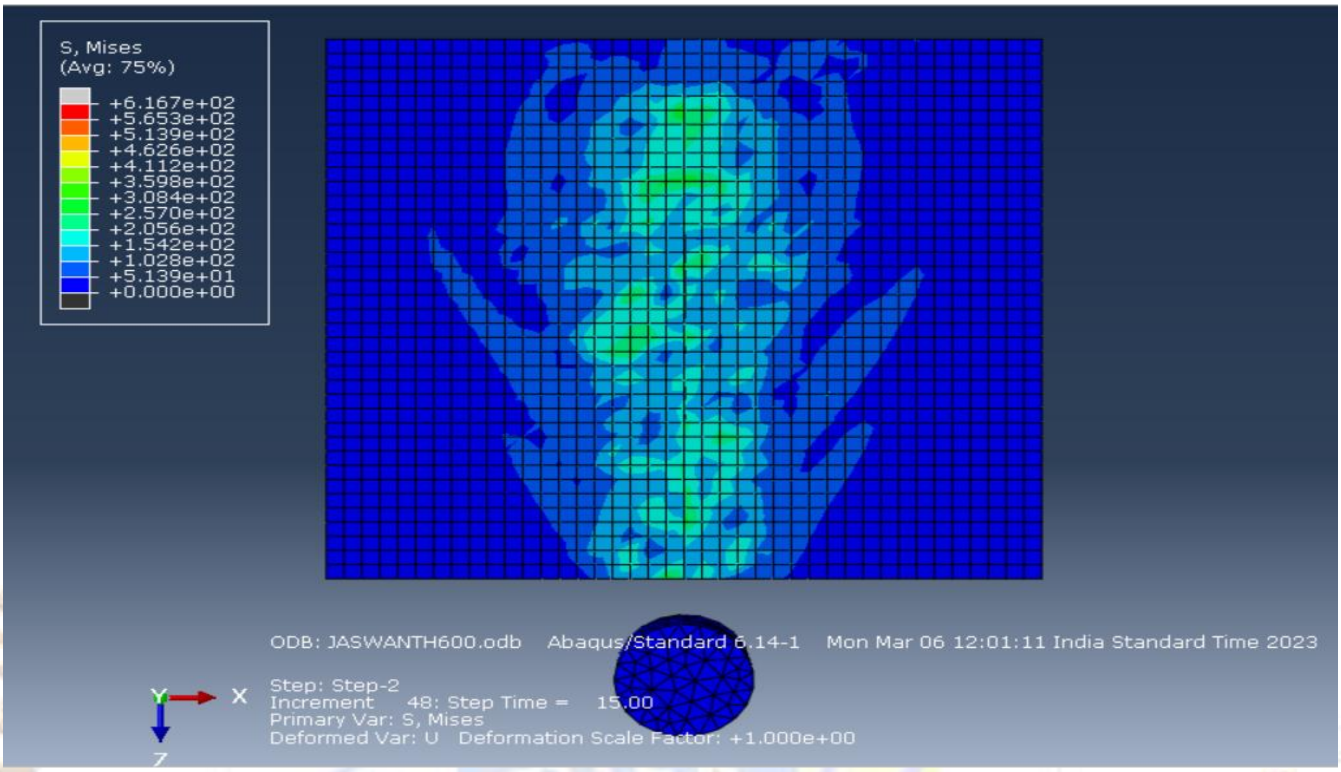
Job

Using the job manger a new job is created for the full analysis and submitted to get the results, and these results are discussed in the next chapter.

V RESULTS :

This Chapter discusses the simulation results of the friction stir welding of Aluminum alloy (AA5083) plates against the steel tool corresponding to the tool rotational speeds of 600, 800 and 1000 rpm respectively with a traverse speed of 20 m/s.

Figure 5.1 shows the von mises stress distribution of the plates welded with the tool rotating at 600 rpm. The maximum stress is 616.7 MPa, and most of the welded region is having 100 MPa (below the yield point of the plate material) and 200 MPa (below the ultimate point).



ODB: JASWANTH600.odb Abaqus/Standard 6.14-1 Mon Mar 06 12:01:11 India Standard Time 2023

Step: Step-2
Increment 48: Step Time = 15.00
Primary Var: S, Mises
Deformed Var: U Deformation Scale Factor: +1.000e+00

Fig. 5.1. Von mises stress distribution of plates with tool at 600rpm

Figure 5.2 shows the von mises stress distribution of the plates welded with the tool rotating at 800 rpm. The maximum stress is 436 MPa, and most of the welded region is having 140 MPa (below the yield point of the plate material) and 240 MPa (below the ultimate point).

