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Experimental Analysis and Parametric Optimization of 6065-Aluminium Alloy in Rotary Friction Welding

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Abstract

When two surfaces are rubbed together without a lubricant, the friction between them converts mechanical energy into heat energy at the interface. The effect is exploited in friction welding. The frictional heat along with application of a light external pressure cause permanent joining of the metals. The input process parameters like w/p rotational speed, upsetting pressure and friction time have a substantial effect on the tensile strength of the resulting joint. Therefore, finding the optimal input parameter combination is very important to ensure a good quality weld. This paper presents an experimental investigation on optimization and the effect of welding parameters on single response (tensile strength) in welding of 6065-Aluminum Alloy rod with a diameter of 20 mm using Taguchi statistical method. Metal joints were made by using different combinations of input parameters each at three different levels. The quality of the weld zone was analyzed by mechanical testing and microstructure study. By statistical analysis, the most influential process parameter was identified and an optimal level of combination of process parameters is achieved for acceptable tensile strength. To validate the optimization, confirmatory test was carried out.

Key Words: Friction Welding, Upset Pressure, Micro-structural Study, Weld Zone, Mechanical Testing, Taguchi Method.

I. Introduction

Friction welding (FW) is a high quality, nominally solid-state joining process, which produces welds of high structural integrity. It generates heat through mechanical friction between a moving work-piece and a stationary component, with the addition of a lateral force called “upset” to plastically displace and fuse the materials [1]. The basic steps in the rotary friction welding process are:

- ✓ One work piece is rotated and the other is held stationary.
- ✓ When the appropriate rotational speed is reached, the two work pieces are brought together under axial force.
- ✓ Abrasion at the weld interface heats the work piece locally and upsetting starts.
- ✓ These two steps occur during the friction stage. Finally, rotation of the work piece ceases and upset (forge) force is applied to consolidate the joint. This occurs during the forge stage.

The quality of welded junction, and particularly the efficiency of the friction welding process, depends on the relative velocity of the friction surfaces and on the axial force applied during the heating period. All other conditions being equal, these factors determine the intensity of the heat introduction for the welding of the given pair of metals.

In the present work some aspects of Rotary friction welding of Aluminum 6065 have been studied. Emphasis has been given to identify the effect of some selected input parameters (Rotational speed, Friction time, Upset pressure) on the quality of butt-welded joint.

Taguchi's design of experiment methodology is a convenient tool to optimize the cutting parameters with less experimental runs [2]. Taguchi primarily recommends experimental design as a tool to make products more robust – to make them less sensitive to noise factors. The experimental design procedure is suitable tool for reducing the effect of variation on product and process quality characteristics [3]. Analysis of Variance (ANOVA) can be employed to identify the most significant variables and interaction effects [4].

Now a day, the objective of the manufacturing industries is to achieve the economical welding condition. The reduction of experimental time and cost have crucial role for selecting the best parameter in economical way.

Li et al, [5] experimented rotary friction welding by taken analytical description of heat generation and temperature field during the initial stage. Concluded that, based on the slide-stick friction transition criterion, an analytical heat generation model for the initial stage of RFW process is proposed. Meanwhile, the relevant mathematical expression of temperature field is also presented. The accuracy of the models is verified by the maximum temperature at friction interface, and it strongly supports the model that the error between the measurement and calculation is around 6%.

Ganesan et al, [6] Experimented rotary friction welding by taken Austenitic Stainless Steel Grade 304L Taguchi optimization and ANOVA. The following conclusions are drawn:

- Friction welded Austenitic stainless steel grade 304L joint has good mechanical properties. The experimental data has been used to determine the tensile strength under various combinations of input parameters within the range of experimental values.

- Upset pressure has greater influence on tensile strength compared with other input parameters. Use of high upset pressure is recommended to obtain the better tensile strength.
- The optimal friction welding parameters are heating pressure 10 bar, upset pressure 24 bars and heating time 7 sec with constant spindle rotation of 1500 rpm.

Several factors directly or indirectly influence output responses in rotary friction welding. The objective of this research was to investigate the effects of major input parameters on the output (tensile strength) and to optimize the input parameters.

II. Experimental Details

6065-Aluminum Alloy bar having 20mm diameter and 140 mm length is use.

TABLE 1. Chemical composition of 6065-Aluminum Alloy

%Al	%Bi	%Si	%Fe	%Cu	%Zn
94.4 to 98.5	0.5 to1.2	0.4 to 0.8	0 to 0.7	0.15 to 0.4	0 to 0.25

TABLE 2. Properties of 6065-Aluminum Alloy

Density	2.8g/cm^3
Poisson’s Ratio	.033
Elastic Modulus	71GPa
Tensile strength	280 to 380MPa
Yield strength	250MPa
Elongation	4.16 to 12%
Reduction Area	66%

The turning operations were carried out in a rigid HMT NH26 lathe machine. The application of an axial force maintains intimate contact between the parts and causes plastic deformation of the material near the weld interface. Fixture contains the Hydraulic jack with pressure gauge & that jack is hold in the tail stock with the help of foundation plate having the taper rod. That taper rod just insert in tail stock & having tight fitting between them. Job is hold in hydraulic jack by using the Drill chuck in front of hydraulic jack.

