A Review on Effect of Process Parameters on Tensile Strength of Friction Stir Welded Aluminium Alloys

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Abstract---Friction stir welding (FSW) is an innovative solid state joining process. This paper discuss about the friction stir welding of joining heat treated aluminum alloys for Aerospace and Automobile industries. These welded joints have higher tensile strength to weight ratio and finer micro structure. FSW of aluminum alloys have the potential to hold good mechanical and metallurgical properties. An attempt is made to determine and evaluate the influence of the process parameters of FSW on the weldments. The aim of this study was to investigate the effect of process parameters on the tensile strength of the welded joints.
Keyword: Friction Stir Welding, Aluminium Alloy, Process Parameters, Tensile strength.

I. INTRODUCTION

Friction stir welding (FSW) is an innovative solid state joining process, developed by The Welding Institute, UK in 1991. FSW is being used in aerospace, automotive, rail, marine industries, fabrication, etc. FSW is more beneficial over traditional welding process, particularly in the areas of weld quality and environmental impacts. The FSW process parameters such as tool rotation and transverse speed, tool tilt and plunge depth, tool design, axial force, play a major role in deciding the weld quality. Among aluminum alloys, aluminum-magnesium-silicon (Al-Mg-Si) heat treatable alloys, although of only medium strength, appears to have weld ability advantage over high strength aluminum alloys. For this reason Al-Mg-Si alloys are widely used for structural components in welded assemblies. FSW may produce high tensile stresses elsewhere in the components, FSW results in a much lower distortion and residual stresses owing to the low heat input characteristics of the process.

A. An Operating Principle:

In FSW, a constant rotating, non-consumable, cylindrical-shouldered tool with a profiled pin fed at constant traverse rate into the material across the joint line forming a sound bond of similar and dissimilar materials.

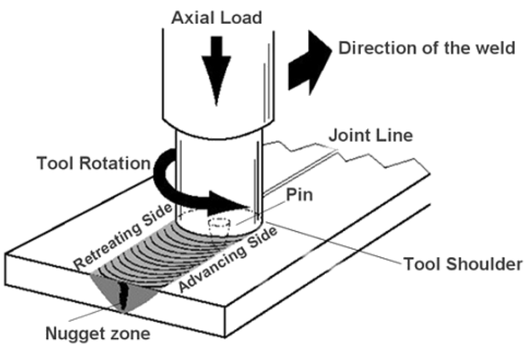

Fig. 1: Schematic Diagram of FSW

The heat generated between the rotating tool and the work piece will plastically soften the work piece material without melting it. As the pin is moved in the direction of welding, forces plasticized material to the back of the pin whilst applying a substantial forging force to consolidate the weld metal.

The parts have to be clamped rigidly onto a backing bar in a manner that prevents the abutting joint faces from being forced apart. The length of the pin is slightly less than the weld depth required and the tool shoulder should be in intimate contact with the work piece surface. The welding of the material is facilitated by severe plastic deformation in the solid state involving dynamic recrystallization of the base material.

B. FSW - Key Benefits

1) Energy efficient and eco-friendly.
2) Produces desirable microstructures in the weld and heat-affected zones.
3) Produces less distortion than fusion welding techniques.
4) No consumables & can be operated in all position.
5) Improved safety due to absence of toxic fumes.

C. Process Parameters

1) Tool Rotation and Traverse Speed.
2) Tool Tilt and Plunge Depth.
3) Tool Design.
4) Welding Forces.
5) Clamping Type and Position.
6) Flow of Material.
7) Generation and Flow of Heat.

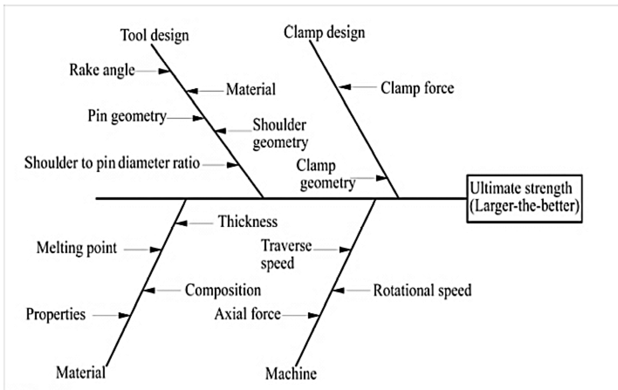

Fig. 2: Cause & effect Diagram of factors influencing Friction Stir Welded joint strength

