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Study of Mechanical Behavior of Friction Welded Joint in a Brass Material and Its Statistical Modelling

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ABSTRACT: *Friction welding is used in many fields because the procedure is easily automated and it is possible to weld similar and dissimilar materials. It can be used to weld the materials which can not be welded by resistance welding due to electrical and heat conductivity. It can also be applied to weld the materials which have the low co-efficient of friction such as BRASS.Brass is an alloy of 57% cu and 40% Zn and 3% Pb its characteristics are high tensile strength, high resistance to corrosion, easily machinable and low co-efficient of friction. In this research the brass was selected because it can not be weld by resistance welding and arc welding due to high conductivity and it can not be welded by friction welding at normal working parameters due to low co-efficient of friction, but by controlling the parameters it is possible to weld with equally good tensile strength and other mechanical properties. Hence this research mainly concentrates on, The suitable friction welding parameters for the brass material by friction welding to attain the required tensile strength.*
Key Words: *- Friction welding, Tensile strength, upset, microstructures, Minitab software, DOE, TAGUCHI, REGESSION, ANOVA.*

I. Statistical Modelling

1.1 Taguchi design:-

A Taguchi Design or an orthogonal array is a method of designing experiments that usually requires only a fraction of the full factorial combinations. An orthogonal array means the design is balanced so that factor levels are weighted equally. Because of this, each factor can be evaluated independently of all the other factors, so the effect of one factor does not influence the estimation of another factor.In robust parameter design, you first choose control factors and their levels and choose an orthogonal array appropriate for these control factors. The control factors comprise the inner array. At the same time, you determine a set of noise factors, along with an experimental design for this set of factors. The noise factors comprise the outer array.The experiment is carried out by running the complete set of noise factor settings at each combination of control factor settings (at each run). The response data from each run of the noise factors in the outer array are usually aligned in a row, next to the factors settings for that run of the control factors in the inner array. For an example, see data for analysis using Taguchi design L9 (3**4)

L9 (34) REPRESENTS:-**

- L9 9 RUNS
- 3 3 LEVELS
- 4 4FACTORS

The following are the 3 Levels which are considered in Taguchi design

- High 3
- Medium 2
- Low 1

1.2 Experimentation

Preparation of specimen:

This project involves the experimental study on friction welding of similar material of brass. For all the friction welding system, rotational speed, friction pressure, forge pressure applied to the parts and friction time are the principle controlling variables which influence the metallurgical and mechanical properties of friction welded joints. These similar joints thus prepared with friction welding techniques have been studied for tensile strength and up set values.

BASE MATERIAL CHEMICAL COMPOSITION:-

Table 1.1: Base material chemical composition

Element	**Cu**	**Zn**	**Lead**
Percentage (%)	**70**	**28**	**2**

1.3 Specifications of work piece:-

- Diameter of Rod 20mm
- Length of Rod 200mm
- Total length 400mm
- Total rods/each weld 2
- Total welds 9
- Total rods 9X2 =8

1.4 Factors considered for Taguchi design of matrix:-

- Speed
- Friction time
- Friction pressure
- Forging pressure

1.5 Response variables:-

- Tensile strength
- Up-set

1.6 Friction-welding factors used For 3 Levels:-

Table 1.2: Friction welding factors for 3 levels

Levels / **Factors**	**High**	**Medium**	**Low**
Speed (R.P.M)	1600	1500	1400
Friction Pressure (Bar)	20	15	10
Friction Time (Sec)	6	5	4
Forging Pressure (Bar)	30	25	20

1.7 Constant Factors in Experiment:-

- Forging Time (Sec) 3
- Brake Delay (Sec) 0.1
- Upset Delay (Sec) 0.3
- Feed (%) 75

1.8 Factors for DOE:-

- Speed C1
- Friction Time C2
- Friction pressure C3
- Forging pressure C4

II. Design Of Experiment:-

2.1 Taguchi Design:

Taguchi Orthogonal Array Design L9 (3**4)
NO of Factors: 4
NO of Runs: 9
NO of Levels: 3
Columns of L9 (3**4)

2.2 Taguchi Orthogonal Array Design L9 (34) considered for conucting the experiment and the data is analysed.**

III. Results and Discussion

3.1 Tensile strength and Upset of Brass:-

Tensile strength and Upset of Brass were calculated for various levels of rotational speed, friction time, friction pressure and forging pressure. Forging time, Upset delay and Brake delay was maintained constant.

