Optimization of Process Parameters Using Taguchi for Friction Stir Welding of brass by Grey and Taguchi Method

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Abstract

response surface methodology (RSM), Grey relation analysis and regression analysis (RA) for predicting the hardness (HRB) strength, percentage of elongation and hardness of brass which is widely used in automotive, aircraft and defense industries by incorporating friction stir welding (FSW) process parameter such as tool rotation speed of 1000 rpm, tool travel speed of 20 mm/min & 2 No. of passes. Established mathematical quadratic regression model was very much fit to the actual experimental results. This experimental analysis also determines the elite combination of input parameters of the FSW technique, which would exhibit the best values of output parameters.

CHAPTER 1

1.1 INTRODUCTION:

Welding is a joining process that fabricates various parts or components so as to produce products of complex shapes and geometry, which are otherwise too difficult to produce through other manufacturing processes. In order to produce efficient, compact complex products that can fulfill their functional and esthetic requirements, it is necessary to use a suitable fabrication process to assemble together several smaller components possessing exotic properties. Welding is a common option to join such components. Joining of dissimilar material often poses serious challenges to such an extent that joining is sometimes not possible at all. This problem is mainly because of difference in mechanical, physical, chemical, and metallurgical properties of the materials being joined. Difference in melting point, thermal expansion coefficient, thermal conductivity, etc. may cause failure at the weldment even during welding. Welding constitutes an essential manufacturing process that enables the production of a wide range of products being used in automotive, shipbuilding, aerospace, and several other industrial sectors. However, welding processes are extremely complex and multidimensional in terms of materials, process, and workmen skill, which make the fabrication of desired quality joint extremely difficult.

2. METHODOLOGY

2.1 OBJECTIVE OF WORK

In summary, the review of response surface methodology in Friction Stir Welding to focusing on 60/40 brass plates has been successfully conducted. This will provide a comprehensive insight for the current and also provide the current state of research on response surface methodology in friction stir welding to 60/40 brass plates in order to fill the gaps with new research approaches and ideas. Furthermore, new studies on response surface methodology in Friction Stir Welding to 60/40 brass plates with respect to the selection of cost effective FSW tools and process optimization to produce sound welds still needs to be developed.

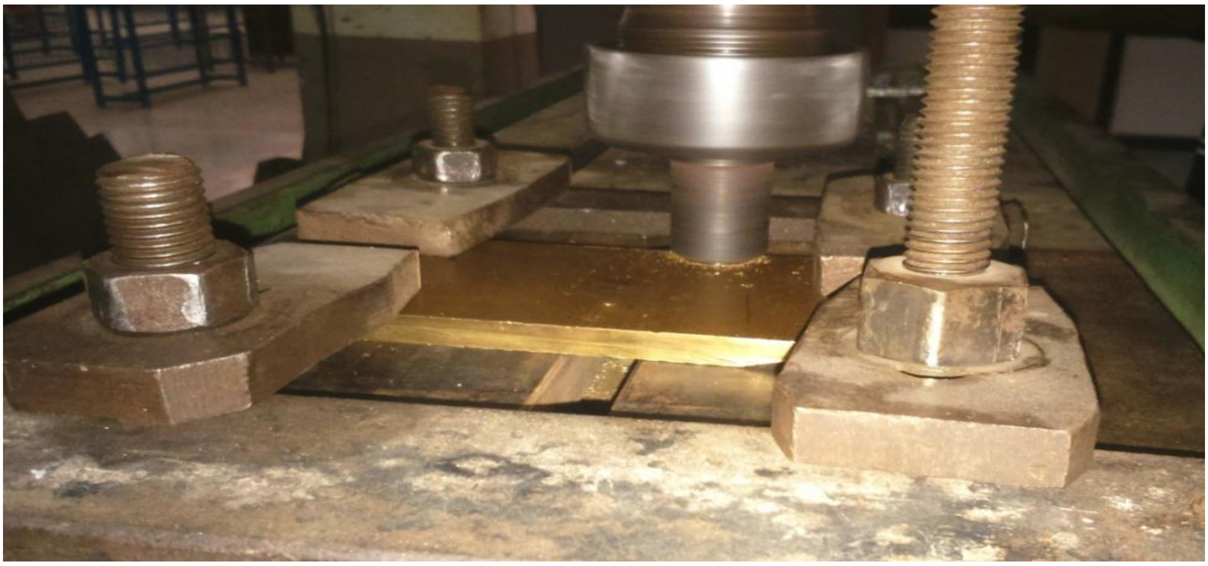


Fig.3.1 Friction Stir Processing (FSP) [42]

