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ANALYSIS OF TOOL USED FOR FRICTION STIR SPOT WELDING BY EXPLICIT MESHING SCHEME

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Abstract : *FSSW is an advanced and popular solid-state material welding method, which has achieved a different variety of popularity in service in industries and automotive. FSSW method (technique) is used for joining similar or dissimilar materials like aluminium, titanium, magnesium and copper alloys etc. This paper presents finite element modeling of friction stir spot welding (FSSW) process using Abaqus/Explicit as a finite element solver. Three-dimensional coupled thermal-stress model was used to calculate thermo-mechanical response of FSSW process. The various factors such as rotational speed, transverse speed and profile of the tool plays a very significant role in the joining quality of material using FSSW.*
The main target of this analysis is to observe the variation of tool profile and welding quality of Ti 6Al 4V alloy as the tool speed varies. Two Ti 6Al 4V were lapped and provided with support to the bottom of the plate known as a back anvil to constrain the motion. This is where we analyzed the material flow due to friction of heat generation in the weld zone. Ti 6Al 4V is one of the most commonly used materials and its applications, where low density and excellent corrosion is applied in a wide range of resistance, are necessary in industries such as aerospace industry and biomechanical, marine, chemical industries, gas turbine, etc.
Keywords – *FSSW, Adaptive meshing, Explicit*

I. INTRODUCTION

FSSW is an advanced and popular solid-state material welding method, which achieves a different variety of popularity in serve industries and automotive. FSSW methods (technique) are used for joining the similar or dissimilar material like aluminum, titanium, magnesium and copper alloys etc [1]. The various factors such as rotational speed, transverse speed and profile of the tool on the joining quality of PCBN. The main target of this analysis is to observe variation of tool profile and welding quality of PCBN as the tool speed varies. Two Ti-6Al-4V plates were lapped and provided support to the bottom of the plate known as back anvil to constrain the motion. This is where we analyzed the material flow due to friction of heat generation in the weld zone. PCBN is one of the most commonly used and its applications is where low density and excellent corrosion is applied in a wide range of resistance are necessary such as aerospace industry and biomechanical, marine, chemical industries, gas turbine, etc. FRICTION STIR SPOT WELDING (FSSW) is a solid state joining process that transforms the metal from solid state into a plastic state and then mechanically stirs the materials together under pressure to form a welded joint[2,3]. In this process of welding, separate spots are weld by pressing a rotating tool with high force onto the surface of two sheets that overlap with each other. The frictional heat and high pressure laminate the workpiece material. The tool consists of a rotating pin and a shoulder. The pin is a part of the tool that penetrates into the material, Tip of the pin plunges into the joint area between the adjacent materials at overlap contour. The pin of the tool is plunged into the sheet until the shoulder is in contact with the surface of the sheet. The shoulder applies high pressure which hook-ups the element metallurgical [4]. After a short dwell time, the tool is pulled out of the workpiece.
This paper presents on-going finite element modeling efforts of friction stir spot welding (FSSW) process using Abaqus/Explicit as a finite element solver. Three-dimensional coupled thermal-stress model was used to calculate thermo-mechanical response of FSSW process [5].

II. PROBLEM DEFINITION

Friction stir spot welding is characterized by a number of process advantages. Any damage to the material caused by the extreme heat, such as that produced by laser or arc welding, will not occur. TIG and MIG is a time-consuming process also this is not suitable for the thick materials. In laser welding, due to the rapid rate of cooling, cracks may be produced in some metals. Friction stir spot welds have a high strength, so they are even suitable for parts that are exposed to particularly high loads [6]. In addition to automotive and rail vehicle construction, the aerospace industry is developing the process e.g. for welding cockpit doors for helicopters. In the electrical industry, aluminum and copper can be friction stir spot welded. Other applications are in facade and furniture manufacture, where the low heat input, especially in anodized sheets, leads to excellent optical properties. There different materials i.e. Aluminum , Magnesium, Copper and copper alloys , Titanium , Steel and ferrous alloys , Hafnium and zirconium , etc. is to be weld by using FSSW . Therefore to analysis the FSSW process by using titanium workpiece material also see the effects on workpiece and tool [7,8].