D. Related Background

L. Karthikeyan et al. conducted [1] experimental studies on friction stir welding of AA2011 and AA6063 aluminum alloys. This study presents the analysis and evaluation of tensile and microstructural properties for friction stir welding of AA2011 and AA6063 alloys. Three different tools feed 40 mm/min. 60 mm/min and 80 mm/min and three different tool rotational speeds 1200 rpm, 1400 rpm and 1600 rpm were employed for fabricating lap joint using FSP. On evaluation it was found that sound weld joints can be produced using FSW. Moreover it was observed that welding strength improves with increased tool rotation speed. Optimum tool rotational speed for defect free nugget zone was found to be 1400 rpm and tool feed was found to be 60 mm/min.

R. Sivasubramanian et al. conducted investigation on [2] optimization of process parameter for friction stir welding of cast aluminum alloy A-319 by taguchi method. TS of FSW Alloy A319 have been evaluated under different processing conditions using 33 full factorial experimental designs. Tool rotation speed has been found dominant parameter for TS followed by welding speed. Axial force shows minimal effect on TS compared to other parameters. A maximum TS (147 Mpa) exhibited by FSW joints with optimal process parameters (tool rotation speed, 1200 rpm; welding speed, 40 mm/min; and axial force, 4 kN) shows a reasonable agreement with experimental value. A nonlinear regression model, developed to correlate TS, has been found to be useful in predicting TS. However, contribution of nonlinear terms in regression model is insignificant. Thus linear regression analysis model may employ successfully for designing process parameters of FSW A319 alloy.

V. Balasubramanian et al. proposed [3] Process parameters optimizations for friction stir welding of RDE-40 aluminum alloy using Taguchi technique.

1) The percentage of contribution of FSW process parameters was evaluated. It is found that the tool rotational speed has 41% contribution, traverse speed has 33% contribution and axial force has 21% contribution to tensile strength of welded joints.

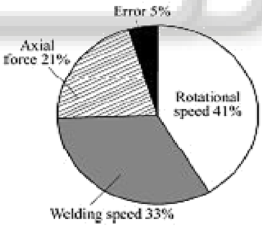

Fig.3: Percentage of Contribution

2) The optimum value of process parameters such as rotational speed, traverse speed and axial force are found to be 1 400 r/min, 45 mm/min and 6 kN respectively.

Moneer H. et al. has evaluated [4] effect of friction stir welding parameters (rotation and transverse) speed on the transient temperature distribution in friction stir welding of AA 7020-T53 .Axial load that measured from experimental work decreases with increase in rotational speed because that decrease in strength due to temperature increases in penetration position; The experimental data show the maximum temperature measured during FSW at mid position 629k and numerically value from the simulation is 642Ko, which is significantly less than the melting temperature of 7020-T53 aluminum alloy at 916Ko;
The temperature at advance side (629k) is higher than retreated side (605k);Numerical results (Tmax = 642K) agreement with measured data (Tmax = 629k) (error 2%);Numerical results show the temperature increases with increase rotating speed (Tmax=642k at1400rpmmm/ min and Tmax=615k at 900rpm-40mm/min); and Numerical results show the temperature decrease with increase travel speed (Tmax = 642k at1400rpm mm/min and Tmax = 680k at 1400rpm-16mm/min).

E. Ceretti et al. performed [5] the effect of process parameters and tool geometry on Mechanical properties of friction stir welded aluminum Butt joints. This study presented the effects of FSW parameters for two different tool geometries. Both rotational speed and feed rate resulted to have significant effects on UTS. The threaded tool design for this study proved to be effective in friction stir welding of AA6060 plates even though no significant differences were found in terms of UTS (compared with the standard tool). The strain values resulted always lower for the joints obtained using the threaded tool. As a general remark and within the limits of the present investigation, it is possible to confirm that a good weld joint can be obtained across a wide range of welding conditions

Y J. Chao et al. evaluated [6] effect of Friction Stir Welding on dynamic properties of AA2024-T3 and AA7075-T7351. In this experiment, the dynamic tests were performed at strain rates of 800/s and 1200/s for AA2024-T3 and 500/s for AA7075- T7351. Yield stresses of both base and friction stir weld material of AA2024-T3 exhibited rate sensitivity. No rate effect was found for AA7075-T7351 friction stir weld material up to the strain rate of 500/s. Friction stir welding reduced the yield stress of both AA2024-T3 and AA7075-T7351 under both high strain rate and quasistatic loading conditions. Strain hardening is similar for both materials at various strain rates.

