Review on Various Process Parameters Affecting the Properties of Material in Friction Stir Welding

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ABSTRACT

There are many alloys which find wide applications in the aerospace and defence industries due to its high strength to weight ratio and good ductility. More over due to their properties these materials are also used in marine industries as well. Friction stir welding (FSW) process, an emerging solid state joining process, is suitable for joining this alloy compared to fusion welding processes. This work presents the formulation of a mathematical model with process parameters and tool geometry to predict the responses of friction stir welds. The responses taken are yield strength, tensile strength and ductility (Percentage elongation).The parameters taken into consideration are spindle speed, welding speed, tilt angle and tool profile. A response Surface methodology was used for checking out the responses. Validation trials were carried out to validate the results. The results so obtained indicated that weld with hexagonal tool pin profile have the highest tensile strength and elongation, whereas the joints fabricated with conical tool pin profile have the lowest tensile strength and elongation.

Keywords: ***Process Parameters review, Mechanical properties, Friction stir welding.etc.***

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1. Introduction:

Use of Fusion Welding always provides difficulties in welding the heat treatable alloys. The difficulties associated with these joints are presence of a tenacious aluminium oxide, high thermal conductivity, high coefficient of thermal expansion, solidification shrinkage, and adsorbed gases in such alloys. Moreover in fusion welding (e.g. TIG OR MIG) due to formation of brittle layer because of eutectic melting and solidification resulting in lower mechanical properties of the material. Cracking due to weak structure also occur. Hence fusion welding is not preferred for welding such materials.

Friction Stir Welding (FSW) is a solid state joining technique developed by TWI, Cambridge, in 1991. This method shows very less defects compared to the Fusion welding Technique. It has improved mechanical properties than Fusion. The Weld microstructure is more refined than the Fusion one as the microstructure observed in Fusion is distorted. The

present research work focuses on the development of mathematical models to predict the mechanical properties (yield strength, tensile strength and percentage elongation) of FSW joints and to study the effects of various process parameters, viz., tool rotational speed, welding speed, tilt angle and tool pin profile, on the mechanical properties of friction stir welded joints.

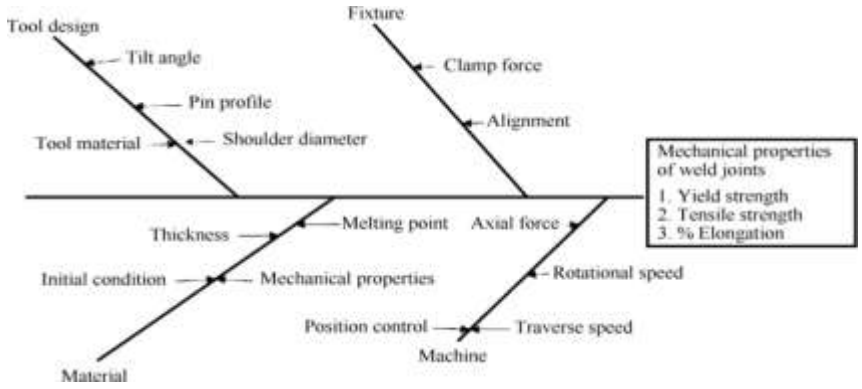
2. Work:

2.1 Identifying the process parameters:

The primary process parameters affecting the mechanical properties, yield strength, tensile strength and percentage elongation were chosen through literature search and several preliminary lab experimentations. These parameters were found as rotational speed, welding speed, tilt angle and tool pin profile.

2.2 Determining the working range:

a) When the rotational speed was less than 600 rpm, no sufficient heat was generated.
b) On the other hand, at rotational speed higher than 1400 rpm, an excess heat was generated during welding.
c) When the tilt angle was lower than 1.5, the tunnel and crack like defects were observed in the middle of the cross section.
d) When the tool tilt was increased above 3.5, the excess flash and thinning of the weld due to excessive penetration of the shoulder into the weld were observed.
e) Tool profile is the secondary process parameter, which purely influences material flow during welding. The profiles of five different tools were chosen viz. conical, triangular, square, pentagon and hexagon .The tools are made from H-13 tool steel.



Cause and Effect diagram for selecting Process Parameters

3. Developing mathematical model

Response surface methodology (RSM) is a collection of mathematical and statistical techniques useful for analyzing the problems in which several independent variables influence.

Table 1
Analyzed chemical composition and mechanical properties of AA 2014 aluminum alloy.

