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Review on Optimization Techniques of friction stir welding

P.Satheesh Kumar[1a], P.Vigneshwaran[1b], T.SriKapilnath[1c]
[1a,1b,1c]UG Scholars
Department of Mechanical Engineering, Sri Ramakrishna Engineering College
Coimbatore - 641022

ABSTRACT

Frictional Stir Welding (FSW) is a technique employed to fuse two or more metal pieces in order to improve its properties. Depending on the tool rotational speed, Transverse speed, Axial Force the properties of the jointed metals varies such as yield strength, tensile strength, corrosion resistance. This review paper provides an overview about the (a) comparison of ultimate tensile strength (UTS) along with the tool rotational speed and the axial force applied in the Aluminium and its alloys (b) the effect of rotational speed in the result of % of elongation in the welded area (c) defects in the welded surface in response to the rotational speed (d) comparison of the Response Surface Methodology (RSM), Taguchi method, Artificial neural network (ANN).

I. INTRODUCTION

FSW is a new technology, of solid state joining process for similar and dissimilar metals. FSW was invented and patented in 1991 by TWI (THE WELDING INSTITUTE) at CAMBRIDGE in UK.. Joining methods for similar and dissimilar polymer structures are used in industry[1]. By this process thickplates can also be welded with high productivity[2]. FSW welds have improved mechanical properties compared with fusion welds[3].This technique can be used to join high strength aluminium alloys and other metallic materials that are difficult to be joined using the conventional fusion welding processes. In FSW, a rotating tool is forced down into the joint line under the conditions where the frictional heating is sufficient to cause a local increase in the temperature of the material to the range where it is readily deformed plastically[5].In conventional welding process it reduces the strength, hot cracking alloy segregation, partial melting zone and porosity for magnesium alloy components, so that it decreases the mechanical properties and corrosion resistance[6]. To overcome the above mentioned drawback, FSW process can be used to weld magnesium alloys.

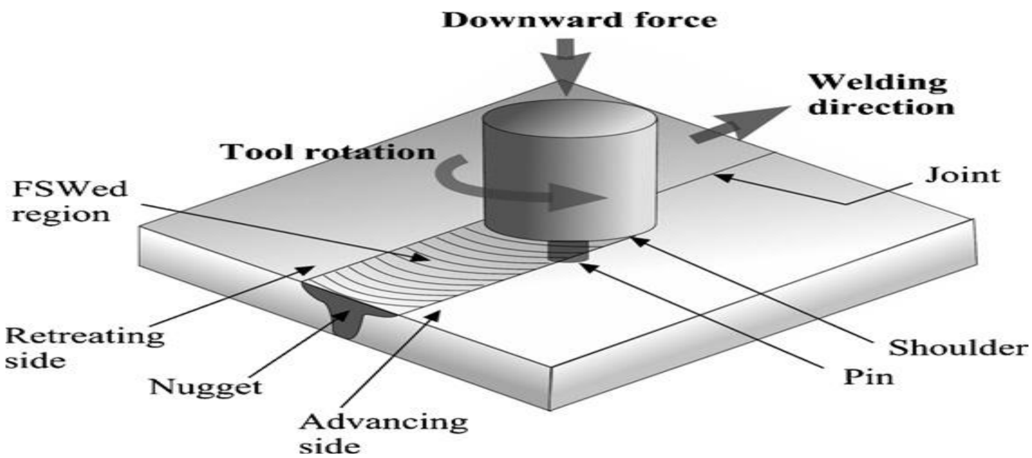

Fig 1 Friction Stir Welding Process

It is a dynamically a continuous solid state joining process that has lower welding temperature , excellent weldability for similar and dissimilar aluminium alloys[7]. FSW the joining process is accomplished by material flow below the melting temperature, many joint defects caused by joint material melting such as porosity, grain boundary cracks and alloys segregation can be eliminated or adequately reduced. These process specialities have FSW very practical for joining dissimilar alloys[8]. The maximum temperature in the aluminium material being welded is usually less than 80% of its melting temperature , Jayaraman et al . developed an empirical relationship to predict the tensile strength the friction stir welded cast aluminium alloy using RSM Rajakumar et al. proposed model using RSM to predict tensile strength of FSW joints of AA 7075 Al alloy [9]. Finally conclusions are made with a particular view on future challenges and research directions.

