Parametric Optimization of Friction Stir welding using Different Tool Profiles: A Review

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Abstract: The parameters like tool rotational speed, tool profile, depth of cut, feed etc. are affecting the properties of welded joints. Amongst the emerging new welding technologies, friction stir welding (FSW), invented and established by The Welding Institute (TWI) in 1991, is used frequently for welding of high strength aluminium alloys such as AA6061, AA6082, etc. which are difficult to weld by conventional fusion welding techniques. Friction welding (FW) is a collection of a series of friction-based solid state joining processes which can produce high quality welds of different components with either similar or dissimilar materials and has been attracting increasing attention. The project aim is to weld two plates of AA 6082 using different tool profiles and to optimize the strength of joint.

Keywords: Speed, Feed, Depth of cut, Tensile strength, bending strength, Hardness.

1. INTRODUCTION

A method of solid phase welding, which permits a wide range of parts and geometries to be welded are called Friction Stir Welding (FSW), was invented by W. Thomas and his colleagues at The Welding Institute (TWI), UK, in 1991. Friction stir welding has a wide application potential in ship building, aerospace, automobile and other manufacturing industries. The process proves predominance for welding non-heat treatable or powder metallurgy Aluminum alloys, to which the fusion welding cannot be applied. Thus fundamental studies on the weld mechanism, the relation between microstructure, mechanical properties and process parameters have recently been started. Friction stir welding is a relatively simple process as shown in Fig.1. In recent times, focus has been on developing fast, efficient processes that are environment friendly to join two dissimilar materials. The spotlight has been turned on Friction stir welding as a joining technology capable of providing welds that do not have defects normally associated with fusion welding processes. Friction stir welding (FSW) is a fairly recent technique that utilize Non consumable rotating welding tool to generate frictional heat and plastic deformation at the welding location, thereby affecting the formation of a joint while the material is in the solid state. Figure.1 shows the schematic drawing of friction stir welding representing all the relevant parameters of the process. A rotating tool is pressed against the surface of two abutting or overlapping plates. The side of the weld for which the rotating tool moves in the same direction as the traversing direction, is commonly

Known as the 'advancing side'; the other side, where tool rotation opposes the traversing direction, is known as the 'retreating side'.

2. APPLICATION

Commercial applications have been reported across many industries, and some selected examples are shown below which illustrate the widening appeal of the process. This list is representative rather than exhaustive, and it should be emphasised that new applications are appearing all the time. It should be noted that FSW does not restrict the operating temperature range of aluminium alloys, with applications ranging from cryogenic temperatures (e.g. liquid oxygen and liquid hydrogen rocket fuel tanks) to mildly elevated temperatures (e.g. heat exchangers in heating systems). Most FSWs used in production are butt welds, although lap welds and friction stir spot welds are also being applied with increasing frequency.

3. PROCESS PARAMETERS

1. Speed: by increasing the speed of tool the temperature rise also increase, so proper tool speed is required.
2. Feed: with the slower speed tool stays longer in contact thus increase the temperature, so proper tool feed is required.
3. Depth of cut: the depth of cut should be according to the thickness of the plate to be welded.
4. Tool profile: different tool profiles interact differently with material of plates to be welded thus optimum tool profile should be selected.
4. LITERATURE SURVEY

A. Friction Stir welding (sept.-2014).
(Karan Singla et al., 2014)

Here in this paper Karan Singla et al. investigated the general information about the Friction stir welding. Friction Stir Welding (FSW) was invented by Wayne Thomas at TWI (The Welding Institute), and the first patent applications were filed in the UK in December 1991. Initially, the process was regarded as a “laboratory” curiosity, but it soon became clear that FSW offers numerous benefits in the fabrication of aluminum products. Friction Stir Welding is a solid-state process, which means that the objects are joined without reaching melting point. This opens up whole new areas in welding technology. Using FSW, rapid and high quality welds of 2xxx and 7xxx series alloys, traditionally considered un-weld able, are now possible. [1]

