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Process Parameters Optimization for friction stir welding of aluminium alloy AA 6101-T6 by Taguchi Method – A Study

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ABSTRACT

This paper deals with Friction stir welding of AA6061-T6Aluminum Alloy by using H13 Tool at different rotational speeds and welding feeds &pin diameters. Experiments were conducted according to L9 Orthogonal array which was suggested by Taguchi. Optimum parameters for optimum Tensile strength, Hardness and ductility were found with the help of S/N ratios. Therefore optimization of input process parameter is required to achieve good quality of welding. In this experiment the effect of process parameters on welded joint was studied and optimizes the parameter by using Taguchi method for tensile strength, hardness, ductility. Assign the rank to each factor which are having more influence on the mean of tensile strength, hardness and ductility.

Keywords: FSW, Taguchi, DOE, Tensile Strength, Hardness, Ductility.

INTRODUCTION

To produce a joint stronger than the fusion arc welded joint, the Friction Stir Welding process (FSW) can be used. Many applications such as aerospace, automotive and ship building industries, widely use the friction stir welding to weld the lightweight materials, such as aluminum, magnesium and titanium. More effective welding and joining techniques are essential, however for further usage of magnesium alloys. Commonly encountered defects in fusion welded joints such as oxide inclusions, porosity, cracks and distortions surrounding the tool must be hot, so that a successful can be reduced using the joining technique of (FSW), because it has a great potential for magnesium alloys. To develop quality joints, the process variables like the rotational speed, travel speed and tool geometry are vital. Friction stir welding is a solid state welding process invented by The Welding Institute (TWI) of UK in 1991.

The work pieces that are to be joined are clamped together on a backing plate. A rotating non consumable tool with a profiled pin and large concentric shoulder slowly plunged in to the joint line between two plates which are clamped together. Here coalescence is created by the combined action of frictional heating between tool and work pieces and the plastic deformation of base metal due to the rotation of the tool. 95% of heat generated in the process is transferred to the work piece and only 5% flows in to the tool. The friction heat generated softens the material around the pin and moves it from the front of the pin to the back due to the rotation and translation of the tool. In conventional welding, dissimilar metals are very difficult to join because of different physical and chemical properties of base metals. The heat generated in the fusion welding process and the subsequent microstructure changes are the main reason for the decay of mechanical properties like strength, hardness and ductility of welded components. Similarly fusion welding of aluminum leads to poor solidification, microstructure and porosity in the fusion zone.

Friction stir welding overcomes majority of the limitations of conventional fusion welding processes and in addition extensive thermo mechanical deformations induces dynamic recrystallization and recovery that refines the stir region. Therefore friction stir welded joints have improved mechanical properties such as tensile strength, ductility, hardness than conventional fusion welded joints. Taguchi methods developed by Genichi Taguchi to improve the quality of manufacturing goods are recently applied to the field of engineering, biotechnology, marketing and advertising. The Taguchi method is a very powerful tool for carrying out experimental design. The main aim of the Taguchi methods is to produce an optimum result by analyzing the statistical data which have been given as an input function. This method allows limited number of experimental runs by utilizing a well balanced experimental design called orthogonal array design and signal to noise (S/N) ratio. Taguchi methods have been successfully utilized by Lakshminarayanan et.al. for optimizing the process parameters of friction stir welding of RDE-40 aluminum alloy. The result shows that the rotational speed, welding speed and axial forces are the main parameters which affect the tensile strength of the joint. Vinod Kumar et.al.

MATERIALS AND METHODS

In this experimental work Gas Metal Arc Welding was used to produce weldments as it is one of the simple and easy methods of producing strong joints in welding industry.

SELECTION OF MATERIAL

For this study material considered was Aluminum alloys 6061 selected. The alloy was taken in the form of 6 mm thick sheets having dimension of 125 x 150 x 6mm. The chemical composition of material can be shown in tabular form as below.

Table 1: Chemical composition of Aluminum alloy

Element	Mg	Si	Cu	Cr	Fe	Mn	Ti	Zn	Al
Wt %	0.345	0.5 -0.8	0.002	0.019	0.32	0.029	0.010	0.005	Rest

The filler metal chosen for present research was commercially available AA 4043 wire having 1.2 mm diameter. Commercially available Argon was used as shielding gas. Now chamfering was done on that side of plate which was to be joined to obtain single V groove joint which allows greater penetration and smooth weld bead. Root gap was taken as 3 mm for welding of each plate.

SPECIMEN PREPRATION AND TESTINGS

Specimen were prepared using wirecut EDM machine. Both surfaces of the pieces were sand blasted and polished just before welding using a SUS brush, a grinder and alumina powders of 0.3 ◦C diameters to remove dirt and oxides. Each weld was cross-sectioned at mid-length and then polished with the help of alumina powders. And the specimens were etched in Keller's reagent [methanol (25 ml) + hydrochloric acid (25 ml) + nitric acid (25 ml) + hydrofluoric acid (3 ml)] for about 30 s to reveal the bead profile. Specimen after the cutting was etched and cleaned thoroughly to reduce any possibility of impurities which may have sticked to welded joints. These impurities in the form of dust particles or any other type of element may lead to inappropriate readings of mechanical testings. So Utmost care has to be taken for preparation of samples in case of such type of aluminium alloys to obtain suitable values.