2. WELDABILITY

The weldability, also known as jointability, of a material refers to its ability to be welded. Many metals and thermoplastics can be welded, but some are easier to weld than others. A material's weldability is used to determine the welding process and to compare the final weld quality to others materials. INTERNATIONAL ORGANISATION FOR STANDARDIZATION(ISO) defines weldability in ISO standard 581-1980 as "Metallic material is considered to be susceptible to welding to an established extent with given processes and for given purposes when welding provides metal integrity by a corresponding technological process for weldedparts to meet technical requirements as to their own qualitiesas well as to their influence on a structure they form.

The weldability of aluminium alloy varies significantly, depending on the chemical composition of the alloy used. Aluminium alloys are susceptible to hot cracking, and to combat the problem, welders increase the welding speed lower the heat input.Preheating reduces the temperature gradient across the weld zone and thus helps reduce hot cracking, but it can reduce the mechanical properties of the bas material and should not be used when the base material is restrained. The design of the joint can be changed as well, and a more compatible filler alloy can be selected to decrease the likelihood of hot cracking. Aluminium alloys should also be cleaned prior to welding, with the goal of removing all oxides, oils, and loose particles from the surface to be welded. This is especially important because of an aluminium weld's susceptibility to porosity due to hydrogen and dross due to oxygen.

3. OPTIMIZATION

Finding an alternative with the most cost effective or highest achievable performance under the given constraints , by maximizing desired factors and minimizing undesired ones. In comparison, maximization means trying to attain the highest or maximum result or outcome without regard to cost or expense.

4. OPTIMIZATION TECHNIQUES

The optimization techniques in friction stir welding Artificial Neural Network(ANN), Response Surface Methodology(RSM), Taguchi Method.

5. PROCESS PARAMETERS

The important parameters taken in FSW process are Tool Rotation speed, Transverse speed, Axial Force. The mechanical properties such as Yield Strength(YS), Ultimate Tensile Strength(UTS) and Percentage Elongation(%EI).

6. RESPONSE SURFACE METHODOLOGY

RamanjaneyuluKadaganchi[3]et.al researched and published" Optimization of process parameters of aluminium alloy AA2014-T6 friction stir welds by Response Surface Methodolgy". The researchers explainthat this work presents the formulation of a mathematical model with process parameters and tool geometry to predict the responses of FSW of AA 2014-T6 aluminium alloy, viz yield strength,tensile strength and ductility. The most important process parameters are spindle speed, welding speed, tilt angle and toolpin profile. The yield strength(YS), ultimate tensile strength(UTS) and percentage elongation (EI%), are taken as the outputs. Validation trials were carried out by the researchers to validate these results. These results indicates that the friction stir welds of AA 2014-T6 aluminium alloy welded with hexagonal tool pin profile have the highest tensile strength and elongation, whereasthe joints fabricated with conical tool pin profile have the lowest tensile strength and elongation.

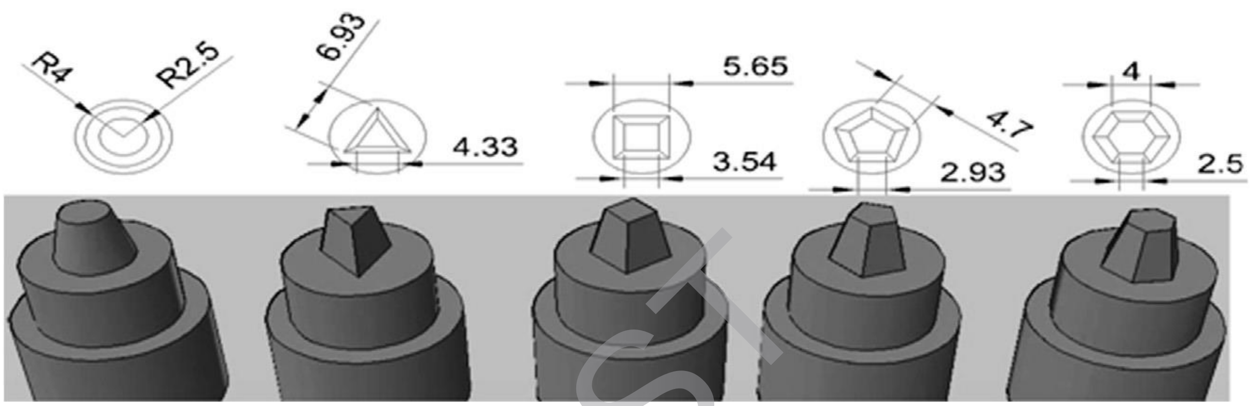

Fig 2 Geometry of tool profiles

G. RAMBABU [5]et.al researched and published "Optimization of friction stir welding parameters for improved corrosion resistance of AA2219 aluminium alloy joints". The researchers main objective of this work is to develop a mathematical model to predict the corrosion resistance of friction stir welded AA2219 aluminium alloy by incorporating FSW process parameters. In this process the welding parameters are tool pin profile, rotational speed, welding speed and axial force. This welding parameters plays a vital role in determining the microstructure and corrosion resistance of welded joint. Dynamic polarization testing was carried out to determine critical pitting potential in millivolt, which is a criteria for measuring corrosion resistance and the data was used in model. To maximize the corrosion resistance of the FSW aa2219 aluminium alloy joints mathematical model was optimized using the stimulated annealing algorithm optimization technique.