B. An overview of friction stir welding (may-October 2013).
(Sureshbabu et al., 2013)

In their research paper they discussed the basic concept about friction stir welding, microstructure formation, influencing process parameters and different type of tool to be used. FSW tool is considered as a heart of the welding process which has two primary parts namely shoulder and pin, which heats the work piece material by friction. Shoulder part of the tool frictionally heats the portion of the work piece and induces the axial downward force for welding consolidation. Three types of shoulder end surfaces are normally used, lat, convex, concave shoulder end. Shoulder end surfaces can also have features like scrolls, ridges, knurling, grooves and concentric circles in order to increase the weld quality and material mixing. In their research they suggested as if joining is established by means of grain refinement which will also lead to increase in mechanical properties. During joining, the number of parameters required to control is limited and which can be easily controlled to produce the sound weld. The paper will also discuss some of the process variants of FSW such as Friction Stir Processing, Friction stir Spot Welding. [2]

(Mandeep Singh Sidhu et al., 2012)

In their research paper they review on the friction Stir welding process, various welding variables like tool rotation, transverse speed, tool tilt, plunge depth and tool design for the welding of aluminium alloys or various dissimilar alloy. Applications, future aspects and several key problems are also described. They summarized key benefits of FSW like environmental, energy, metallurgical benefit. They investigate the effect of tool rotation and transverse speed, tool tilt and plunge length; Tool design. They suggested five commonly used tools profile like as straight cylindrical, tapered cylindrical, threaded cylindrical, triangular and square pins to fabricate the joints, in FSW. They concluded in their future scope is to analyses the influence of the processing parameters on the transition, plunging and welding stages. They have to perform the analysis on other heat treatable and non-heat-treatable aluminium series. The future work will also be focused on the investigation of the thermo-mechanical phenomenon, leading to the uncharacteristic force and torque behaviour, etc. They observed following type of problem.

- Forming of FSW welds is still challenging due to the limit formability.
- The studies on the relationship between formability and micro structural stability of FSW joint are rare. (Yuan S.J. et al., 2012).

The essential drawback of this technique, however, is the low stability of the welded material against abnormal grain growth during subsequent annealing, (Mironov S. et al., 2012). [3]

D. Influence of process and tool parameters on friction stir welding, (July-September 2014).
(Aleem pasha m.d. et al., 2014)

In this research they reviewed of basic concepts of Friction Stir Welding. Applications and advantages of FSW, role of tool materials and tool design, contribution of welding process parameters and mode of metal transfer for producing a better weld. Further the extensive application of Friction Stir welding on magnesium and Aluminium alloys. They observed is expected that this process will produce a weld with less residual stress and distortion as compared to the fusion welding methods, since no melting of the material occurs during the welding. They reviewed about the weld microstructure in which the observed complex interactions between simultaneous thermo mechanical processes. These interactions affect the heating and cooling rates, plastic deformation and flow, dynamic recrystallization phenomena and the mechanical integrity of the joint. The grains within the nugget are often an order of magnitude smaller than the grains in the base material. The thermo mechanically affected zone (TMAZ) occurs on either side of the stir zone. The strain and temperature levels attained are lower and the effect of welding on the material microstructure is negligible. The heat affected zone (HAZ) is common to all welding processes. This region is subjected to a thermal cycle but it is not deformed during welding. They regards the material selection by Weld quality and tool wear are two important considerations in the selection of tool material, the properties of which may affect the weld quality by influencing heat generation and dissipation. The weld Microstructure may also be affected as a result of interaction with eroded tool material. Apart from the potentially undesirable effects on the weld microstructure, significant tool wear increases the processing cost of FSW. From this research paper we concluded that friction stir welding Cost effective and long life tools are available for the FSW of aluminium and other soft alloys. They are needed but not currently available for the commercial application of FSW to high strength materials. Tool material properties such as strength, fracture Toughness, hardness, thermal conductivity and thermal expansion coefficient affect the weld quality, tool wear and performance. [4]
E. Comparison of heavy alloy tool in friction stir welding (Jan-Feb, 2012).
(Dr.T.Parameshwaran Pillai et al., 2012)
Investigation is done by the Dr. T. Parameshwaran Pillai, S.K.Selvam, related to Friction stir welding in that renowned technology widely used for joining materials. It avoids many of the common problems that persist in fusion welding. It is most suitable for joining soft materials like Aluminium and Magnesium alloys. Though this technology has been proven commercially feasible for soft materials, the same for harder alloys is yet to be established. The development of cost effective and durable tools, which lead to structurally sound welds, is still awaited. Material selection and design intensely affect the performance of the tools. Investigation effort has been made for newer compositions of heavy alloy tool manufactured through powder metallurgy route. Establishing welding parameters such as tool rotations speed, traverse speed and various mechanical properties of Heavy alloy tool by numerical analysis and computational fluid dynamics model predicted values from it. Heavy alloy tool is suitable for cost effective and durable tool in hard alloys such as stainless steel. [5]