Chemical composition (*wt*%)								Mechanical properties		
Cu	Si	Mn	Mg	Zn	Cr	Fe	Al	Y.S/MPa	UTS/MPa	%El
4.0	0.8	0.60	0.4	0.25	0.1	0.7	Bal	414	483	13

Now for example an Aluminium Alloys is taken whose properties are stated above. And the below table states the various range of parameters through which the Aluminium Alloys is tested.

Table 2
Process parameters and their working range.

Sl. no	Process parameter	Levels				
		−2	−1	0	1	2
1	Spindle speed (x_1)/rpm	600	800	1000	1200	1400
2	Traverse speed (x_2)/(mm·min^{-1})	200	400	600	800	1000
3	Tilt angle (x_3)/(°)	1.5	2.0	2.5	3.0	3.5
4	Tool profile (x_4)	Conical	Triangle	Square	Pentagon	Hexagon

The table shown below states the responses of the alloy. As the above given parameters change the effect of such changes leads to change on the responses like their tensile and ultimate strength.

Table 3
Design matrix with responses (mechanical properties of welds).

Sl. no		Process parameters				Responses		
Standard order	Run order	x_1	x_2	x_3	x_4	% El	Y.S/MPa	UTS/MPa
1	15	−1	−1	−1	−1	1.6	224	273
2	2	+1	−1	−1	−1	4.45	288	360
3	6	−1	+1	−1	−1	3.25	275	385
4	10	+1	+1	−1	−1	2.26	289	293
5	11	−1	−1	+1	−1	1.5	210	225
6	4	+1	−1	+1	−1	2.5	285	320
7	23	−1	+1	+1	−1	4.85	328	407
8	12	+1	+1	+1	−1	1.4	286	290
9	19	−1	−1	−1	+1	3.85	290	367
10	1	+1	−1	−1	+1	8.2	290	413
11	16	−1	+1	−1	+1	2.6	284	291
12	14	+1	+1	−1	+1	1.7	268	300
13	7	−1	−1	+1	+1	6.1	292	415
14	30	+1	−1	+1	+1	10.85	287	426
15	24	−1	+1	+1	+1	8	295	428
16	3	+1	+1	+1	+1	9	307	428
17	29	−2	0	0	0	7.5	302	416
18	9	+2	0	0	0	4.65	291	369
19	20	0	−2	0	0	3.2	269	328
20	25	0	+2	0	0	2.3	308	318
21	28	0	0	−2	0	7.1	301	415
22	5	0	0	+2	0	9.15	311	435
23	8	0	0	0	−2	2.1	300	327
24	13	0	0	0	+2	2.2	330	445
25	27	0	0	0	0	2.9	303	362
26	18	0	0	0	0	5.2	310	385
27	22	0	0	0	0	2.9	303	376
28	17	0	0	0	0	5.3	308	390
29	26	0	0	0	0	2.9	309	378
30	21	0	0	0	0	5.2	306	382

The objective of the response surface methodology is to find those settings of process parameters that give an optimum value of the response. In addition, it provides a regression model that establishes relationship between the process parameters and response.

This relationship can be used to predict the response when the process parameters are varied within the selected ranges. Such plots make it possible to visualize the relation between the response and process parameters.

The above-mentioned regression model or the response surface model is the form of

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 + b_{44}x_4^2 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{14}x_1x_4 + b_{23}x_2x_3 + b_{24}x_2x_4 + b_{34}x_3x_4 \cdots$$

where y = either Y.S or UTS or Percentage elongation as case may be x1-tool rotational speed, x2-tool traverse speed, x3-tilt angle, x4-tool profile.

4. Result and Discussion.

From the regression models, the effects of friction stir welding process parameters viz. tool rotational speed, welding speed, tool tilt angle and tool profile on yield strength, ultimate tensile strength and percentage elongation of friction stir welded joints were evaluated. The four operating parameters considered directly affect on generation of frictional heat and causes the plastic flow of the material. The effects on the properties were observed.

From the Above methodologies the effect of these process parameters, their effect on tensile strength, percentage elongation, and yield strength is observed.

And in this way the strength of weld is known to us from the above process which helps us to know which process to choose for higher strength of weld.

5. Conclusion

a) Regression equations were developed based on the experimental values.
b) Based on the regression models the effects of operating parameters on yield strength, ultimate tensile strength and percentage elongation of the friction stir welded joints were presented and interpreted in detail.
c) This work helps us to decide the proper set of process parameters to be chosen so as to get better strength of the weld in Friction stir welding.

6. References

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