Table 3.3: Significant parameters of FSW technique and their levels for Brass

Level	A	B	C
	Tool Rotation Speed (rpm)	Tool Travel Speed (mm/min)	No. of passes
1	710	20	1
2	1000	28	2
3	1400	40	3

Table: 3.4 Proposed Design matrix and results of experimental runs

Experiment No.	A	B	C	D Error
	Tool Rotation Speed (rpm)	Tool Travel Speed (mm/min)	No. of passes	
1	710	20	1	
2	710	28	2	
3	710	40	3	
4	1000	20	2	
5	1000	28	3	
6	1000	40	1	
7	1400	20	3	
8	1400	28	1	
9	1400	40	2	

5. Optimization methodology using grey relational analysis

Step-1

The data is first to be normalized because of avoiding different units and to reduce the variability. It is essentially required since the variation of one data differs from other data. A suitable value is derived from the original value to make the array between 0 to 1 (NoorulHaq et al., 2008). In general, it is a method of converting the original data to a comparable data. If the response is to be minimized, then smaller-the-better characteristics is intended for normalization to scale it into an acceptable range by the following formula.

Equation is selected and it can be expressed as

$$.Y_i(k) = \frac{Y_i(k) - \min Y_i(k)}{\max Y_i(k) - \min Y_i(k)} \quad (1)$$

The first standardized formula is suitable for the benefit – type factor.

$$x_i(k) = \frac{\max x_i(k) - x_i(k)}{\max x_i(k) - \min x_i(k)} \quad (2)$$

The second standardized formula is suitable for defect – type factor.

$$x_i(k) = \frac{|x_i(k) - x_0(k)|}{\max x_i(k) - x_0(k)} \quad (3)$$

The third standardized formula is suitable for the medium – type factor.

The grey relation degree can be calculated by steps as follows:

a) The absolute difference of the compared series and the referential series should be obtained by using the following formula [15]:

$$\Delta x_i(k) = |x_0(k) - x_i(k)| \quad (4)$$

And the maximum and the minimum difference should be found.

b) The distinguishing coefficient *p* is between 0 and 1. Generally, the distinguishing coefficient *p* is set to 0.5.

c) Calculation of the relational coefficient and relational degree by (12) as follows.

In Grey relational analysis, Grey relational coefficient ξ can be expressed as follows [15]:

$$\xi_i(k) = \frac{\Delta \min + p\Delta \max}{\Delta x_i(k) + p\Delta \max} \quad (5)$$

And then the relational degree follows as:

$$r_i = \sum [w(k)\xi(k)] \quad (6)$$

In equation (13), ξ is the Grey relational coefficient, *w (k)* is the proportion of the number *k* influence factor to the total influence indicators. The sum of *w (k)* is 100%. The result obtained when using (12) can be applied to measure the quality of the listed software projects.

Step-6

After optimal combination of process parameters are found out, the next step is very the improvement of grey relational grade through conducting confirmatory experiment. The predicted value of grey relational grade for optimal level can be obtained as follows,

$$\hat{\gamma} = \gamma_m + \sum_{i=1}^{0} \hat{\gamma}_i - \gamma_m \quad (7)$$

Where γ_m is the total mean grey relational grade, $\hat{\gamma}_i$ is the mean grey relational grade at the optimal level of each parameter, and the number of the significant process parameters (Sahoo&Sahoo, 2013).

The predicted optimum values are listed in Table 5.9. The value of $\hat{\gamma}$ is calculated 0.4413fromabove equation. To check the reliability of predicted GRG, Confidence Interval (CI) is also determined using Equation (7) (Çaydaş & Hasçalık, 2008; Ju-Long, 1982).

5.1. Implementation of methodology to find multi-response parametric optimization

Step-1

The experimental data have been normalized for Material removal rate (Gm. /Min), Total metal removed presented in Table 5.1 called grey relationalgenerations.Pre-processing is important in GRA because the data sequences that will be compared have different ranges and units. Therefore, all data sequences must be standardized between the same lower and upper limits. They are defined here as 0 and 1. For Larger the Better Characteristics (e.g. MRR), the input quantity is normalized using equation (1). For Larger the Better characteristics (MRR), equation (2) is used. These equations are taken from [3].

