EVALUATION AND OPTIMIZATION OF FRICTION WELDING MACHINE PARAMETER ON BIMETALLIC LUG (ALUMINUM + CUPPER)

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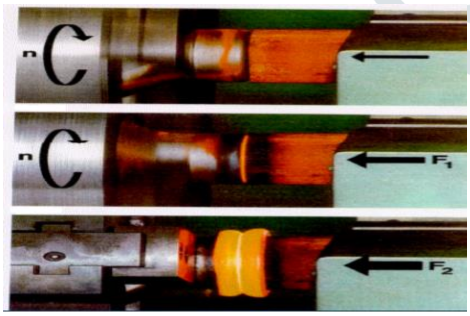
Abstract : This paper presents an effective approach for the optimization of rotational welding machine process of Al.-Cu with multiple performance characteristics based on the ANOVA and Gray relational analysis.9 experimental runs based on the Taguchi method of orthogonal arrays were performed to determine the best factor level condition. The response table and response graph for each level of machining parameters were obtained from the Gray Relational grade. In order to optimize the multiple responses problem Technique for order preference by similarity to an ideal solution (TOPSIS) methodology is used to get a single numerical index. In this study, the rotational welding machine parameter such as speed and pressure optimization with consideration of multiple-performance characteristics, such as w/p hardness and UTS. By analyzing the gray relational grade and ANOVA, it is observed that the welding rotational speed has more effect on response rather than pressure. Effect of variable parameters on properties like tensile strength & yield strength will be analysed by analysis of variance (ANOVA) by which impact of each process parameter will be determined on properties considered. And this technique will be used for predicting best variable process parameters. It is clearly shown that the above performance characteristics in welding process can be improved effectively through this approach.

***Index Terms* - evaluation, optimization and standardization friction welding, bimetallic joint, aluminium, copper**

I. INTRODUCTION

The temperature in the welding region for steels is between 900 and 1300 ^{0}C. Heated metal at the interface accumulates by increasing pressure after heating phase. Thus, a type of thermo mechanical treatment occurs in the welding region and this region has stable particle structure. Metals and alloys, which cannot be welded by other welding methods, can be welded using friction welding. In order to obtain welding connection between parts, untreated surfaces need to be contacted to one another. This contact is efficient because friction corrects contacting problems. The melting process does not normally occur on contacted surfaces. Even though, a small amount of melting may occur, accumulation caused by post-welding process makes it invisible. Figure gives the stages of friction welding. One of the parts is stationary while the other one rotates. When the rotational speed rises to a certain value, axial pressure is applied and lavational heating occurs in parts at the interface. Then, rotation is stopped, heated material at the interface accumulates. The stages of friction welding during the welding process are given in Figure.



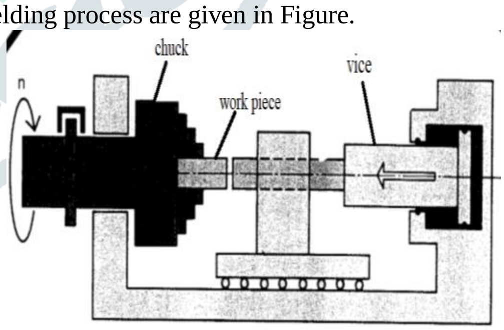


Figure 1.4.1 Rotational friction welding

I. RESEARCH METHODOLOGY

1. Taguchi method: This experiment design proposed by Taguchi involves using orthogonal array to organize the parameters affecting the process and the levels at which they should be varied; it allows for the collection of the necessary data to determine which factor most affect product quality with a minimum amount of experimentation, thus saving time and resources.

2. Design Summary
   Taguchi Array L9 (3^2)
   Level: 3
   Factors: 2
   Runs: 9

Factors	**Unit**	**Level 1**	**Level 2**	**Level 3**
A	RPM	2000	2200	2400
B	Friction pressure	04	05	06

Sr No.	Material	Tool Rotational Speed (RPM)	Friction pressure (kg/cm^2)	UTS (MPa)	Hardness (FRH/HRH)	
					Cu.	Al.
1	(al+cu)	2000	4	15.97	59	-12
		2000	5	16.80	56	-8
		2000	6	18.19	58	-22
2		2200	4	17.35	56	-20
		2200	5	18.73	61	-5
		2200	6	20.10	60	-16
3		2400	4	19.55	57	-19
		2400	5	21.20	63	-13
		2400	6	22.86	55	-15

EXPERIMENATAL DATA

IV. RESULTS AND DISCUSSION

A) Analysis of variance (ANOVA)

The analysis of variance (ANOVA) is the statistical treatment most commonly applied to the results of the experiments to determine the percentage contribution of each factors. Study of ANOVA table for a given analysis helps to determine which of the factors need control and which do not. Once the optimum condition is determined. It is usually good practice to run a confirmation experiments. In case of fractional factorial some of the tests of full factorial are conducted. The analysis of the partial experiment must include an analysis of confidence that can be placed in the results. So analysis of variance is used to provide a measure of confidence. Analysis provides the variance of controllable and noise factors. By understanding the source and magnitude of variance, robust operating condition can be predicted.

