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A Review of Using Response Surface Methodology in Friction Stir Welding

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ABSTRACT

Friction Stir Welding (FSW) is a comparatively new joining process that has exhibited many advantages over traditional arc welding processes, including greatly reducing distortion and eliminating solidification. Friction stir welding used to join high strength joints aluminum pipes. The present work explains review and overview of Response Surface Methodology in Friction stir welding which contain the basic connotation of the process, mechanical properties and Suggested model in FSW process. This paper gives the review of basic concepts of response surface methodology in Friction Stir Welding for alloys on process parameters. It is established that response surface methodology in FSW of alloys is appropriate an increasingly overripe technology with many commercial applications.

Keywords: *Friction Stir Welding; Alloy; Response Surface Methodology.*

1.0 Introduction

The aluminum alloys are increasingly used in many significant industrialization areas, such as the automobile industry, aeronautic and military, because of their less density and good mechanical properties; however, the welding of aluminum alloys has always represented a great challenge for designers and technologists. Many difficulties are correlating with this kind of joint process. It is clear that earnest problems, such as tenacious oxide layer cavities, hot cracking sensitivity, and porosity, may occur when fusion welding is applied to aluminum alloys. Furthermore, the conventional techniques, such as fusion welding, often lead to significant strength deterioration in the joint because of a dendritic structure formed in the weld zone.

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)[1].

Dhancholia et al. [2] in this study dissimilar alloys of aluminium. Process parameters like rotational speed, welding speed, tool design, vertical force plays important role in determining the joint properties. Rotational speed and welding speed has its major role in producing the necessary frictional heat to plasticise the material which on solidification produces the weld joint. The welds are taken on rotational speed of 800 rpm to 1000 rpm and welding speed for 30 mm/min to 50 mm/min. Response surface methodology is used to optimise the parameters and responses taken as mechanical properties like tensile strength, yield strength, impact strength, and hardness value.

Pawarr [3] in this work to Welding is a multiinput-out put process in which quality of welded joint is dep ends upon a input parameter. Therefore optimization of input process parameter is required to achieve good quality of welding. There are so many methods of optimization in which Taguchi method and Response surface methodology are selected for optimization of process parameter. In this review the effect of process parameter on welded joint studied and optimizes the parameter by using Taguchi method and Response surface methodology. The study of Friction stir welding of Aluminium alloy and High density polyethylene sheets shows the improvement in welded joint quality by optimization of process parameter. The main process parameters which affect the strength of welded joint is tool rotational speed, welding speed, axial force and tool pin profile.

El-Kassas et al. [4] This work presents a systematic approach to addition welded joints of 6061 aluminum pipe fabricated by friction stir

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welding of pipes has been investigated. 5%, 10%, 15% and 20% Aluminum Oxide (Al2O3) powder was added to weld interface. Welding was performed on the pipe with different material thickness 2 to 4mm, rotational speeds 1800 RPM and a traverse speed 4 mm/min was applied.

The Mechanical properties of welded joints were investigated using different mechanical tests, including nondestructive test (visual inspection) and destructive test (tensile strength and hardness). This paper presents indicated that the addition percentage of added material has a major effect on the mechanical properties of friction stir welding of pipes joint. The results have been obtained at 20% Aluminum Oxide (Al2O3) powder at the weld interface.

Elatharasan[5]The welding parameters such as tool rotational speed, welding speed and axial force plays a major role in deciding the joint characteristics. In this investigation central composite design technique and mathematical model was developed by response surface methodology with three parameters, three levels and 20 runs, was used to develop the relationship between the FSW parameters (rotational speed, traverse speed, axial force,) and the responses (tensile strength, Yield strength (YS) and %Elongation (%E) were established.

Shanavas[6]Friction stir welding between AA5052-H32 aluminium plates is performed by central composite design technique of response surface methodology. It is found that the welding parameters such as tool pin profile, tool rotational speed, welding speed, and tool tilt angle play a major role in deciding the joint characteristics. The joints fabricated using tapered square pin profile tool with a tool rotational speed of 600 r/min, welding speed of 65 mm/min, and tool tilt angle of 1.5° result in an unexpected weld efficiency of 93.51%. Mathematical models are developed to map the correlation between the parameters and responses (ultimate tensile strength and elongation) and these models are optimized to maximize the ultimate tensile strength of the friction stir welded joint. Response plots generated from the mathematical models are used to interpret the interaction effects of the welding parameters on the response variables. Adequacy of the developed models is validated using analysis of variance (ANOVA) technique. Results from the confirmatory experiments plotted in scatter diagram show a good agreement with predicted models. Different grain structures in various zones of the weld are examined by observing the micro and macro structures of the weld.

