A Comprehensive Review of a Frictional Stir Welding

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Abstract—This paper concentrates on wide review in the field of friction stir welding. Friction stir welding a latest solid state joining technique which is mostly been used in the industries to join dissimilar metal alloys which is not possible to join by conventional welding process. Since, it is a very highly complex process due to having various phase change solid liquid phenomena. Therefore researchers were still working in this field to explore its application by understanding the complex phenomenon of friction stir welding. Various computational and experimentation has been perform to examine the effect of various process parameters such as tool pin configuration, rotational and transverse speed to tool, etc. The work related to FSW till date has been presented in this article.

Keywords—Friction Stir welding, Mechanical behavior, Numerical investigation, CFD

I. INTRODUCTION

Friction stir welding (FSW) is a solid-state joining technique which was invented at The Welding Institute (TWI), UK, in 1991 [1]. The FSW has been found to be effective for joining hard-to-weld metals and for joining plates with different thickness or different materials. In the FSW process a non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of workpieces to be joined and traversed along the line of the joint, as shown in Fig. 1 [2].

As the tool travels, heat is created by the contact friction between the shoulder and the workpiece, and by the plastic deformation of the materials in the stir zone. The high strain and heat energies
experienced by the base metal during stirring causes dynamic recrystallization, which is the formation of new grains in the weld zone [6]. Although Fig. 1 shows a butt joint for illustration, other types of joints, as shown in Fig. 2, also can be fabricated by FSW [8]

Figure 2 Joint configurations for FSW

Rodes et al 1997 7075 Al plate has been successfully joined by friction stir techniques. Unlike fusion welding, this is a solid-state process with no evidence of melting. The weld is characterized by a recrystallized nugget having a 2-4 pm grain size.[4] The dislocation density in the nugget is lowered from that in the parent metal; strengthening precipitates appear to have been solutionized during the welding process, with the larger ones re-precipitating on cooling. The process, thus, provides a method for joining an unweldable aluminum alloy without introducing a cast microstructure.

Ulyssse 2002 This paper presents an attempt to model the stir-welding process using three-dimensional visco-plastic modeling. The scope of the project is focused on butt joints for aluminum thick plates.[5] Parametric studies have been conducted to determine the effect of tool speeds on plate temperatures and to validate the model predictions with available measurements. In addition, forces acting on the tool have been computed for various welding and rotational speeds. It is found that pin forces increase with increasing welding speeds, but the opposite effect is observed for increasing rotational speeds. Numerical models such as the one presented here will be useful in designing welding tools which will yield desired thermal gradients and avoid tool breakage.

Figure 3 Temperature contours (in °C) on the tool and workpiece surfaces [5]
Guerra et al. 2003 use faying surface tracer for investigating the metal flow and nib frozen at the weld zone. The flow comprises of two process, i.e. wiping of material from the advancing front side of the nib and second process is an entrainment of material from the front retreating side of the nib that fills in between the sloughed off pieces from the advancing side.[6]

Song and Kovacevic 2003 present 3D heat transfer model in which; a moving coordinate is introduced to reduce the complexity of modeling the moving tool. During simulation, heat input from the tool and the shoulder is considered. [7]. The obtained results are verified with the experimental result and are within acceptable limit and conclude that preheating of the work piece is beneficial to FSW.

Deng and Xu 2004 perform 2D simulation, where material flow and spatial velocity field around the rotating tool are investigated.[8] And found that material particles in front of the tool pin tend to pass and get behind the rotating pin from the retreating side of the pin. Moreover, exclusive comparison has been addressed for velocity fields based on two different tool work piece interface models.

Heurtier et al 2006 a three-dimensional thermomechanical model for Friction Stir Welding (FSW) is presented. [9] Based on the velocity fields classically used in fluid mechanics and incorporating heat
input from the tool shoulder and the plastic strain of the bulk material, the semi-analytical model can be used to obtain the strains, strain rates, and estimations of the temperatures and micro-hardness in the various weld zones. The calculated results are in good agreement with experimental measurements performed on a AA2024-T351 alloy friction stir welded joint.

![Figure 6 Local heat generation along intersection between tool and centerline [9]](image)

Zhang et al. 2005 Two-dimensional results of the material flow patterns and the residual stresses are presented. The flow of metal during FSW is investigated using tracer particles. It is shown that the flows on the advancing side and retreating side are different. After several rotations the material which is rotating around the nib sloughs off in its wake of the pin, primarily on the advancing side.[10] The residual stresses of the welded plate are investigated in this analysis. The distribution of the longitudinal residual stress along the direction perpendicular to the welding line is a double feature curve. With the increase of the translational velocity, the maximum longitudinal residual stress can be increased.
Lammlein et al. 2009 via tapered retraction procedure and a ramped rotational velocity, Lammlein explore the application to closed contour welding, variable thickness welding, and open-loop control welding. [11] The Effective tool geometries and process variables are establish via experimental analysis. Thermal, tensile, macro section and process force data are obtained with a computational fluid dynamics (CFD) process model. It is revealed that this type of tooling is capable of producing acceptable welds when applied to butted aluminum plates and that similar methods would likely be effective in the applications described previously.

Ji et al 2012 conduct Finite volume analysis using ANSYS Fluent. The effect of shoulder geometry and pin geometry on material plastic flow behavior is studied and reveals that the flow velocity of material inside weldment is increased by decreasing the cone angle of pine or decreasing the width of screw groove.[12] From the view of improvement of material flow, the concentric-circles-flute shoulder is superior than the inner-concave-flute shoulder or the plane shoulder. Therefore, choosing the reasonable shoulder geometry and the reasonable pin geometry can be good for improving the material flow during the friction stir welding process and avoiding the root defects.
Figure 9 Solid model of rotational tool with big groove of screws and Material flow velocity of different sections under the condition of small screw groove [12]

Wang and Colegrove 2013 presents a novel for characterizing the contact conditions that occur during FSW method by explaining the outcomes of mechanical and thermal during stick and slip condition. The proposed model yields more realistic heat generation estimate, as validated by the experimental thermal measurements.[40]

Chen et al 2013 studied the total heat generation and the spatial distribution of the heat flux using CFD. The simulated result of temperature distribution is compared with the experimental result and show good agreement and concludes that the total heat generated was 0.75 times proportional to the power of the tool rotating speed. Furthermore, in the shoulder region the heat flux at different rotating rate is a parabolic function [13].

II CONCLUSION

On the basis of review of friction stir welding various conclusions has been drawn

- In friction stir welding Rotational tool is the most important geometry for FSW and greatly influences the material flow behavior during FSW
- In FSW, the maximum flow velocity of material appeared near the edge of shoulder
- It has been found that the conical tool can passively accommodate variation in the height of the material surface relative to the tool, due to material thickness variations in linear welds or system eccentricities in rotary welds
- The conical tool can be used for in-process adjustment of penetration depth
- On increasing the transverse and rotational speed of tool the residual stress increases concurrently.
- The grain structure is highly been affect by the temperature distribution at the weld zone.
- At the retreating side and advancing side the temperature variation is quite different.
- The grain structure at the retreating side and advancing side is quite different

REFERENCES