1) UTS ANOVA RESULT

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
RPM	2	26.9418	13.4709	162.31	0.000
pressure	2	11.4438	5.7219	68.94	0.001
Error	4	0.3320	0.0830		
Total	8	38.7176			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.288088	99.14%	98.29%	95.66%

R-sq value for specimen geometry was 99.14%, which means that most of the variability of the response data is around its mean.

2) HARDNESS COPPER ANOVA RESULTS

R-sq value for specimen geometry was 27.38 %, which means that most of the variability of the response data is around its mean.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
PRESSURE	2	12.667	6.333	0.62	0.581
RPM	2	2.667	1.333	0.13	0.881
Error	4	40.667	10.167		
Total	8	56.000			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
3.18852	27.38%	0.00%	0.00%

3) HARDNESS ALUMINIUM ANOVA RESULTS

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
PRESSURE	2	150.889	75.444	3.26	0.144
RPM	2	6.889	3.444	0.15	0.866
Error	4	92.444	23.111		
Total	8	250.222			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
4.80740	63.06%	26.11%	0.00%

R-sq value for specimen geometry was 63.06 %, which means that most of the variability of the response data is around its mean.

B) GREY RELATIONAL ANALYSIS (GRA)

In the grey relational analysis, experimental results were first normalized and then the grey relational coefficient was calculated from the normalized experimental data to express the relationship between the desired and actual experimental data. Then, the grey relational grade was computed by averaging the grey relational coefficient corresponding to each process response (3 responses). The overall evaluation of the multiple process responses is based on the grey relational grade.

In the study, a linear data pre-processing method for the yarn tenacity is the higher-the-better and is expressed as:

$$x_i(k) = \frac{y_i(k) + minyi(k)}{maxy_i(k) - miny_i(k)}$$

Which is the lower-the-better can be expressed as:

$$x_i(k) = \frac{maxy_i(k) - y_i(k)}{maxy_i(k) - miny_i(k)}$$

An ideal sequence is $x^0(k)$ (k=1, 2, 3) for three responses. The definition of the grey relational grade in the grey relational analysis is to show the relational degree between the twenty-seven sequences ($x^0(k)$ and $x^i(k)$, i=1, 2, . . . , 27; k=1, 2, 3).

$$\Delta_{0i}(k) = \| x_0(k) - x_i(k) \|$$

The higher value of the grey relational grade means that the corresponding cutting parameter is closer to optimal. In other words, optimization of the complicated multiple process responses is converted into optimization of a single grey relational grade.

RESULT OF GREY RELATIONAL ANALYSIS:-

Table: The sequences of each performance characteristic after data pre-processing

Exp. No.	Hardness Cu	Hardness Al	UTS
1	0.5000	0.4118	0.0000
2	0.8750	0.1765	0.1204
3	0.6250	1.0000	0.3222
4	0.8750	0.8824	0.2002
5	0.2500	0.0000	0.4005
6	0.3750	0.6471	0.5994
7	0.7500	0.8235	0.5195
8	0.0000	0.4706	0.7590
9	1.0000	0.5882	1.0000

Reference sequence = 1.000

Table: the deviation sequence

Ex no.	Δ_{oi} (1)	Δ_{oi}(2)	Δ_{oi}(3)
1	0.5000	0.5882	1.0000
2	0.1250	0.8235	0.8796
3	0.3750	0.0000	0.6778
4	0.1250	0.1176	0.7998
5	0.7500	1.0000	0.5995
6	0.6250	0.3529	0.4006
7	0.2500	0.1765	0.4804
8	1.0000	0.5294	0.2410
9	0.0000	0.4118	0.0000

Table: Grey relational grade

Exp. No.	Cu	Al	UTS	Grade	Order
1	0.5000	0.5882	1.0000	0.6961	2
2	0.1250	0.8235	0.8796	0.6094	3
3	0.3750	0.0000	0.6778	0.3509	6
4	0.1250	0.1176	0.7998	0.3475	7
5	0.7500	1.0000	0.5995	0.7832	1
6	0.6250	0.3529	0.4006	0.4595	5
7	0.2500	0.1765	0.4804	0.3023	8
8	1.0000	0.5294	0.2410	0.5901	4
9	0.0000	0.4118	0.0000	0.1373	9