III. METHOD, MODEL AND PROCESS DESCRIPTION

Model description-

Tool dimensions- PCBN tool having 5 mm tip diameter and 20 mm shoulder diameter is used for study. Different types of tool tips are used like circular, taper, triangular and square.

Plate dimension- Two Ti6-Al-4V plate are used having 3 mm thick and 80 mm length of each plate placed as shown in fig. 1

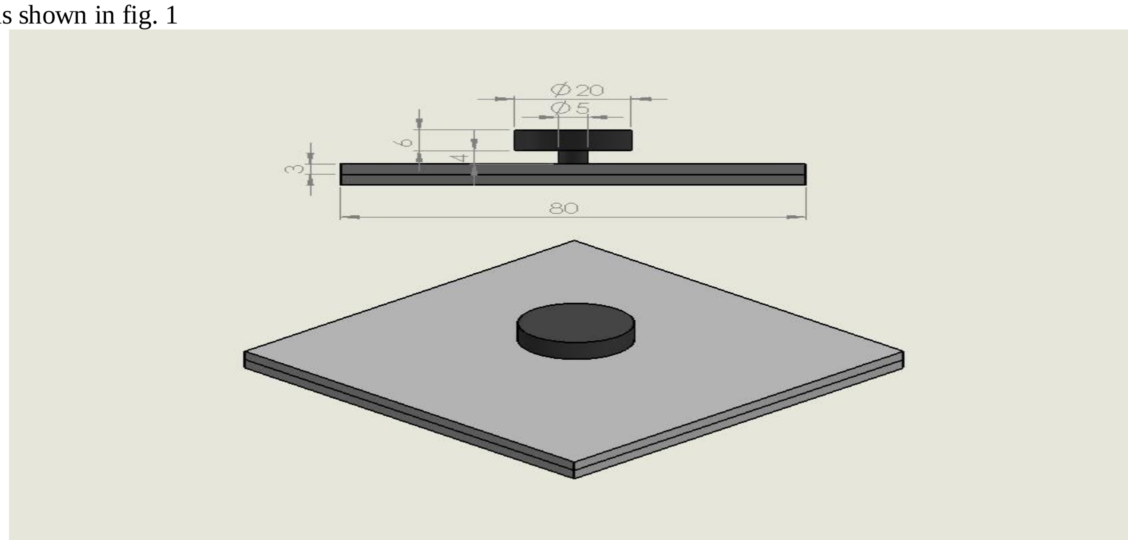


Fig1: Solid model of the FSSW

Process description-

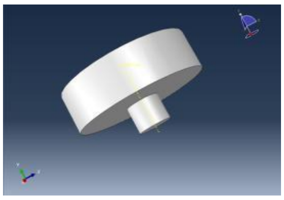
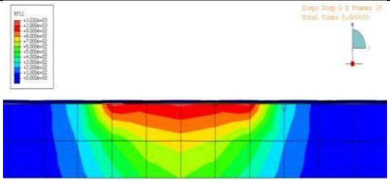
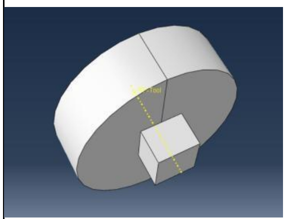
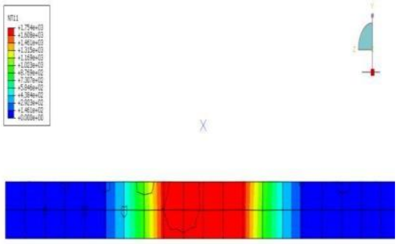
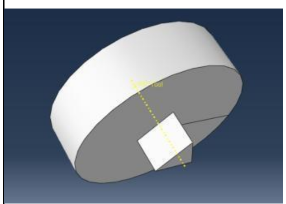
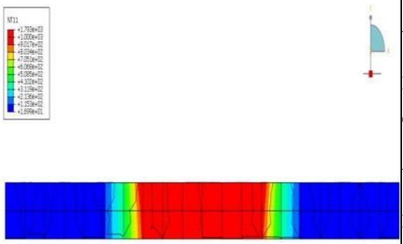
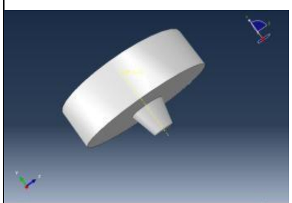
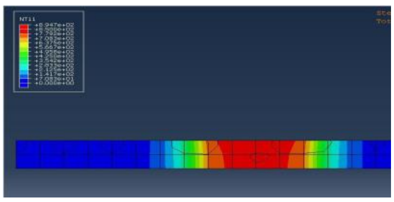
PLUNGING - During this process, a rotating tool with a probe is plunged into the material from the top surface for a certain period of time to generate frictional heat. At the same time, a backing plate contacts the lower sheet from the bottom side to support the downward force.