Fig.1 Experimental Setup

Fig.2 Pressure Gauge

Each piece has the dimension 140mm × 20mm. joints are made by welding such pieces. Nine welded samples are thus made, by carrying out welding at different level Rotational speed, upset pressure, friction time, as per orthogonal array design of experiment. Three input parameters with their levels are shown in Table 2.3. A L9 orthogonal array was chosen for conducting experiments [7, 8]. The complete experimental plan along with response (surface roughness) for coated and uncoated tools is shown in Table 2.4. The responses are converted into signal-to-noise ratio (S/N ratio) for higher-the-better quality characteristic. Analysis of responses is carried out by MINITAB 14 software.

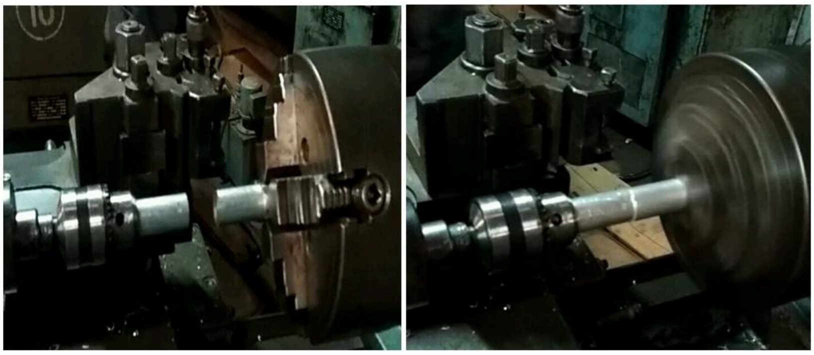

Fig.3 Alignment & Constant phases of the friction welding process

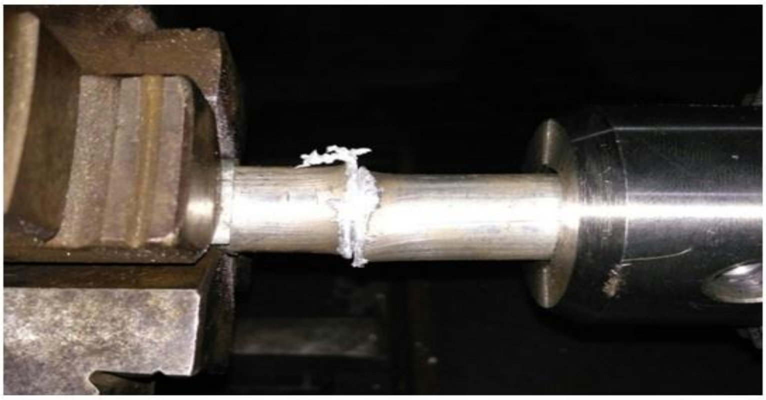

Fig.4 Forge phases of the friction welding process

Fig.5 Photographic view of after welding

TABLE 3. Process/Input parameters and Their Levels

Parameters	Levels		
Rotational Speed (N), rpm	900	1200	1500
Upset Pressure (P), kg/cm^2	60	80	100
Friction Time (T), min	5	7	9

TABLE 4. L_9 Orthogonal Arrays

TEST	PARAMETER 1	PARAMETER 2	PARAMETER 3
1	1	2	1
2	1	1	2
3	1	1	3
4	2	2	2
5	2	2	3

6	2	2	1
7	3	3	3
8	3	3	1
9	3	3	2

III. Results and Discussion

The results of the experiments have been shown in Table 3.1. Analysis has been made based on those experimental data in the following chapter. Optimization of the output has been done by Taguchi method. Confirmatory tests have also been conducted finally to validate optimal results. Again hardness of w/p material and welded joints are measured and compared.

TABLE 5. Experimental Results of 6065-Aluminum Alloy

SL.NO	Input parameter			Output
	N (rpm)	P (Kg/cm^2)	T (min)	UTS (MPa)
1	900	60	5	232
2	900	80	7	268
3	900	100	9	277
4	1200	60	7	292
5	1200	80	9	286
6	1200	100	5	280
7	1500	60	9	341
8	1500	80	5	302
9	1500	100	7	334

Optimization techniques are applied on the observed data corresponding to Taguchi's L9 orthogonal array experiments. First, optimization has been carried out separately for maximization of ultimate tensile strength (UTS) Only Taguchi's method has been used for single objective optimization. In which maximization of ultimate tensile strength has been performed.