Rajakumar etal.[7] this paper focuses on the development of empirical relationship for the prediction of tensile strength of friction stir welded AA 1100 aluminium alloy joints. The experimental part of the study is based on five level central composite designs of six (process and tool) parameters. Optimisation of the model is carried out to maximise the tensile strength using design-expert software. A sensitivity analysis is carried out and compared the relative impact of input parameters on tensile strength in order to verify the measurement errors on the values of the uncertainty in estimated parameters. The results obtained show that developed empirical relationship can be applied to estimate the effectiveness of process and tool parameters for a given tensile strength. The rotational speed is more sensitive than tool hardness, followed by axial force, shoulder diameter, pin diameter and welding speed. A. Farzadi[8]Response surface methodology was employed to optimize effective factors during friction stir welding of AA7075 aluminum alloy. The effect of operational parameters on the ultimate tensile strength of welded joints was studied. Five levels of the tool rotation speed, the welding speed, the shoulder diameter, and the pin diameter in the range of 350–650 rpm, 35–95 mm/min, and 12–18 and 4–6 mm were investigated using a central composite design. In order to have rotatable and orthogonal design, 36 experiments consisting of 12 center points were conducted. Moreover, the distance of each axial point from the center point was 2. All welded joints were defect free. The statistical model showed that the welding speed and the rotation speed compared to the shoulder diameter and the pin diameter have greater impact on the response. It was found that the joint efficiency of 85% was achievable under the intermediate rotational speeds and the high welding speeds using a tool with the moderate shoulder diameters and the large pin diameters. The joint produced using the rotation speed of 513 rpm and the welding speed of 95 mm/min, the shoulder diameter of 16.1 mm and pin diameter of 5 mm yielded the highest joint strength. This joint had a joint efficiency of about 94%.

Gupta[9]presents the friction stir welding (FSW) of aluminum alloy AA-5083-O using vertical milling machine. In present FSW experimentation, effects of different process parameter namely tool rotation speed, welding speed, tool geometry, and tool shoulder diameter have been determined on welding quality of two pieces of AA-5083-O using response surface methodology (RSM). The optimal sets of process parameters have been determined for weld quality characteristics namely tensile strength (UTS) and percentage elongation (%EL). In present experimentations, a specially designed tool made of high carbon steel with different shoulder diameters (15mm, 17.5mm, and 20 mm) having constant pin length (6 mm) were used for FSW of two pieces of aluminum alloy. The ANOVA and pooled ANOVA were used to study the effect of FSW parameters on UTS and %EL. Multi response optimization has been carried out using desirability function in conjunction with RSM to obtain the optimal setting of process parameters for higher UTS and lower %EL.

Sabry etal.[10], systematic approach was presented to discuss the modeling of tool geometry effects on the friction stir 6061 aluminum pipes welds using response surface methodology(RSM). The tool design with the different pin probe geometries tool designing was made for two pins of tools, based on two types of probes such as conical Pin, and triangular Pin. Then, the influences of pin geometries on friction stirred aluminum welds were experimentally scrutinized with respect to hardness(HVN) , tensile strength(UTS) and surfaces roughness(Ra) in order to demonstrate the feasibility of friction stir welding for joining Al 6061 aluminum alloy welding was performed on pipe with different axial force 1 ,1.5 and 2 KN, rotational speeds 1000,1400 and1800 rpm and a traverse speed 4 ,8 and10 mm/min was applied, The response surface methodology was found to be appropriate for locate the FS weldment properties. The developed mathematical model can be used effectively at 98% and 99% confidence level D1(conical pin) and level D2(triangular pin). The result conical pin profile is better than the triangular pin profile because the obtained hardness values are higher for friction stir welded joint.The surfaces roughness created by FSW of conical profile tool better than triangular pin profile

Palanivel etal. [11], this paper presents a systematic approach to develop the mathematical model for predicting the ultimate tensile strength, yield strength, and percentage of elongation of AA6351 aluminum alloy which is widely used in automotive, aircraft and defense Industries by incorporating (FSW) friction stir welding process parameter such as tool rotational speed, welding speed, and axial force. FSW has been carried out based on three factors fve level central composite rotatable design with full replications technique. Response surface methodology (RSM) is employed to develop the mathematical model. Analysis of variance (ANOVA) Technique is used to check the adequacy of the developed mathematical model. The developed mathematical model can be used effectively at 95% confdence level. The effect of FSW process parameter on mechanical properties of AA6351 aluminum alloy has been analyzed in detail.