STIRRING -In this stage for a particular duration of time frictional heat is generated between the wear resistant welding components and work pieces. This heat, along with that generated by the mechanical mixing process softens the materials without melting. Heated and softened material adjacent to the tool causes plastic flow. In addition, the tool shoulder gives a strong compressive force to the material.

DRAWING OUT - After the dwell period, the tool is withdrawn from the plunged zone and drawn away from the material, a solid-phase weld is produced between the upper and the lower sheets. The material hardens on cooling thereby welding the two pieces together [9,10].

IV. RESULTS AND DISCUSSION

FSSW of 3 mm thick Ti6Al4V sheets are presented. Different process conditions were obtained with varying tool rotation and tool pin geometry. From the obtained results it can be stated that, although the best mechanical resistance obtained with the two tools is similar, almost constant resistance is found with the conical pin, while a significant loss of performance is observed for the cylindrical one. A longer dwell time can lead to a higher peak temperature but also to a lower plunging force and torque, which is an indication of higher softening degree of the metals as well as lower material flow stress during welding.

DIFFERENT SHAPE OF TOOL TIPS	**TEMPERATURE RESULT AT 600 RPM**	**DISCUSSION**
 Temperature result of circular tip		The temperature reaches 1032 ^{O}C at 600 rpm. The temperature achieved lies between the plastic state range which means that friction stir spot welding has been successfully done.
 Temperature result of square tip		At 600 rpm the temperature reaches 1754 ^{0}C which is above the melting point material, melting point of material Ti6Al4V is 1632 ^{0}C. The material melts at 600 rpm. The temperature we achieve does not lie between the plastic state range of material Ti6Al4V which means that friction stir spot welding has not been done.
 Temperature result of Triangular tip		At 600 rpm the temperature reaches to 1793 ^{0}C which is above the melting point material, melting point of material Ti6Al4V is 1632 ^{0}C. The material melts at 600rpm.The temperature we achieve does not lie between the plastic state range of material Ti6Al4V which means that friction stir spot welding has not been done.
 Temperature result of conical tip		The temperature reaches 894 ^{O}C at 600 rpm. The temperature we achieve lies between the plastic state range which means that friction stir spot welding has been successfully done.

V. CONCLUSION

We perform the FSSW process on 3 mm thick Ti6Al4V plate sheets. In this, we considered the tool with the Lagrangian model and plate Eulerian model. The model type is the Coupled Eulerian Lagrangian (CEL).Taper tool tip is used in this experiment. We considered the tool material is PCBN which is non-deformable and non-consumable. The rotational speed is 600 rpm, plunge velocity is 4.3mm/time and plunge depth is 4 mm. Plunge time is 4 sec and dwell time is 1.2 sec. The plastic state range of material Ti4Al4V is 850-1100 ^{0}C where the actual welding process is done. In the plastic state the material changes its physical appearance, the material gets softened and ready to weld.

After observation, we can conclude that circular with a taper tool gives effective welding. In addition, the taper tool used low to high RPM (300 rpm to 2000 rpm). The finite element method has been delineated for simulation and analysis of friction stir spot welding process which make use of effective meshing and abatement algorithm using an ABAQUS the combination of this features allow the thermo-elasto-plastic response to be obtained which evidently shows the extension of the thermo-mechanically affected zone and temperature profile quickly after the operation is completed. Without the effective meshing and abatement, schemes severe element distortion during the welding process would prevent the simulation from converging. Even though, the capability of friction stir spot welding to weld high strength, lightweight aluminum alloys to other materials is advantageous, extending this process into high melting temperature materials has proven challenging due to tool cost and tool wear rates.

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