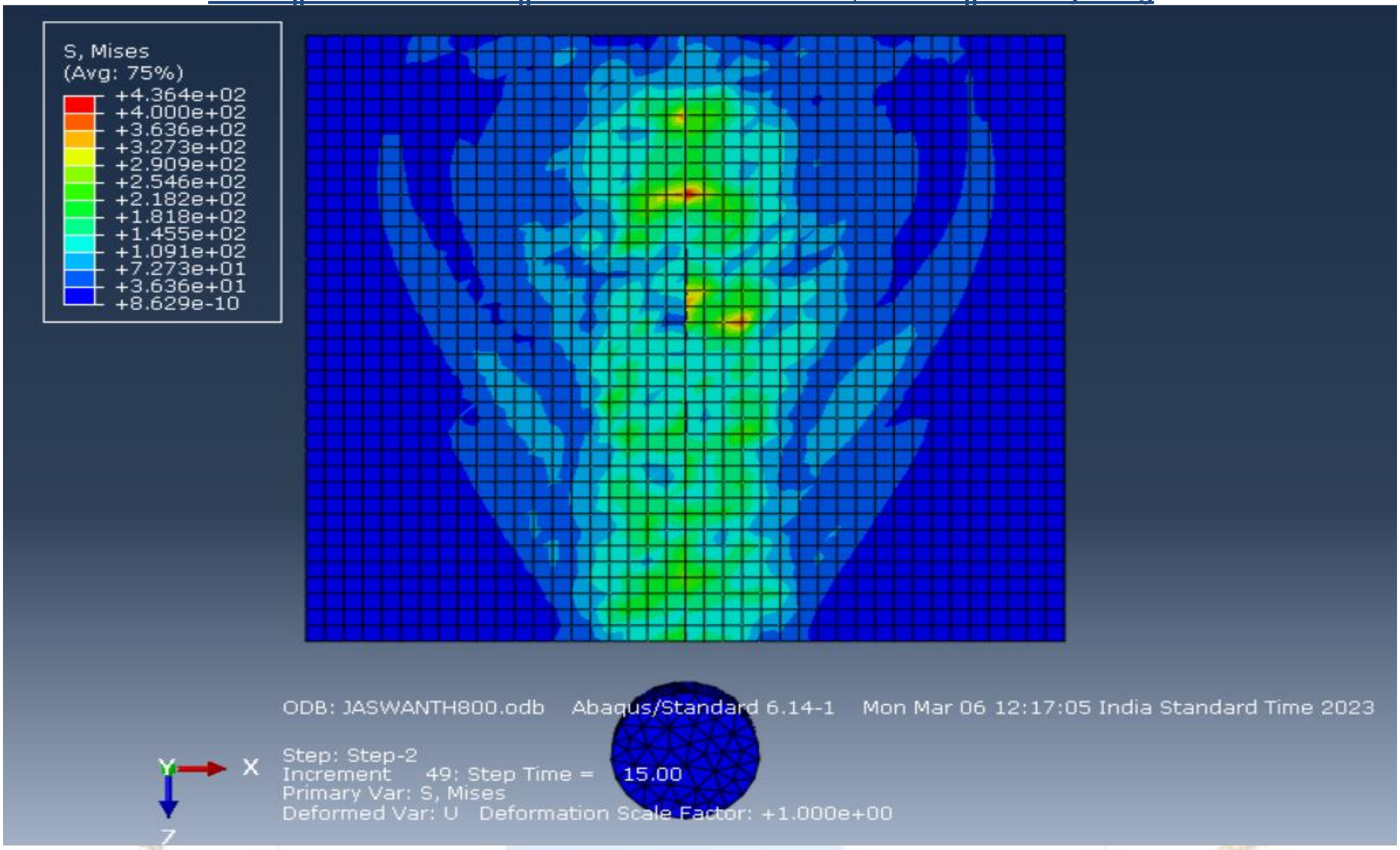


Fig. 5.2. Von mises stress distribution of plates with tool at 800rpm

Figure 5.3 shows the von mises stress distribution of the plates welded with the tool rotating at 1000 rpm. The maximum stress is 415 MPa, and most of the welded region is having 220 MPa (above yield point of the plate material) and 270 MPa (below the ultimate point).