Table 5.4 grey relational grade (GRG)

Experinat No.	Hardness	Normalization	Deviation sequence	Grey relation coefficient	GRG	RANK
1	79.8333	0.621	0.379	0.569	0.284	2
2	77.3333	0.448	0.552	0.475	0.238	3
3	72.5	0.115	0.885	0.361	0.180	8
4	85.3333	1.000	0.000	1.000	0.500	1
5	72.6667	0.126	0.874	0.364	0.182	7
6	75.6667	0.333	0.667	0.429	0.214	4
7	73.3333	0.172	0.828	0.377	0.188	6
8	70.8333	0.000	1.000	0.333	0.167	9
9	74.6667	0.264	0.736	0.405	0.202	5

MIN	70.833	2.06939E-05	0
MAX	85.33	1.000227633	1.000206939

Table 5.4 shows the evaluated relative closeness (Ci) and Rank of TOPSIS. The best combination of machining parameters in turning can be arranged as 1-2-3-5-6-4-8-7-9 through TOPSIS.Results of analysis of variance for the grey relational grade are shown in

Step-4

5.6 Response Table for Means Response Table for Means

Process Parameter	Grey relation grade				Rank
	Level 1	Level 2	Level 3	Max-Min	
Too Rotation Speed (rpm)	0.2342	**0.2988**	0.1858	0.1130	3
Tool Travel Speed (mm/min)	**0.3242**	0.1955	0.1990	0.1287	2
No. of passes	0.2218	**0.3133**	0.1836	0.1297	1
Mean value of grey relation grade= 114.05					

Average value of grey relational grade = 0.239In Table 5.6, the bold letter indicates the optimum value of the grey relational grade From Table 5.6, the identified optimal setting of process parameters for attaining maximum values of the hardness is A2B1C2.