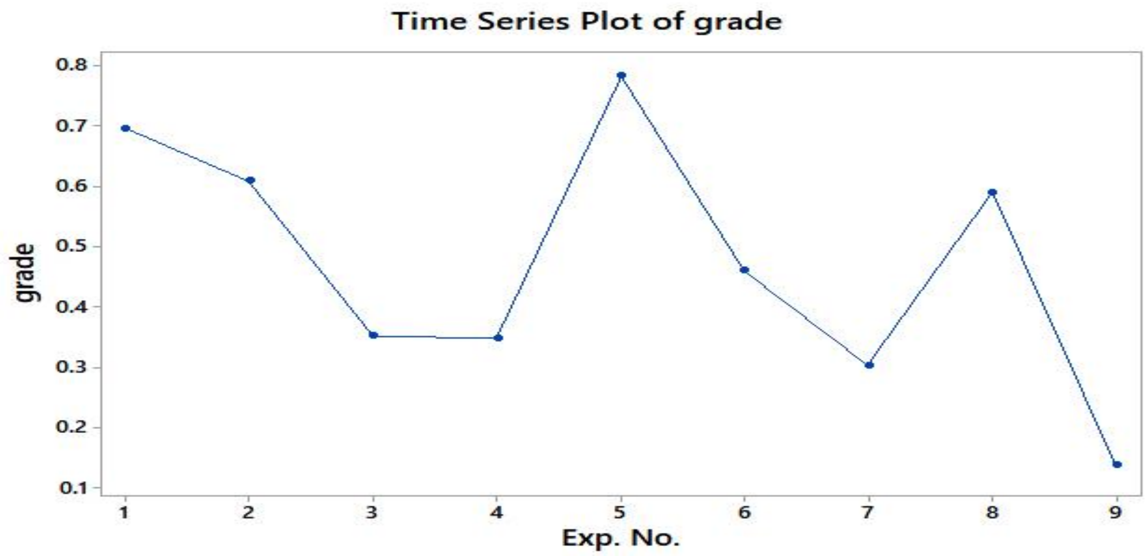


Fig.: time series plot of grade

C) Technique for order preference by similarity to an ideal solution (TOPSIS)

It was based on the principal of positive ideal solution and negative ideal solution The Positive ideal solution and negative ideal solution is a hypothetical solution for which all the experiments results are within limit in between maximum and minimum .It gives a solution that is not only closest to the hypothetically maximum (best) result but also farthest from the hypothetically minimum (worst) result. The basic thought is to find a solution according to the closeness-coefficient between the feasible solution and the ideal solution

Step-I: Normalization the matrix by using the following equation.

$$T_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

Step-II: The weight of each response for MRR, TWR and Ra are depending on diction holder.
Step-III: The weighted normalized decision matrix is calculated by multiplying the normalization matrix by its related weights .The weighted normalized decision matrix is found by the following equation.
$V_{ij} = W_i * T_{ij}$
Step-IV: The positive ideal solution (V+)is for the best possible value and the negative ideal solution(V-) worst value of every attribute from the weighted decision matrix are determined as follows.
$V^+ = (V_1^+ \ldots Vn^+)$ Maximum value
$V^- = (V_1^- \ldots Vn^-)$ Manimum value
Step-V: The Separation distance of every solution i.e the positive ideal solution (S+) and the negative ideal solution (S-) are calculated by flowing equation.

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_J^+)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_J^-)^2}$$

Step-VI: The Closeness Co-efficient (CC_0) is getting by the following equation.

$$CC_O = \frac{S_i^-}{S_I^+ + S_i^-}$$

Step-VII: Ranking the CCo result. The result of CCo is ranked accordance with the ascending order of the closeness-coefficient value.

Results of the TOPSIS

In this paper TOPSIS method is used to optimize the multi machining characteristics. The objective of this method is to found a single numerical value by calculating the three responses such as MRR, TWR and Ra. Initially the results are changed in the form of decision matrix as per results shown in Table. From the Table the Normalized matrix is found as per the equation shown in Table. The MRR is considered as higher value, While TWR and Ra are considered as lower value attribute. Therefore the relative weights are to be considered as MRR=0.5, Ra=0.3 and TWR=0.2. The Normalizing weight matrix is found by using equation as shown in Table.