TABLE 6. Analysis of Variance for S/N ratios for tensile strength

Source	DF	Seqss	Adj SS	Adj MS	f	P	% contribution
N	2	6.0431	6.0431	3.0216	22.31	0.043	74.72%
P	2	0.2163	0.2163	0.1081	0.80	0.556	2.67%
T	2	1.5573	1.5573	0.7787	5.75	0.148	19.25%
Residual Error	2	0.2708	0.2708	0.1354			3.34%
Total	8	8.0875					100

TABLE 7. Response Table for S/N Ratio of Ultimate tensile strength

Level	N	P	T
1	48.24	49.09	48.62
2	49.13	49.10	49.45
3	50.24	49.42	49.54
Delta	2.00	0.33	0.93
Rank	1	3	2

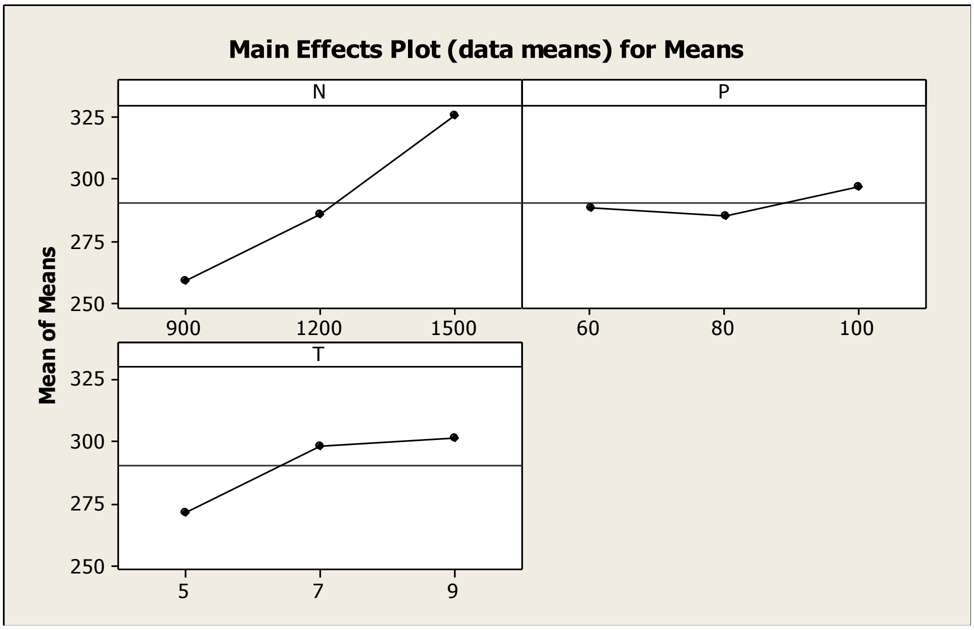

Fig.6 Main effect plots for mean of ultimate tensile strength

IV. Conclusions

The following can be concluded from the present work.

1. Friction welding of industrially important similar Aluminum 6065 is successfully accomplished due to less HAZ and thermal stress developed.
2. Taguchi approach is very simple and efficient way to find out the optimality condition with single response and its predicted value.
3. The optimum parameters are found to be rotational speed 1500 rpm, friction time 9 min and upset pressure 100 kg/cm ^{2}.
4. Analysis of variance indicates that Rotational speed is the most influencing parameter for maximizing response.
5. For the optimized input values of Taguchi method, friction joints are processed. Joints exhibited higher quality. The optimum value of tensile strength in the confirmatory test is 341MPa.

V. References

[1] M.I. Khan, "*Welding Science and Technology*", New age International Publishers, New Delhi, 2000.

[2] R.H Locner, J.E Matar, 1990, Designing for quality, Productivity Press.

[3] T.P Ryan, 2000, Statistical Methods for Quality Improvement, 2nd Edn. John Wiley and Sons, USA., ISBN: 10: 0471197750, pp: 592.

[4] G.R Henderson, 2006, "Six Sigma: Quality Improvement with MINITAB". John Wiley and Sons, England, ISBN: 10: 0470011556, pp: 452.

[5] Peng Li ,Jinglong Li b, Honggang Donga; Analytical description of heat generation and temperature field during the initial stage of rotary friction welding. Journal of Manufacturing Processes, Vol. 25, 181–184 ,2017.

[6] M.Ganesan, P.Marimuthu, Experimental Investigation of Tensile Strength Behavior on Friction Welded Austenitic Stainless Steel Grade 304L Joints. Vol.11, 1251-1255, 2016.

[7] P. J Ross, 1996, Taguchi Techniques for Quality Engineering, McGraw-Hill Book Company, New York.

[8] S. S Mahapatra, A. Patnaik, P.K Patnaik, 2006, "Parametric Analysis and Optimization of Cutting Parameters for Turning Operations based on Taguchi Method" Proceedings of the International Conference on Global Manufacturing and Innovation, pp. 1 –8, July.