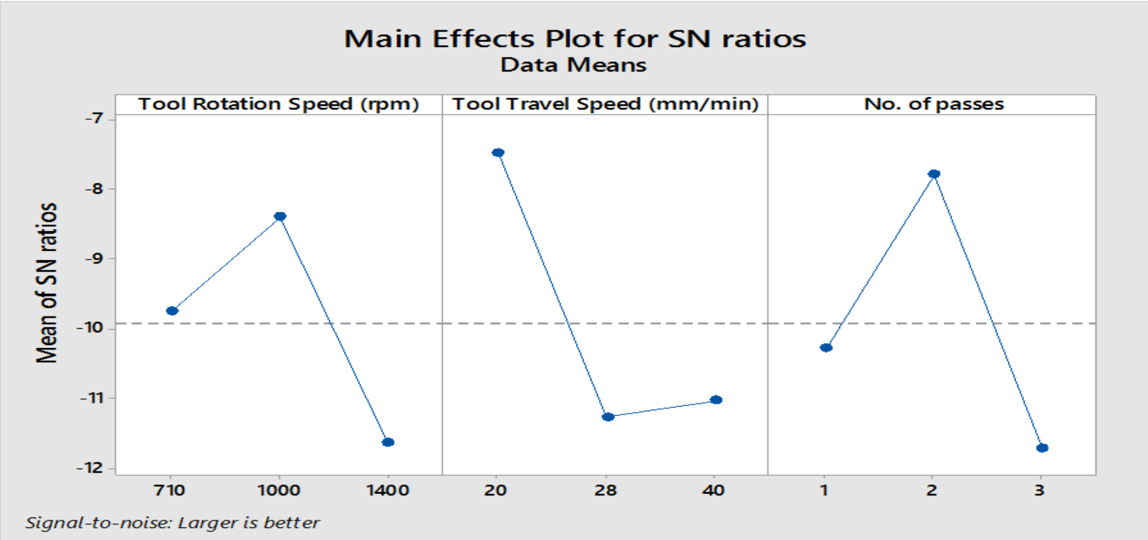


Fig.5.1 Main effect plot for SN ratio

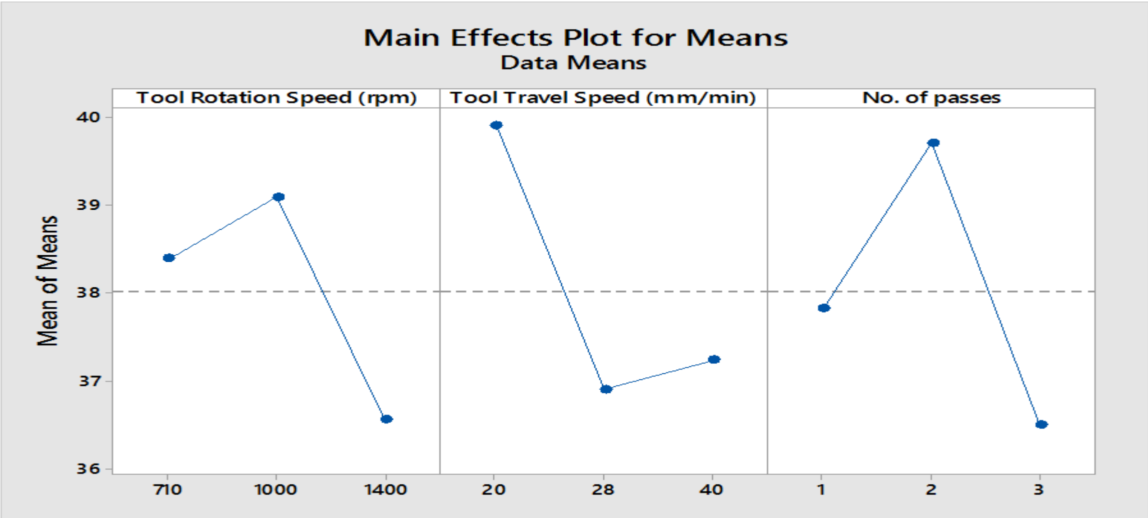


Fig.5.2 Main effect plot for means

Table 3.3: Significant parameters of FSW technique and their levels for Brass

Level	A	B	C
	Tool Rotation Speed (rpm)	Tool Travel Speed (mm/min)	No. of passes
1	710	20	1
2	1000	28	2
3	1400	40	3

Step-5

Next, analysis of variance (ANOVA) table is formulated considering grey relational grade value which has been shown in Table 5. This table gives the significance of process parameters on multi-responses. From the ANOVA table, it is revealed that feed is the significant process parameters affecting multi responses as its p-value is less than 0.05 at 95% confidence level. Cutting speed, depth of cut and feed rate are significance on all three responses simultaneously. It may be noted that cutting speed might have an effect on some performance characteristics individually and its effect is probably significant, when all responses are considered together as it has been observed in presented research.