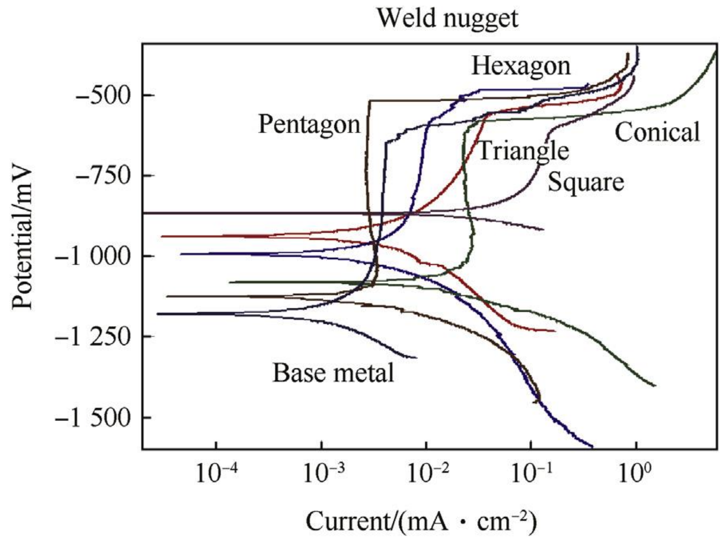

Fig3Potentio-dynamic polarization curves of AA2219 FS welds by five tool pin profiles.

The results indicate that the pin has significant effect on the joint structure and the corrosion properties. The best quality weld was acquired using hexagonal tool profile. This model was developed to predict the corrosion resistances of FSW AA2219 aluminium alloy joints with 95% of confidence level.

G. Elatharasan [9] et.al researched and published " An experimental analysis and optimization of process parameter on friction stir welding of AA6061-T6 aluminium alloy using RSM". In this analysis the welding parameters are tool rotational speed, welding speed and axial force. The central composite design technique and mathematical model was developed by RSM with three parameters , three levels and 20 runs, was used to develop the relationship between the FSW parameters and the results (tensile strength, yield strength and % elongation) were established.

EFFECT OF PROCESS PARAMETER ON UTS

The decrease in tool rotational speed and tool axial force result in the decrease in UTS of the FS welded joints, when the welding speed is decreased it results in the increase in UTS.

EFFECT OF PROCESS PARAMETRS ON YS

The defects in WZ of joint is decreased due to the increase in rotational speeds, decrease in welding speeds and higher axial force. The YS is increased due to enough friction and plastic flow of material.

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EFFECT OF PROCESS PARAMETER ON %E

The defects in WZ of joint is decreased due to the increase in rotational speeds, decrease in welding speeds and higher axial force. The TE is higher due to enough friction and plastic flow of material.

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R.PalaniveL[l0] et .al researched and published a journal on "Prediction and optimization of wear resistance of friction stir welded dissimilar aluminium alloy". In this paper they attempt to improve the FSW process parameters to identify the wear resistance of friction stir welded dissimilar aluminium alloys. To minimize the number of experiments 4 factors, 5 levels central composite rotatable design are used. The tool pin profile, tool rotational speed and axial force are taken as the welding parameters. The wear resistance of the welded joints has been analyzed and the predicted trends are developed by analyzing the results of the FSW process parameters. Response Surface Methodology (RSM) optimization technique is used to maximize the wear resistance.

7. ARTIFICIAL NEURAL NETWORK (ANN)

A.Paoletti[1]et.al published a journal "Optimization of friction stir welding of thermoplastics". In this paper friction spot stir welding is applied to poly carbonate sheets of 3mm thickness. The tool rotational speed, preheating time, tool plunge rate (mm/min) are taken as the welding parameter. The result of FSSW parameters on the maximum torque, maximum plunging force and joint strength of polycarbonate sheet welds has been modelled by means of Artificial Neural Network. The accuracy of the ANN model predictions has been evaluated by considering different indicators including the mean square error and maximum error correlation coefficient R^2.

