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Green Technology Friction Stir Welding of Aluminium Alloy 1100

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Abstract

This paper presents a systematic approach to develop the mathematical model for predicting the ultimate tensile strength of AA1100 aluminum alloy which is widely used in fin stock, heat exchanger fins, spun hollowware, dials and name plates, decorative parts, giftware, cooking utensils, rivets and reflectors, and in sheet metal work. Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required. In marine parts ,automotive, aircraft by incorporating (FSW) friction stir welding process parameter such as tool rotational speed, welding speed, and axial force .The mechanical properties of friction stir welded aluminium alloy typically exceed those of arc welds produced. The advantages of FSW are decreased heat input ,decreased distortion and residual stress, absence of solidification cracking, porosity , oxidation etc. the welding process does not require any filler metal, shielding gas, thus removing environmental degradation. For this reason it can be called as green welding. A mathematical model is developed to predict the tensile strength of aluminium alloy using full factorial design. Analysis of the model is done using design expert software.

Keywords: Friction stir welding; Design Of Experiments; Factorial design; Design Expert.

1. Introduction

Friction stir welding is carried out with a specially designed cylindrical tool ,rotating at severel hundred rpm. The tool consist of a nib extending from the shoulder that is slowly plunged into the joint line the nib may have a diameter one third of the cylindrical tool and typically has a length slightly less than the thickness of the plates being welded. the vertical penetration of the nib into the plates is halted when the shoulder makes contact with the plate surface. A downward forging pressure from the shoulder helps to prevent the expulsion of softened material , in addition to providing supplementary frictional heating. the surface friction of the shoulder with the plates creates additional heat and plasticizes a cylindrical metal coloumn around the inserted pin and the immediate material under the shoulder. As the tool is moved forward , material is forced to flow from the leading edge to the trailing edge of the tool, and the material that flows around the tool undergoes extreme levels of plastic deformation.

Aluminium is a silverish white metal that has a strong resistance to corrosion and like gold, is rather malleable. It is a relatively light metal compared to metals such as steel, nickel, brass, and copper with a specific gravity of 2.7g/cm³. Aluminium can have a wide variety of surface finishes. It also has good electrical and thermal conductivities and is highly reflective to heat and light. The typical tensile strengthis 103 MPa. The wide range of ultimate tensile strength is largely possible due to different strain hardening conditions

2. Working Principle of Friction Stir Welding

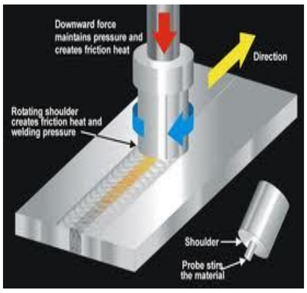

Fig. 1: Schematic diagram of FSW process.

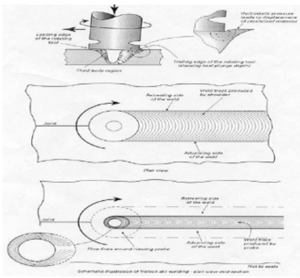
Fig. 2: welded part.


Fig. 3: Cutting tool.

3. Work Material

3.1 AA 1100

It is categorized as *strain – hardened Wrought Aluminum Alloy* Conforms to IS : 737 Gr.19002

The chemical composition of metal selected for project is as per table .1 given below.

Al	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Cr
99.16 %	0.123%	0.036	0.185	0.322	0.023	0.025	0.052	0.023	0.020	0.010	0.005

3.2 Tool Material

EN 8 Steel

EN8 is a very popular grade of through-hardening medium carbon steel, which is readily machinable in any condition. EN8 is suitable for the manufacture of parts such as general-purpose axles and shafts, gears, bolts and studs. It can be further surface-hardened typically to 50-55 HRC by induction processes, producing components with enhanced wear resistance. EN8 in its heat treated forms possesses good homogenous metallurgical structures, giving consistent machining properties.Good heat treatment results on sections larger than 63mm may still be achievable, but it should be noted that a fall-off in mechanical properties would be apparent approaching the centre of the bar.It is therefore recommended that larger sizes of EN8 are supplied in the untreated condition, and that any heat treatment is carried out after initial stock removal. This should achieve better mechanical properties towards the core.

4. Plan of Investigation

The research work was planned to be carried out in the following steps:

1. Identifying the important process parameter
2. Finding the upper and lower limits of the process parameter Viz. tool rotational speed (N), welding speed (S), and axial force (F)
3. Development of design matrix
4. Conducting the experiments as per the design matrix
5. Recording the responses, viz. Ultimate Tensile Strength (UTS), percentage of elongation , hardness value
6. Analysis of responses using design expert software

5. Identifying the Important Process Parameter

Based on literature review the important process parameters of friction stir welding are idendified as tool rotational speed . weld speed , axial force , tool shoulder diameter , tool pin diameter , tool pin shape etc.,

6. Finding the Upper and Lower Limits of the Process Parameter VIZ. Tool rotational Speed (N), Welding Speed (S), and Axial Force (F)

Trial runs are conducted to find the upper and lower limits of the process parameters by varying one of the parameter and keeping the rest of parameters at constant values. Feasible limits of the parameters are chosen in such a way that the joint should be free from visible defects . upper limit of parameter is coded as HIGH and lower limit as LOW

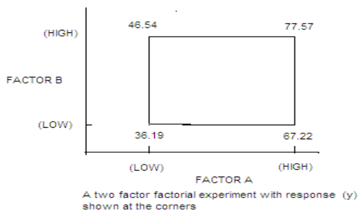

Fig. 4

Table 2: Design matrix.