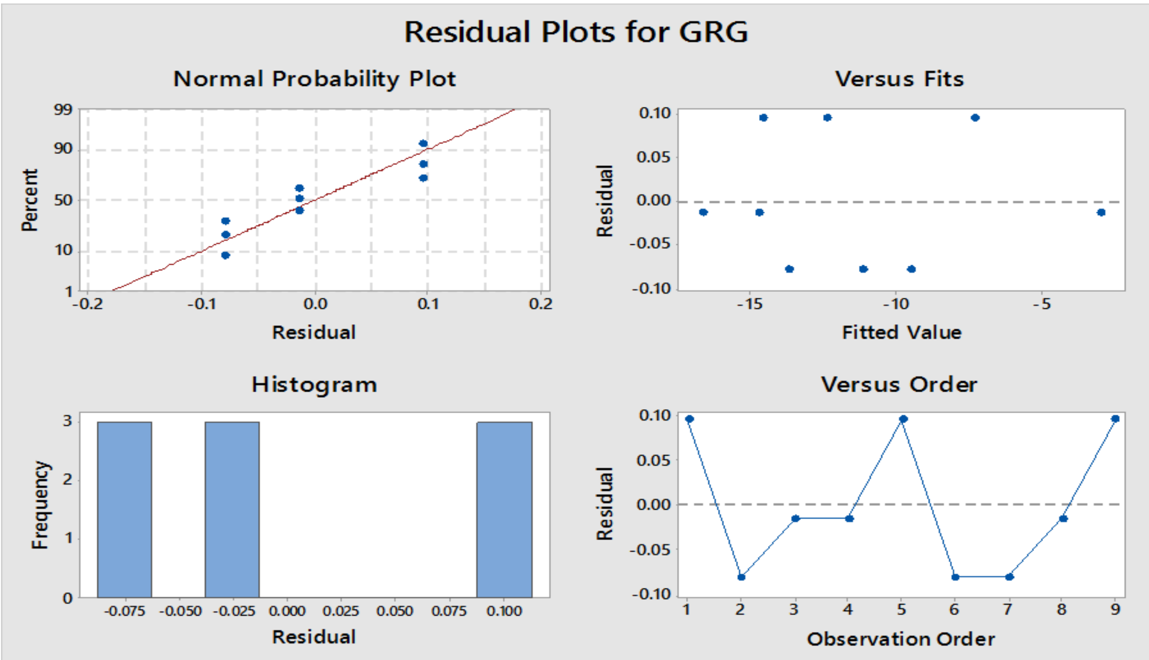


Figure 5.2 Residual plots for grey relation grades

Table 5.8 Analysis of Variance

Analysis of Variance for Transformed Response

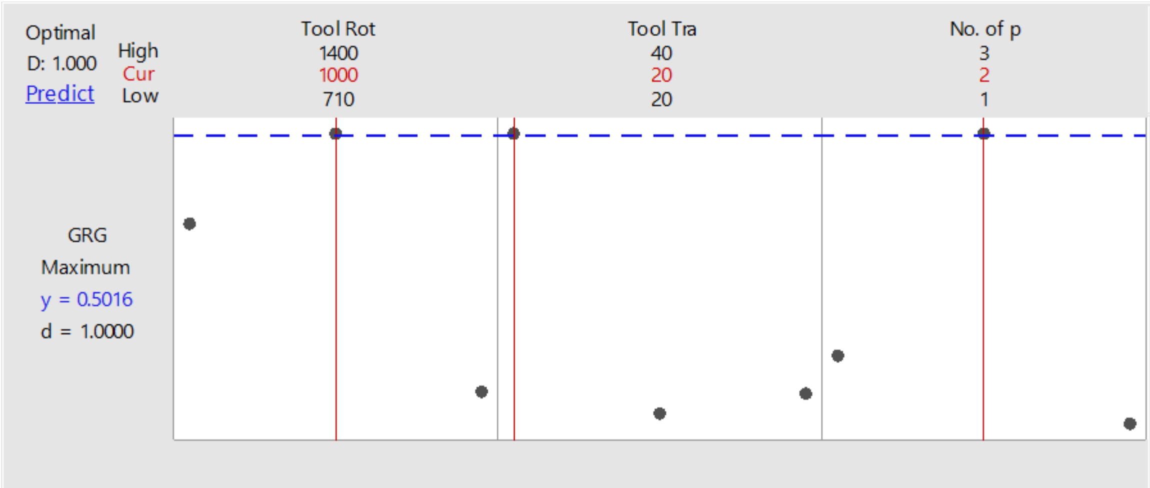
Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Tool Rotation Speed (rpm)	2	36.682	25.00%	36.6819	18.3410	785.73	0.001
Tool Travel Speed (mm/min)	2	54.689	37.27%	54.6887	27.3444	1171.43	0.001
No. of passes	2	55.324	37.70%	55.3242	27.6621	1185.04	0.001
Error	2	0.047	0.03%	0.0467	0.0233		
Total	8	146.741	100.00%				

Model Summary for Transformed Response

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
0.152783	99.97%	99.87%	0.945379	99.36%

Confirmation test:

The objective of the confirmation at optimum levels is to validate the conclusions drawn during the analysis phase. Once the optimal level of process parameters is selected, the next step is to verify the improvement in response characteristics using optimum level of parameters. Confirmatory tests for the optimal level were performed to verify the enhancement in the machining performance. The estimated grey relational grade can be calculated as: A conformity test is conducted using the following equation:



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A clear comparison between predicted and experimental values are presented in Table 4.5.1

Table 5.9 Predicted and experimental values for optimal machining parameters

Process parameters	Initial settings	Optimal parameter settings	
		Predicted	Confirmation test
Setting level	A1B1C1	A2B1C2	A2B1C2
Tool Rotation Speed (rpm)	710	1000	-
Tool Travel Speed (mm/min)	20	20	-
No. of passes	1	2	-
Grey relational grade	0.284	0.5.16	0.500
Improved G.R.G	0.33		

The improvement of grey relational grade from initial parameter combination (A1–B1–C1) to the optimal parameter combination (A2–B31C2) is found to be 0.33

CONCLUSION AND FUTURE SCOPE:

Experiments were conducted for various combinations of tool rotational speed and welding speed at three levels in Taguchi's orthogonal array. The strength of the joints was analyzed by hardness test.

The following observations were made from the studies:

1. Taguchi's orthogonal array has been successfully used to determine the optimal level of process parameter setting.

2. The optimum process parameter levels discovered to achieve greater hardness are as follows: Maximum hardness values are obtained by averaging the measured values for Tool Rotation Speed (rpm) A2 1000 rpm (b) Tool Travel Speed (mm/min), B1 20 mm/min (c) No. of passes.

3. Hardness ANOVA result It is discovered that Tool Travel Speed (mm/min), (P=0.015) (66.94 percent), and No. of Passes (P=0.015) (64.02 percent) have the greatest influence on hardness, followed by Tool Rotation Speed (rpm) (A) (P=0.023) (42.13 percent). In the current study, parameters play a significant role in hardness.

4. Contour plots are created to investigate the interaction effect of welding speed.

5. Grey relational grade improves by 0.33 from the initial parameter combination (A1–B1–C1) to the optimal parameter combination (A2–B31C2).

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