N.D. Ghetiya[17] et.al published a paper on "Prediction of tensile strength in friction stir welded aluminium alloyusing artificial neural network".In this paper the welding parameters are tool shoulder diameter, tool rotational speed, welding speed and axial force play a major role in deciding the joint strength. Here the 4 mm thick AA8014 plate have been welded by friction stir welding process. ANN has been developed based on back propagation (BP) of error for prediction of the tensile strength in FSW. The input welding parameters are tool shoulder diameter, tool rotational speed, welding speed and axial force whereas the output parameter of the model is the tensile strength of joint. The ANN was subsequently trained with experimental data. ANN is tested using experimental data not used during training. The results showed that the outcomes of the ANN are in good agreement with the experimental data; this indicates that the developed neural network can be used as an alternative way for calculating tensile strength for given process parameters. The developed neural network can be used to identify the tensile strength of welded aluminium plate for the given FSW process parameters.

8. TAGUCHI METHOD

R.K. Kesharwani[4] et.al published a journal paper "Multi Objective Optimization of Friction Stir Welding Parameters for Joining of Two Dissimilar Thin Aluminium Sheets". To design the experiments L9 orthogonal array has been used and the experiments have been conducted in VMC by varying the rotational speed, worktable translation speed, tool shoulder diameter and tool pin geometry. The weld strength and percentage elongations are calculated using uniaxial tensile test. According to taguchi grey method, 1800 rpm of rotational speed, 50 mm/min worktable translation speed, 20 mm of tool shoulder diameter and square pin geometry are the optimum parameters for fabrication of AA5052-H32 and AA5754-H22 dissimilar 2.0 mm thin tailored friction stir butt welded blanks.

Prakash Kumar[6] et.al published a paper "Multi-response optimization of process parameters in friction stir welded AM20 magnesium alloy by Taguchi grey relational analysis". The main purpose of this paper is to optimize the parameter to get the better mechanical properties offriction stir welded AM20 magnesium alloy using Taguchi Grey relational analysis (GRA). The welding parameters are translation speed, tool rotation speed, tool shoulderdiameter and plunging depth. By using Taguchi's L18 factorial design the experiments were done. The welding parameters were optimized and the parameters are arranged based on the Taguchi Grey relational analysis. The percentage influence of each process parameter on the weld quality was also quantified. A better experimental run was conducted using optimal process condition, to show the improvement in mechanical properties of the joint.

This study also shows the feasibility of the GRA with Taguchi technique for improvement in welding quality of magnesium alloy.

C. Elanchezian[8] et.al published a paper on" Parameter Optimization of Friction Stir welding of AA8011-6062 using Mathematical Method". In this paper The basic principle of Friction stir welding (FSW) is heating the metal to a temperature below the re-crystallization temperaturethus reducing the welding crack such as porosity band hot crack with are commonly formed in the conventional welding method due to alloy's low crystallization temperature and high heat dissipation nature. The quality of friction welding is good when compared to other fusion welding technique. The main influence parameter in FSW is rotational speed welding traversing speed and pressure applied against the joint. AA6061 and AA8011 aluminium alloy has high strength to weight ratio. They have main application in the field of marine, aerospace and automobiles. As it is difficult to perform number of experiments to find out the level combinations which yield good mechanical properties like tensile strength, impact strength and hardness number, Taguchi L9 orthogonal array is used to reduce the number of experiment. The material is bought and are cut into specific material and polished. They are then welded based on the different experiment obtained from Taguchi method. After welding is done the metals are cut as per the specific standard. The results are then analyzed by using ANOVA statistical tools. ANOVA table clearly shows the percentage of contribution of each factors can be determined. The best welding quality is found out by comparing the result obtained from tensile testing, impact testing and by micro-hardness testing. Scanning Electron Microscope (SEM) technique was used to examine the quality of surface texture.

JAIGANESH.V [2] et.al published a journal on "Optimization of process parameters on friction stir welding of high density polypropylene plate". The frictional heat produced through a contact between the rotating tool and the work piece in friction stir welding is the joining of thermoplastics. The tool rotational speed varies between 800 and 1200 (rpm), transverse speed varies between 40 and 200 (mm/min), axial force is from 1to 5(KN) are taken as the process parameters. Here they attempted to fuse the polypropylene plate of 5mm thickness with different tool profiles (square, cylindrical and triangular threaded pin profile). The tensile strength and micro structural analysis are evaluated to test the quality of joint. The yield strength of welded material was found to be10 Mpa which was almost 45% of the parent materials strength and characteristic. The optimized spindle speed of 950 to 1000 rpm and feed rate of 9 to 12mm/min and tilt angle of 1degree, a better weld was obtained.