The welding parameters for experiment were taken as:

Table 2: Selection of Welding Parameters for first three runs

Welding Parameters	Run 1	Run 2	Run 3	Sample No.
Welding Current(A)	150	160	170	1
Arc Voltage(V)	20	22	24	2
Gas Flow Rate(L/min)	14	14	14	3

Now to observe the changes in weldements due to the effect of welding parameters the Gas flow rate in the process was increased fom 14L/Min to 18L/Min. The arc voltage and welding current were altered in the same manner as for first three samples. The root gap maintained was also similar as in the above mentioned welding process. Filler wire for this experiment was also same. The effect on Mechanical properties of weldements was analysed for all these 6 samples along with base metal mentioned latter in the article.

Table 3: Selection of Welding Parameters for next three runs

Welding Parameters	Run 1	Run 2	Run 3	Sample No.
Welding Current(A)	150	160	170	4
Arc Voltage(V)	20	22	24	5
Gas Flow Rate(L/min)	18	18	18	6

Now after obtaining 6 welded plates of Aluminum alloy samples were prepared to conduct mechanical testing. To carry out the tensile testing using UTM machine with capacity 100 KN and resolution 0.05KN. Tensile testing was done at Industrial Devlopment Facility Centre,Chandigarh,India. The testing conditions were taken as temperature of 25 degree Celsius and relative humidity of 40-60%. These specimen were loaded on UTM and a gradually increasing load was applied.

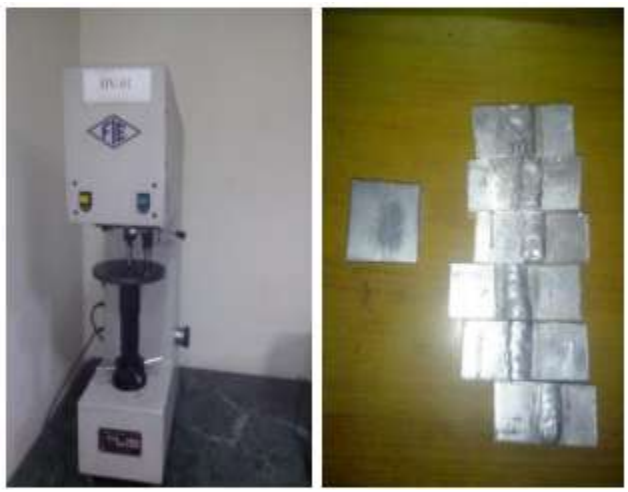

Fig. 1 (a) Vickers Hardness Tester (b) Samples for Hardness Testing

The actual images of finally prepared samples are shown above. Similarly Hardness test was performed using Vicker Hardness tester with same testing conditions as used in Tensile test also shown above in figure 1. After Hardness testing micro structural changes were observed using Standard Metallurgical Microscope. Microhardness of all the samples along with base metal was also tested at Indiana Test, Calibration and Certification Services, Mohali, India.

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),

Figure 2: The manufactured square pin profile tool

Yield Strength (YS), Percentage of Elongation (POE)

6. Development of the mathematical model
7. Checking the adequacy of the models developed
8. Conducting the conformity test runs and comparing the results.
9. Presenting the effects of the process parameters on the mechanical properties in graphical form and analyzing the results.

IDENTIFYING THE IMPORTANT PROCESS PARAMETER:

Based on preliminary trials, the independent process parameters affecting the mechanical properties were identified as: tool rotational speed (N), welding speed (S) and axial force (F).

FINDING THE LIMITS OF CONTROL VARIABLE

Trial runs are conducted to find the upper and lower limit of process parameters, by varying one of the parameter and keeping the rest of them at constant values. Feasible limits of the parameters were chosen in such a way that the joint should be free from visible defects shown in Figure 3. The upper limit of a factor was coded as +1.682 and lower limit as -1.682. The intermediate coded values being calculated from the following relationship. Xi=1.682[2X-(Xmax+Xmin)]/(Xmax-Xmin) Where Xi is the required coded value of a variable X; and X is any value of the variable from Xmin to Xmax, Xmin is the lower limit of the variable and Xmax is the upper limit of the variable.

Figure 3: Typical FS welded plate having tunneling defect in welded area

CONCLUSION

The conclusions drawn from these experiments are that defect free welds can be obtained on 6 mm thick aluminium alloy plates using Gas Metal Arc Welding process with current range of 150-170 A and at Gas Flow rate of 14- 18L/Min.Some of welding samples as in case of sample 4 and sample 6 failed in the region of welding when conducting the Tensile tests due to inappropriate values of welding. The Hardnes was increased due to the fine grain structure of silicides.Sample 2 and Sample 5 were found to be best samples among others having welding parameters of 160 A and Gas flow rate of 14L/min and 18L/min respectiviely showing mechanical properties are dependent on specific values of welding parameters.

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