As per the decision of the discussion maker the Positive ideal solution (V+) for MRR is the higher value and for TWR, Ra lower value. Similarly for Negative ideal solution (V-) MRR is considering as lower value and for TWR, Ra higher value. The values are found by equation is given in Table. The separations are calculated as per the equation. The values are shown in Table .The Closeness coefficients (CCO) are found by using the equation as shown in Table . The CCo are ranked according to their results. Higher the CCo value is the best combination of parameters among the other.

Table: Normalized matrix

Ex. No.	UTS	Hardness Cu	Hardness AL.
1	0.2795	0.3368	0.2601
2	0.2941	0.3197	0.1734
3	0.3184	0.3311	0.4769
4	0.3037	0.3197	0.4336
5	0.3212	0.3483	0.1084
6	0.3518	0.3425	0.3468
7	0.3422	0.3254	0.4119
8	0.3711	0.3597	0.2818
9	0.4001	0.3140	0.3252

Table: Normalizing weight Matrix

Ex. No.	UTS	Hardness Cu	Hardness AL
1	0.1398	0.0674	0.0780
2	0.1471	0.0639	0.0520

3	0.1592	0.0662	0.1431
4	0.1519	0.0639	0.1301
5	0.1606	0.0697	0.0325
6	0.1759	0.0685	0.1040
7	0.1711	0.0651	0.1236
8	0.1856	0.0719	0.0845
9	0.2001	0.0628	0.0976

Table: Positive and Negative ideal solution

	UTS	Hardness Cu	Hardness AL.
V^+	0.2001	0.0628	0.0325
V^-	0.1398	0.0719	0.1431

Table: Separation Matrix

Exp. No.	Si+	Si-
1	0.0757	0.0653
2	0.0565	0.0917
3	0.1180	0.0202
4	0.1089	0.0195
5	0.0401	0.1126
6	0.0757	0.0533
7	0.0956	0.0375
8	0.0547	0.0744
9	0.0651	0.0761

Table: Closeness- coefficients value with Rank order

Exp. No.	CCo	Rank
1	0.4631	5
2	0.6188	2
3	0.1462	9
4	0.1519	8
5	0.7374	1
6	0.4132	6
7	0.2817	7
8	0.5763	3
9	0.5390	4

Experiment No. 5 has the highest TOPSIS rank. Thus, the fifth experiment gives the best multi-performance characteristics among the 9 Experiment.

CONCLUSION

The suggest TOPSIS method is easy and promising technique to optimize the multi-machining characteristics into single numerical value known as Closeness coefficient.

Experiment No. 5 has the highest TOPSIS rank. Thus, the fifth experiment gives the best multi-performance characteristics among the 9 Experiment.

A Grey Relational analysis of the work piece rotational speed and pressure obtained from the taguchi method can convert optimization multi performance characteristics into optimization single performance characteristics.

Experiment No. 5 has the highest grey relational grade. Thus, the fifth experiment gives the best multi-performance characteristics among the 9 Experiment.

From the analysis of the results using the analysis of variance with help of taguchi's optimization method, the following can be concluded:

(1) Higher UTS value is obtain when rotational speed 2400 rpm and friction pressure is 6 (kg/cm^2). Shown plot,

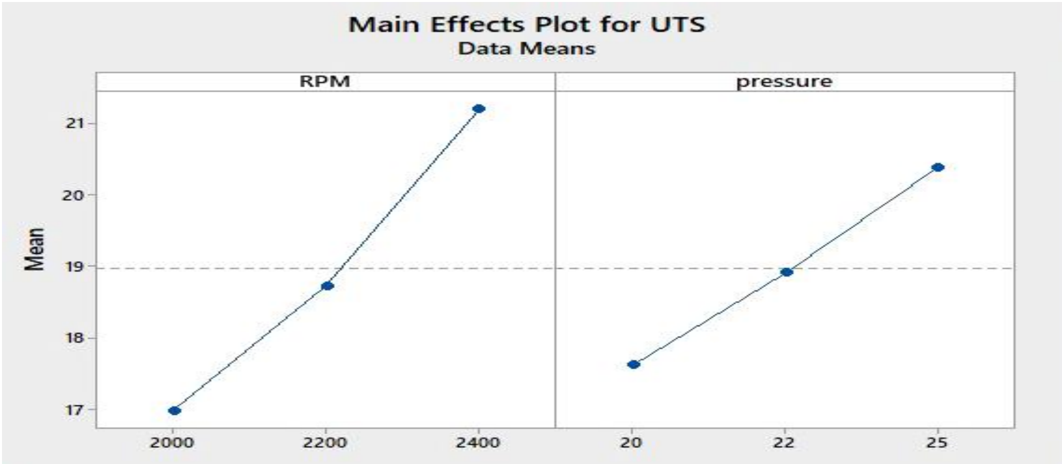


Figure 7.1.1 main plot for UTS

(2) Higher BHN value of Cu. is obtain when rotational speed 2000 rpm and friction pressure is 4 (kg/cm^2). Shown below plot of main effects plot,