AtulSuri(7) et.al published the paper "An Improved FSW Tool for Joining Commercial Aluminum Plates". Here the aluminum plate of 6.5 mm thickness was welded by friction stir welding process using improved flat pin tool with side radius. The flat pin tool is compared with standard straight threaded pin tool with flat collar made of hardened steel. The tool rotational speeds ranging from 400 rpm to 1400 rpm, at a constant feed rate at 30 mm/min for making comparison between the improved flat pin tool and the standard straight threaded pin tool and the effect of friction stir welding is studied on toughness, strength, microstructure, hardness. The standard straight threaded tool produces lower tensile strength than the newly improved flat pin tool in the whole range of tool rotational speed. The improved flat pin tool produces a better tensile strength. The improved flat pin tool increases the hardness of weld zone at lower tool rotational speed, but the refined microstructure is identified on the surface of the weld zone when the tool rotational speed is high. The surface finish gets decreasedwhen the tool rotational speed maintains 1400 rpm in standard straight threaded pin tool. This is due to excessive melting of the base metal in the weld nugget using standard tool whereas improved tool produces better surface at 1400rpm. The increase of rotational speed decreases the hardness of the workpiece. Improved flat pin tool indicates better hardness of weld zone in the entire range of tool rpm. Maximum percentage elongation is observed to be 4.0% using improved tool at 1400rpm.

Ho-Sung Leea,b et.al(13) published the paper**"** Friction Stir Welding Process of Aluminum-Lithium Alloy 2195". The process uses a rotating tool with a profiled pin that penetrates the parts to be joined; the tool then starts to travel along the join line. By keeping the tool rotating and moving it along the join line to be welded, the softened material due to the frictional heat is stirred and mixed together by the rotating pin forming a weld in solid state without melting. FSW provides a better welding over conventional fusion welding and is preferred for joining of Al-Li alloys. The temperature distribution during FSW is measured because friction stir welding is both the deformation and thermal process. For different friction stir welding conditions the microstructure and mechanical properties of welded joint were investigated. While welding the surface temperatures are measured and by using microscopy the microstructure was characterized. The effect of surface oxide on the tensile strength of joint is investigated by comparing to specimen without surface oxide.By lowering the rotating speed condition of 300 and 400 rpm the effect of removing oxide is effective.

S. Chainaronget.al**(**12**)** published the paper" Friction Stir Processing of SSM356 AluminiumAlloy ".By friction stir processing the mechanical properties of aluminium alloys are improved which is a solid-state joining technique for microstructural modification using the heat from a friction and stirring. Travelling speed, rotational speeds are taken as the welding parameters. The parameters of friction stir welding for aluminum alloys were studied at three different travelling speeds: 80, 120 and 160 mm/min under three different rotation speeds 1320, 1480 and 1750 rpm. 64.55 HV is the hardness of friction stir welding which was higher than the base metal (40.58 HV). The optimal processing parameter was travelling speed at 160 mm/min with therotation speed at 1750 rpm. The microstructure after the friction stir welding at all conditions have a very refined structure, which consists of a silicon particles in aluminium alloy matrix uniformly distributed throughout the area to be stirred. The travelling speed at 120 and 160 mm/min with any tool rotational speed increases the hardness of the workpiece. The highest hardness is obtained at 1750 rpm with travel speed at 160 mm/min, is equal to 64.55 HV, an increase of 59.07% compared to the base metal. It was found to be that the rotational speed of 1750 rpm and the travelling speed of 160mm/min provides a good tensile strength.

CONCLUSION

Following points are the conclusion for the optimization technique of friction stir welding that are reviewed

Rotational speed is one of the important parameters which plays a major role in friction stir welding process. Increase in rotational speed increases the yield strength, percentage elongation for aluminium alloy. The ultimate tensile strength will also increase when the axial force and tool rotational speed increases. In Response surface methodology the Hexagonal Tool Profile gives a better weld quality in friction stir welding process have the highest tensile strength and elongation for aluminium alloy. Conical tool pin profile has the lowest tensile strength and elongation. It also predicts the corrosion resistance while using the hexagonal tool pin profile. Thus yield stress, percentage elongation; ultimate tensile strength can be increased using friction stir welding process by varying the tool rotational speed, transverse speed, axial force.

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