	24	**40**	**185**	**Yi**
390	46.54	62.05	77.57	186.16
690	41.37	56.88	72.39	170.64
1130	36.19	51.71	67.22	155.13
Yj	124.11	170.64	217.18	Yi …= 511.93

7. The Two-Factor Factorial Design

Main effect of factor A (tool rotational speed)

= (36.19+67.06)/2 – (46.54+77.57)/2 = - 10.35

Main effect of factor B (weld speed) = (77.57+67.22)/2 – (46.54+36.19)/2 = 31.03

β_1 = -10.35/2 = -5.175

β_2 = 31.03 /2 =15.52

β_{12} = ½ = 0.5

β_0 = (46.54 + 77.57+67.22+36.19)/4 =56.88

Fitted regression model is (Y) = $\beta_0 + \beta_1$ **A** + β_2 **B** + β_{12} AB

Response (Y) = 56.88 – 5.18 A + 15.52 B – 0.5 AB

Where Y – tensile strength in MPA ; A – tool rotational speed in RPM ; B – weld speed in MM/MIN

8. Design Expert Software Output

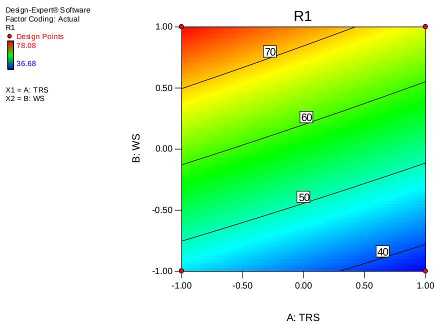

Fig. 5: Contour plot

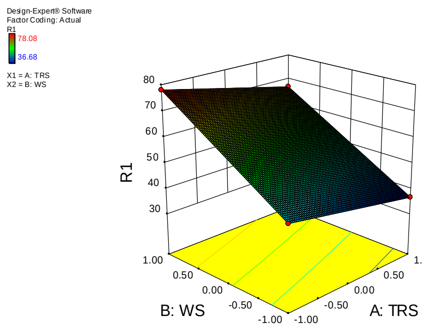

Fig. 6: Response surface.

9. Discussion

9.1 Effect of tool rotational speed

The tensile strength of all the joints are lower than that of the base material, irrespective of the rotational speeds used to fabricate the joints. Of the 8 rotational speeds used to fabricate AA1100 joints, the joint fabricated at a rotational speed of 1200 rpm yielded superior tensile properties. At lower rotational speed (800 rpm) tensile strength of the FSW joints is lower.The tensile strength is increased when rotational speed reaches a maximum at 1200 rpm. If the rotational speed is increased above 1200 rpm, the tensile strength of the joint decreased.

9.2 Effect of welding speed

The welding speed has a strong impact on friction stir welding of aluminium alloy sections. A significant increase in welding speed is achieved with high weld quality and excellent joint properties. The softened area is narrower for the higher welding speed than that for the lower welding speed. Thus, the tensile strength of welded aluminium alloy has a proportional relationship with welding speed .Higher welding speeds are associated with low heat inputs, which result in faster cooling rates of the welded joint. This can significantly reduce the extent of metallurgical transformations taking place during welding When the welding speed is slower than a certain critical value, the FSW can produce defect-free joints. When the welding speed is faster than the critical value, welding defects can be produced in the joints. The defects act as a crack initiation site during tensile test. Therefore, the tensile properties and fracture locations of the joints are determined by the welding speed .

10.Disadvantage to the Process

It is that the 'keyhole' remains when the tool is retracted at the end of the joint. This has been overcome by the use of friction taper plug welding. Tools with a retractable pin are also being investigated and have given some promising results . the welding parameters are machine tool settings and can be easily monitored and used to determine weld quality, any deviation from the required settings being cause for rejection.

11.Advantages of FSW over other Welding Process

It is green technology It does not require filler rod, shielding gas etc., No Gas porosity. No Oxide inclusions and No oxide filming. No Solidification (hot) cracking or hottearing.

No Reduction of corrosion resistance. no melting means that solidification and liquation cracking are eliminated; the stirring and forging action produces a fine-grain structure with properties better than can be achieved in a fusion weld , low boiling point alloying elements are not lost by evaporation advantages are low distortion, no edge preparation, no porosity, no weld consumables such as shield gas or filler metal and some tolerance to the presence of an oxide layer.

12.Conclusion

A mathematical model has been developed to predict the mechanical properties of friction stir welded aluminium alloy AA1100 joints by in corporating welding parameters and using statistical tools such as design of experiments , analysis of variance and regression analysis.

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