F. Effect of Tool Tilt Angle on Aluminium - Friction Stir Welds (2014).
(G. Gopala Krishna et al., 2014)
In this paper attempt has been made by G. Gopala Krishna, P. Ram Reddy & M. Manzoor Hussain to study the influence of tool tilt angle on Aluminium 2014-T6 welds. A study on FSW of AA2014 Aluminium alloy at varying tool tilt angle ranging from 0 to 3 degrees at an interval of 0.5° and keeping other process parameters constant are presented in this paper. Present work also examines the force and torque during FSW with respect to defect development. This is due to owing to process parameters variation which results in variation in heat generation. The force on the pin in the metal flow direction (which is also called X-axis force) was correlated with defect formation, high X-axis force is recommended for defect free welds. [6]

(P. Prasanna et al., 2013)
In this paper attempt has been made by P. Prasanna, Dr.Ch. Penchalayya, Dr. D. Anandamohana Rao to study the effect of four different tool pin profiles on mechanical properties of AA 6061 aluminium alloy. Four different profiles have been used to fabricate the butt joints by keeping constant process parameters of tool rotational speed 1200RPM, welding speed 14mm/min and an axial force 7kN. Different heat treatment methods like annealing, normalizing and quenching have been applied on the joints and evaluation of the mechanical properties like tensile strength, percentage of elongation, hardness and microstructure in the friction stirring formation zone are evaluated. From this investigation, it is found that the hexagonal tool profile produces good tensile strength, percent of elongation in annealing and hardness in quenching process. [7]

(L.V. Kamble et al., 2013)
Tool design and selection of process variables are critical issues in the usage of this process. This paper tackles the same issues for AA6101-T6 alloy (material used for bus bar conductor, requiring minimum loss of electrical conductivity and good mechanical properties). Two different tool pin geometries (square and hexagonal) and three different process variables, i.e. rotational speeds and welding speeds were selected for the experimental investigation. The welded samples were tested for mechanical properties as well as microstructure. It was observed that square pin profile gave better weld quality than the other profile. Besides, the electrical conductivity of the material was maintained up to 95% of the base metal after welding. [8]

I. Parametric Analysis of Friction Stir Welding on AA6061 Aluminium Alloy.
(V.L. Srinivas et al., 2012)
This paper aim to investigate the influence of process parameters on mechanical properties of friction stir welded AA6061 Aluminium alloy. Tool diameter, rotational speed and welding speed are found to be the key factors during Friction Stir Welding. Experiments are planned as per the matrix developed based on Design of Experiments. Hardness is measured using Vickers Hardness Tester, Tensile is predicted with Universal Testing Machine and Yield Strength and % of elongation is estimated using the predicted data. Analysis of variance (ANOVA) is carried out to check the adequacy of the experimental domain. The effect of input parameters over the response are presented and discussed.

Following conclusions are obtained:
1. Tool probe geometry is very much responsible for deciding the weld quality. 2. The relationships between tool probe geometry and process parameters for FS welding of AA6061 aluminium alloy have been established. The response surface methodology is adopted to develop the regression models, which are checked for their adequacy using ANOVA test and found to be satisfactory. 3. Confirmation experiments shows that the developed models are reasonably accurate. [9]

J. OPTIMIZING THE PROCESS PARAMETERS OF FRICTION STIR WELDED JOINT OF MAGNESIUM ALLOY AZ31B.
(G.Surya Prakash Rao et al., 2013)
This paper deals with Friction stir welding of AZ31B Mg alloy by using H13 Tool at different rotational speeds and welding speeds. Experiments were conducted according to L4 Orthogonal array which was suggested by Taguchi. Optimum parameters for optimum Tensile strength, Hardness and Ductility were found with the help of S/N ratios. Therefore optimization of input process parameter is required to achieve good quality of welding. In this experiment the effect of process parameters on welded joint was studied and optimizes the parameter by using Taguchi method and stated regression equation for tensile strength
and hardness. Assigns the rank to each factor which are having more influence on the mean of tensile strength and hardness. [10]

5. CONCLUSION
Thus we can verify the different input parameters like speed, feed, depth of cut, tilt angle and profile of tool for friction stir welding and tool geometry to get optimum welded joint properties like better tensile strength, bending strength and microstructure.

REFERENCES