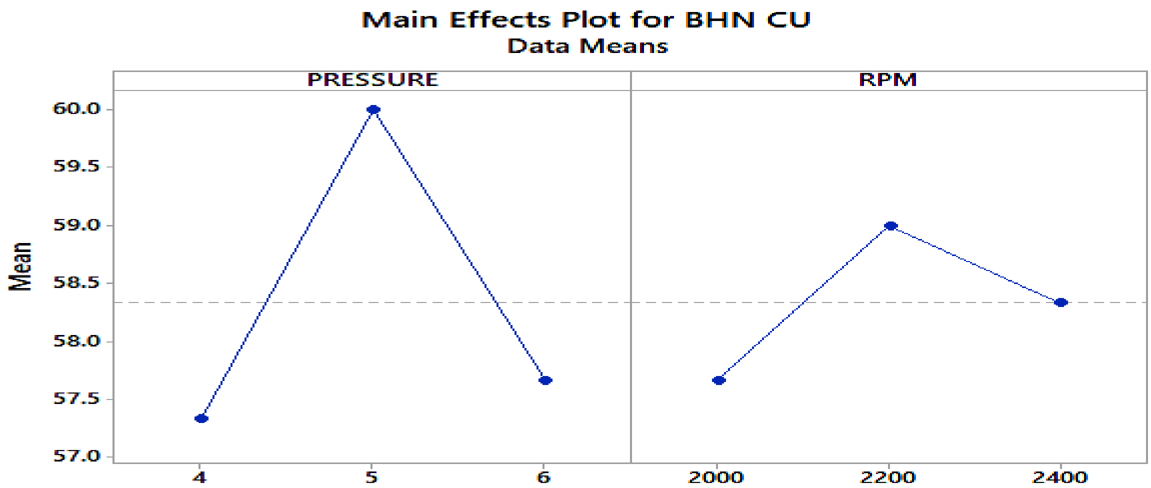


Figure 7.1.2 main plot for BHN Cu.

(3) Higher UTS value is obtain when rotational speed 2400 rpm and friction pressure is 6 (kg/cm^2). Shown below plot of main effects plot,

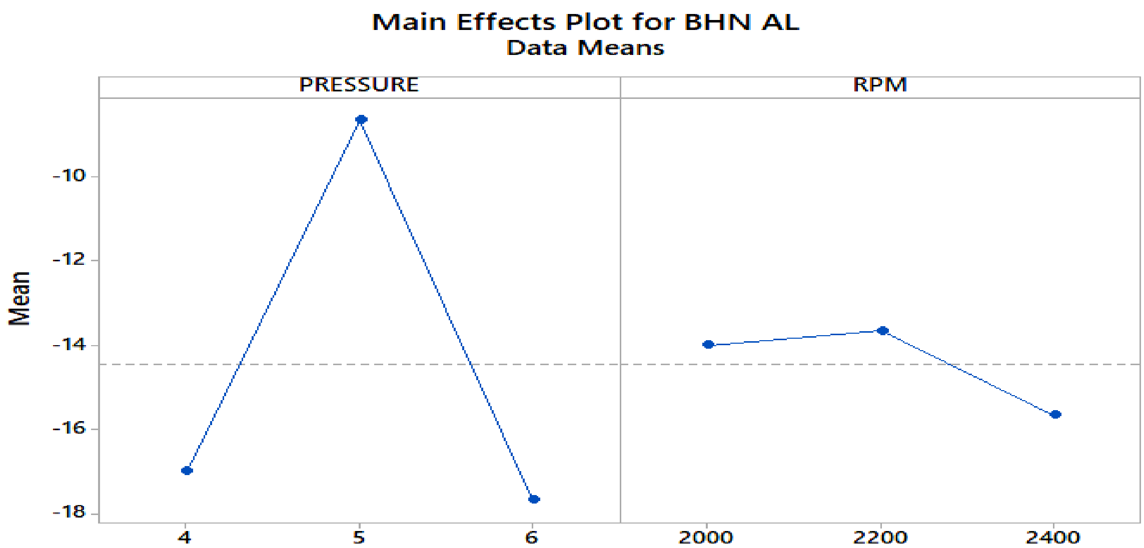


Figure 7.1.3 main plot for BHN Al.

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