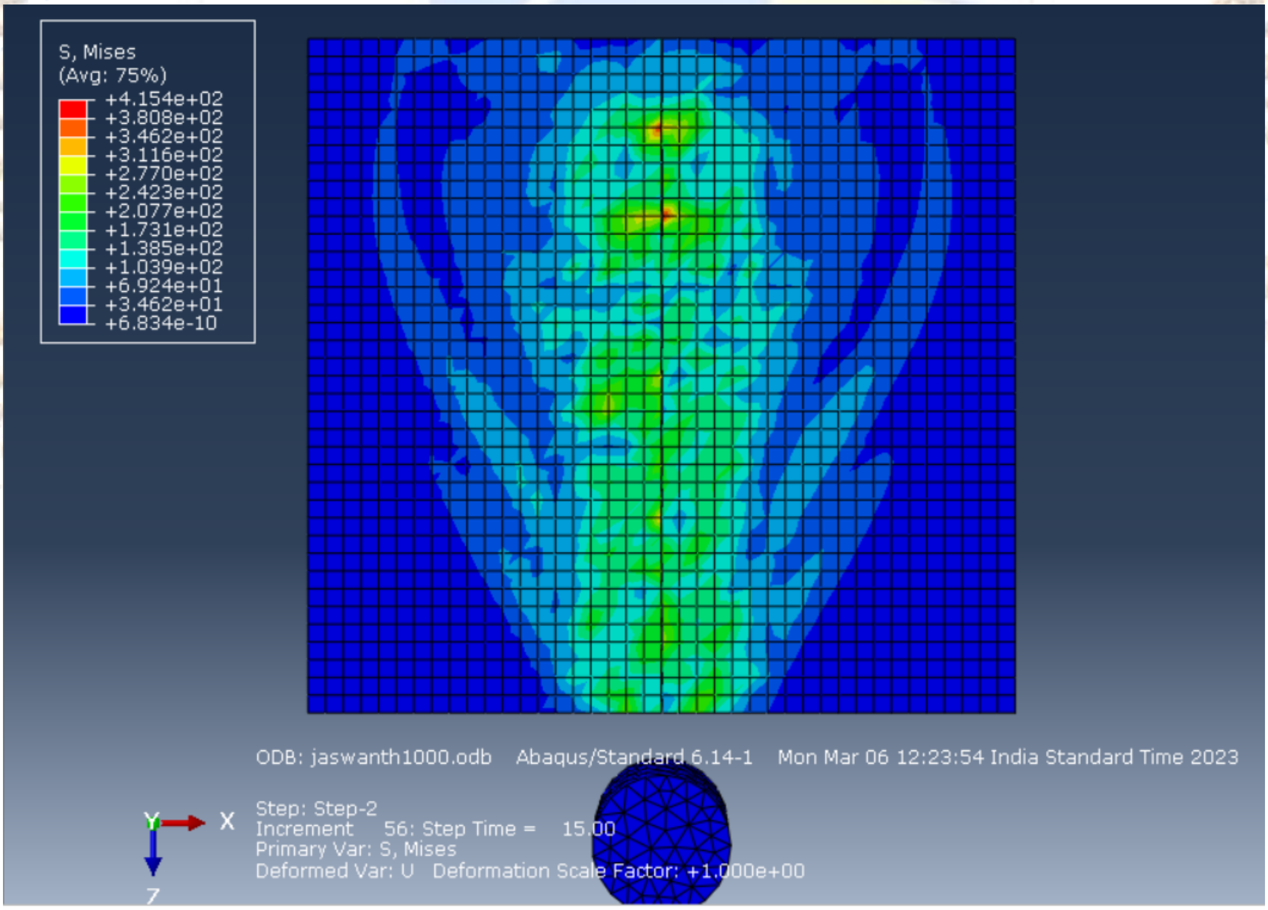
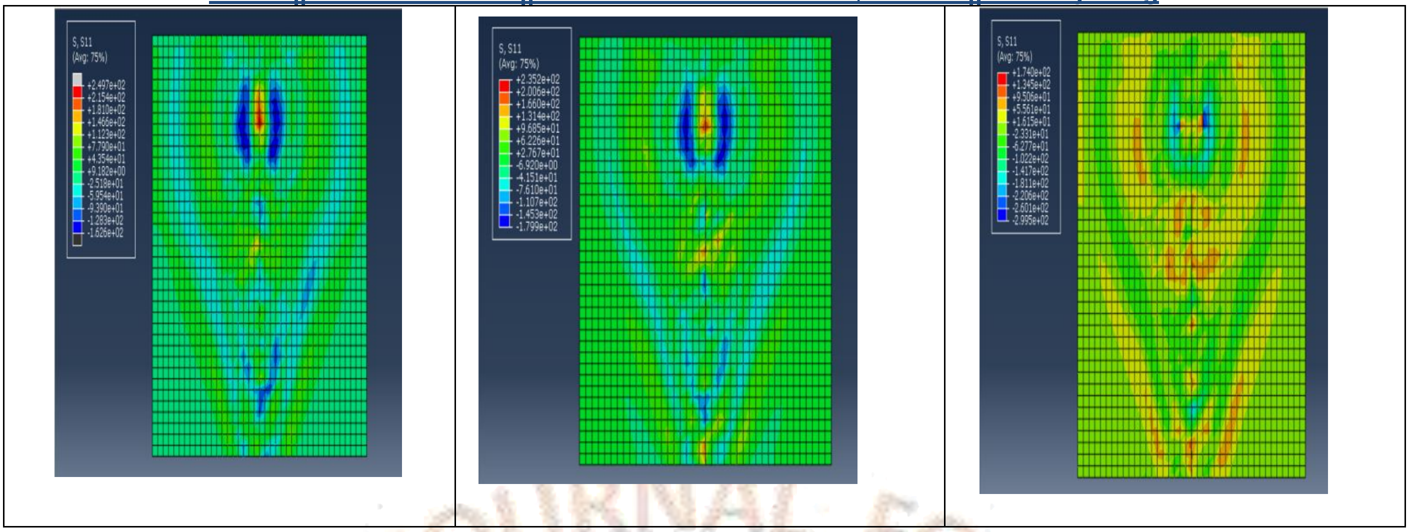
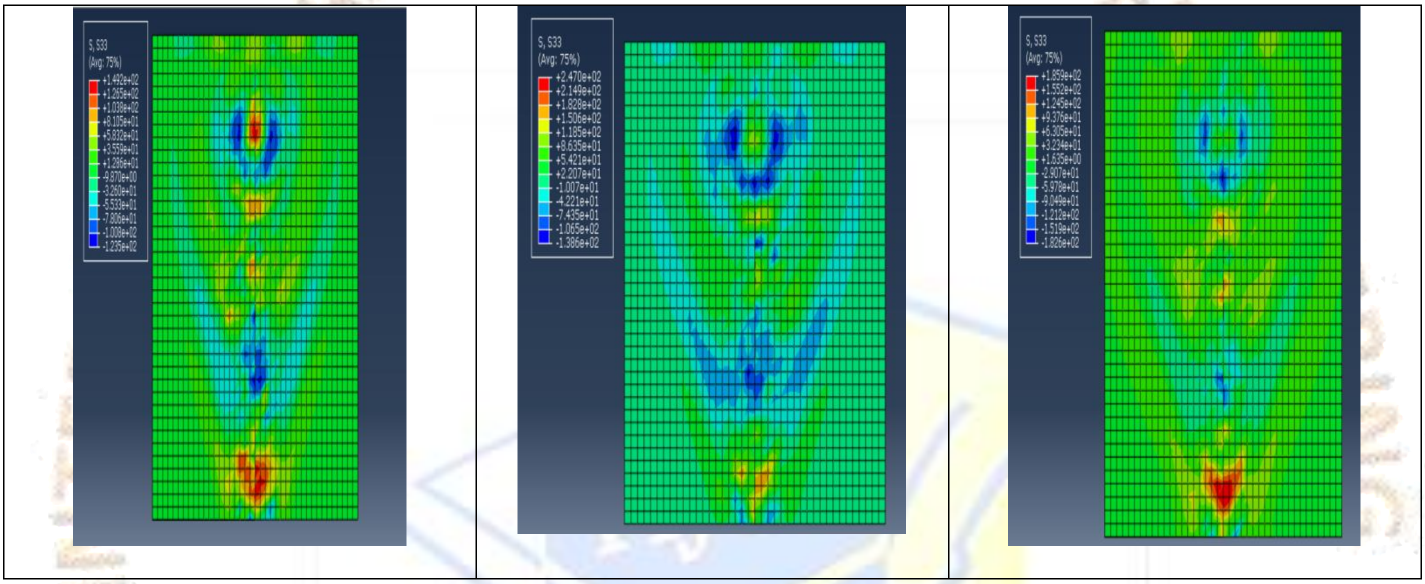


Fig. 5.3. Von mises stress distribution of plates with tool at 1000rpm



(a) (b) (c)

Fig.5.4 Transverse residual stresses (S11) on plates with tool at a) 600rpm, b) 800rpm and c)1000rpm S33 longitudinal stress



(a) (b) (c)

Fig.5.5 Longitudinal residual stresses (S11) on plates with tool at a) 600rpm, b) 800rpm and c)1000rpm

VI. CONCLUSION

In the previous chapter von Mises stress distributions of the welded plates are provided for different rotational speeds of a tool such as 600, 800, and 1000 rpm. The welding region must establish proper joining of metals which can be identified by the equivalent stress, which should stay above the yield point and below the ultimate point. For the plate made of AA5083-O material, the yield point is 176 MPa and the ultimate point is 275 MPa. The results in the welded region shown in figure 5.3 have most of its region at between 220 MPa (above the yield point of the plate material) and 270 MPa (below the ultimate point). So, friction stir welding corresponding to the steel tool rotating at 1000 rpm, traversing at 20m/s is suggested for the two plates (width 80mm; thickness10mm; length150 mm) made of AA5083-O material.

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