INPUT Variables for 9Runs, 3Lvels and 4 Factors:-

Table 3.1: Input variables for 9Runs, 3Lvels and 4 Factors

Runs	Speed(R.P.M)	Friction Pressure (bar)	Friction Time (Sec)	Forging pressure
1	1400	10	4	20
2	1400	15	5	25
3	1400	20	6	30
4	1500	10	5	30
5	1500	15	6	20
6	1500	20	4	25
7	1600	10	6	25
8	1600	15	4	30
9	1600	20	5	20

The Above Table Represents or Explains about the Input variables which were considered for calculating the tensile strength for three levels which are High, medium and low. These 4 factors entered into the table according to Taguchi design matrix which is shown in table 5.1.

3.2 Constant Factors which were considered in Friction welding are as under:-

Table 3.2: Constant Factors which were considered in Friction welding

Constant Factors	Forging time (sec)	Brake Delay (sec)	Upset Delay (sec)	Feed %
1 to 9 Runs	3	0.1	0.3	75

The Above Table 5.3 Shows the constant values which were considered for 4 factors for all 9 runs.

3.3 Ultimate Tensile Strength Test results:-

Table 3.3: Ultimate Tensile Strength Test results

RUNS	Breaking or MAX. Load (N)	Ultimate Tensile Strength (N/mm^2)	Fractured At
1	49200	314.97	WELD
2	54000	343.75	WELD
3	**53600**	**347.56**	**NECK**
4	**55600**	**363.12**	**NECK**
5	52400	345.68	WELD
6	44400	295.88	WELD
7	52400	346.67	WELD
8	56000	354.97	WELD
9	50800	344.48	WELD

The Table 3.3 Which Shows the Ultimate Tensile Strength, Breaking Loads and Where the Fractured takes place. In that above Results Only 7 samples were fractured at the weld portion i.e. (1, 2, 5, 6, 7, 8, and 9) and 2 samples were fractured at the Neck portion i.e. (3, 4)

For the samples 3 and 4 which were fractured at Neck portion have the more Ultimate Tensile Strength than the base material, because they failed at neck portion. The friction welded joint has the more tensile strength than the base material. In that 2 samples which were failed at neck one sample has more ultimate tensile strength than the other sample. The sample 4 has more tensile strength (363.12 N/mm^2) and it with stand more load (55600 N), which was welded at rotational speed of 1500 R.P.M , friction time 5 sec, friction pressure 10 bar forging pressure 30 bar.

3.4 Input variables and Test results of RUN4 or Specimen 4:-

Table3.4: Input variables and Test results of RUN4 or Specimen 4

Run	Speed R.PM	Friction time(sec)	Friction pressure(bar)	Forging pressure(bar)	Maximum Load(N)	Tensile Strength (N/mm^2)	Fracture At
4	1500	5	10	30	55600	363.12	NECK

After observation input variables of specimen 4 which gets more tensile strength, the Rotational speed and Forging pressure are has more importance in the friction welding because in this specimen Rotational speed is 1500 R.P.M and forging pressure is 30 bar which were considered for medium and high level respectively in the Taguchi Design matrix. Friction time has the medium effect on the friction welding. In this specimen friction time was 5 sec which was considered for medium level in the Taguchi design. Friction pressure has low effect on the friction welding. In this specimen friction pressure was 10 bars which were considered for low level in the Taguchi design.

3.5 Optimum input variables of friction welded joint for Optimum Tensile strength: (BRASS).

- Rotational speed 1500 R.P.M
- Friction Time 5 Sec
- Friction Pressure 10 bar
- Forging Pressure 20 bar

3.6 UPSET Test results:-

Table 3.5: shows the Upset results for 9 Runs, 4 factors and 3 levels.