Mustafa Kemal Kulekci et al. performed [7] friction stir welding process and carried out at a constant tool rotation of 1600 rpm and welding speed of 200mm/min and observed that the average tensile strength of the base metal is 290MPa and for FSW is 270MPa, it seen 7% lower than base metal and stirring effect of the FSW process gives a finer microstructure to the weld.

R. Madhusudhan et al. performed [8] an Experimental Study on the Effect of Weld Parameters on Mechanical and Micro structural Properties of Dissimilar Aluminum Alloy FS Welds. Plates of 6mm thick of 6262-T6 and 7075-T6 Al alloys were friction stir butt welded using a tool made of H13 tool steel having 18mm shoulder diameter and the swept diameter of the square pin measuring 6mm. AA 6262 was kept on the advancing side (AS) of the tool and AA 7075 was kept on retreating side (RS). Total 27 experiments were carried out with varying process parameters. Better mechanical properties (hardness and tensile strength) were obtained with the FSW plate fabricated with 1200 rpm tool rotational speed; 0.6 mm/sec weld speed and 9kN axial force compared to all other conditions.

K. Prasada Rao et al. conducted [9] optimization of process Parameters for friction stir welding of dissimilar Aluminum alloys (AA2024 -T6 and AA6351-T6) by using Taguchi method. Total 27 experiments were carried out with varying process parameters such as axial force, rotational speed and traverse speed. The optimum value of process parameters such as rotational speed, traverse speed and axial force are found to be 1200rpm, 1.2 mm/sand 7000N respectively. The optimum parameters were evaluated and the percentage of contribution of FSW process parameters was evaluated. It was found that the tool rotational speed had 67.31% contribution, traverse speed had 13.7% contribution and axial force had 14.5% contribution in yield of welded joints.

N D. Ghetia et al. evaluated [10] influence of Friction Stir Welding parameters on Tensile Strength of AA8011 Aluminum. The welding parameters such as tool shoulder diameter, tool rotational speed, welding speed, axial force were varied for deciding the joint strength. Friction stir welding is carried out on the 4mm thick AA8011 plate. The tensile strength is checked by using the universal testing machine. Result indicates that the maximum tensile strength found in the FSW welded joint is 75 % of the parent metal tensile strength. The tensile strength of joint increases with the increase in welding speed and in travel speed. It reaches maximum and then start decreases, same effect is also observed by varying the axial force. Maximum joint tensile strength is achieved by using 18 mm shoulder diameter. The maximum tensile strength achieved in the FSW joint is 75% of the parent metal tensile strength.

N. Rajamanickam et al. described [11] effect on process parameters on mechanical properties of FS welds using DOE. With 9 working experiments, varying process parameters such as tool rotation speed and weld speed. The samples were characterized by means of tensile strength, hardness and elongation. It is found that increase in weld speed increases the tensile strength. The sample welded with TRS of 1200rpm and WS of 8mm/min showed the maximum elongation, while the sample welded with the 600rpm and 20 mm/min yielded minimum elongation.

II. EXPERIMENTAL PROCEDURE

Experimental work is carried out on Simple Vertical Milling Machine. All Friction Stir Welded plates undergo Universal Testing Machines, for measuring Tensile Strength of joints.

No.	Process Parameters	Range	Level I	Level II	Level III
1	Rotational Speed	800-1600 RPM	800	1200	1600
2	Traverse Speed	0.35-1.5 mm/s	0.35	0.7	1.2
3	Axial Force	1000-7000 N	3000	5000	7000

Table. 1: Process Parameters with Their Value at Corresponding Levels

Using Design of Experiment (DOE) method, the tensile strength of work pieces are compared with process parameters. After analysis and evaluation, the optimized set of process parameters which gives higher tensile strength is carried out as outcome.

III. CONCLUSION

Friction stir welding (FSW) has matured since its introduction into industrial manufacturing to a level of an acceptable joining method for aluminum alloys. The FSW process has demonstrated its capabilities and been approved as a novel method for joining aluminum and other metals. FSW is opening up totally new areas of welding daily.

From critical literature reviews it is concluded that all the process parameters have their impact on Tensile Strength. It is necessary to find out which combination of process parameters gives higher Tensile Strength for Friction Stir Welded joints for the real time predictions. It is also concluded that the weld speed is the main input parameter that has the highest statistical influence on mechanical properties like, tensile strength, elongation and hardness.

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