Mathews[12], systematic approach was presented to develop the empirical model for predicting the ultimate tensile strength of AA5083-H111 aluminum alloy which is widely used in ship building industry by incorporating friction stir welding (FSW) process parameters such as tool rotational speed, welding speed, and axial force. FSW was carried out considering threefactor fivelevel central composite rotatable design with full replications technique. Response surface methodology (RSM) was applied to developing linear regression model for establishing the relationship between the FSW process parameters and ultimate tensile strength.

Analysis of variance (ANOVA) technique was used to check the adequacy of the developed model. The FSW process parameters were also optimized using response surface methodology (RSM) to maximize the ultimate tensile strength. The joint welded at a tool rotational speed of 1 000 r/min, a welding speed of 69 mm/min and an axial force of 1.33 t exhibits higher tensile strength compared with other joints.

Zhang et al. [13] represent the 3D material flows and mechanical features under different processparameters by using the finite element method based on solid mechanics. Experimental results are also given tostudy the effect of process parameters on joining properties of the friction stir welds. Numerical results indicate that the tangent flow constitutes the major part in the material flow. The shoulder can accelerate the materialflow on thetop half of thefriction stir weld.

Muthukumaran et al.[14] states that Electromagnetic radiation is emitted during the transient stage of elastic to plastic deformation of metals and alloys. In the present work, aluminium plates were welded byfriction stir welding (FSW) at different process parameters, such as tool rotational speed, traverse speed and rake angle. The EMR fundamental frequencies emitted during the tensile failure of the welds were measured and recorded. The variation in the fundamental frequency was analyzed by fuzzy modelling using MATLAB and it was observed that an increase in the first mode of metal transfer decreases the fundamental frequency. Further, the fundamental frequency of a weld was estimated from the obtained model and found to be closer to the experimental results. It will be more useful for metal flow analysis as well as online condition monitoring of the welds which are used in critical applications.

Kumaran et al. [15],showed numerous advancements have been occurring in the field of materials processing. Friction welding is an important solid-state joining technique. In this research project, friction welding of tube-to-tube plate using an external tool (FWTPET) has been performed, and the process parameters have been prioritized using Taguchi's L27 orthogonal array. Genetic algorithm (GA) is used tooptimize the welding process parameters.The practical significance of applying GA to FWTPETprocesshasbeen validated by means of computing the deviation between predicted and experimentally obtained welding process parameters.

Elangovan et al. [16] focuses on the development of an effective methodologyto determine the optimum welding conditions that maximize the strength of joints produced by ultrasonic welding using response surface methodology (RSM) coupled with genetic algorithm (GA).RSMisutilizedtocreate an efficient analytical model for welding strength in terms of welding parameters namelypressure, weldtime, and amplitude. Experiments were conducted as per centralcomposite design of experimentsforspotandseam welding of 0.3- and 0.4-mm-thick Al specimens.

An effective second-order response surface model is developed utilizing experimental measurements. Response surface model is further interfaced with GA tooptimize the weldingconditions for desired weld strength.Optimum welding conditionsproducedfromGAareverified with experimental results and are found to be in good agreement.

Sabry etal.[17] findaluminum can't successfully be arc welded in an air environment, due to the affinity for oxygen. If fusion welded in normal atmosphere oxidization readily happens and this outcome in both slag inclusion and porosity in the weld, greatly reducing its mechanical properties. This work presents a systematic approach to develop the suggestion model by three (ANN), response surface methodology (RSM) and regression analysis (RA) for predicting the ultimate tensile strength, percentage of elongation and hardness of 6061 aluminum alloy which is widely used in automotive, aircraft and defense industries by incorporatingfriction stir welding(FSW) process parameter such as tool rotation speed, welding speed and material thickness. The results obtained through regression analysis and response surface methodology were compared with those through artificial neural networks.

2.0 Conclusions

In summary, the review of response surface methodology in Friction Stir Welding to focusing on aluminum alloy has been successfully conducted. This will provide a comprehensive insight for the current and also provide the current state of research on response surface methodology in friction stir welding to aluminium alloys in order to fill the gaps with new research approaches and ideas. Furthermore, new studies on response surface methodology in Friction Stir Welding to aluminium alloys with respect to the selection of cost effective FSW tools and process optimization to produce sound welds still needs to be developed.

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