Runs	Length(L1) mm	Length(L2) mm	Total length (L) (before welding) (L1+L2) mm	Final length (L_R) (after welding) mm	UP SET (Loss in length) (L-L_R) mm
1	**100**	**100**	**200**	**194**	**6**
2	100	100	200	187	13
3	100	100	200	180	20
4	100	100	200	187	13
5	100	100	200	187	13
6	100	100	200	186	14
7	100	100	200	183	17
8	100	100	200	185	15
9	100	100	200	183	17

The above results given that how much length was reduced after friction welding process.Upset means how much length reduced after welding process, In 9 Runs or 9 specimens Loss in length was very small for specimen 1 which was welded at rotational speed, friction time, friction pressure and forging pressure were 1400 R.P.M, 4 Sec,10 bar and 20 bar respectively. Optimum Upset obtained at low level factors which were considered for low level in Taguchi design. It means that the speed, friction time, friction pressure and forging pressure have the uniform effect on the upset. If rotational speed, friction time, forging pressure and friction pressure decreases Upset also decreases effectively.

3.7 Optimum input variables of friction welded joint for Minimum UPSET: (BRASS)

- Rotational speed 1400 R.P.M
- Friction Time 4 Sec
- Friction Pressure 10 bar
- Forging Pressure 20 bar

3.8 Summary of Experimental Results of Tensile and Upset for 9 Runs:

Table 3.6: Summary of Experimental Results of Tensile and Upset for 9 Runs

S. NO	L1 mm	L2 mm	L-Total mm	Final length mm	Upset mm	Friction time sec	Friction pressure bar	Forging pressure bar	R.P.M	Forging time sec	Brake delay sec	Upset delay sec	FEED	MAX LOAD (KN)	FAILS AT	Tensile strength N/mm^2
1	**100**	**100**	**200**	**194**	**6**	**4**	**10**	**20**	**1400**	**3**	**0.1**	**0.3**	**75**	**49.2**	**WELD**	**314**
2	100	100	200	187	**13**	5	15	25	1400	3	0.1	0.3	75	54	**WELD**	**343**

3	**100**	**100**	**200**	**180**	**20**	**6**	**20**	**30**	**1400**	**3**	**0.1**	**0.3**	**75**	**53.6**	**NECK**	**347**
4	**100**	**100**	**200**	**187**	**13**	**5**	**10**	**30**	**1500**	**3**	**0.1**	**0.3**	**75**	**55.6**	**NECK**	**363**
5	100	100	200	187	**13**	6	15	20	1500	3	0.1	0.3	75	52.4	**WELD**	**345**
6	100	100	200	186	**14**	4	20	25	1500	3	0.1	0.3	75	44.4	**WELD**	**295**
7	100	100	200	183	**17**	6	10	25	1600	3	0.1	0.3	75	52.4	**WELD**	**346**
8	100	100	200	185	**15**	4	15	30	1600	3	0.1	0.3	75	56.0	**WELD**	**354**
9	100	100	200	183	**17**	5	20	20	1600	3	0.1	0.3	75	50.8	**WELD**	**344**

IV. Taguchi Analysis by Minitab software for Means of Tensile strength:-

Table 4.0: Response Table for Means of Tensile strength

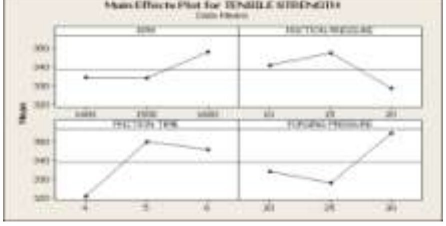
Level	Speed	Friction pressure	Friction time	Forging pressure
1	334.7	341.0	321.0	334.3
2	334.3	347.3	350.0	328.0
3	348.0	328.7	346.0	354.7
Delta	13.7	18.7	29.0	26.7
Rank	4	3	1	2

The response tables show the average of each response characteristic (means) for each level of each factor. The tables include ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on Delta values; rank 1 to the highest Delta value, rank 2 to the second highest, and so on. Use the level averages in the response tables to determine which level of each factor provides the best result. In this Experiment the ranks indicate that Friction time has the greatest influence on the mean, forging pressure has the next greatest influence, Friction pressure has the next greatest influence, followed by Rotational speed.From this Experiment, our goal is to increase Tensile strength of friction welded joint for brass material, required factor levels that produce the highest mean. In Taguchi experiments, we always want to maximize the Mean. The level averages in the response tables show that means were maximized when the Friction time was 5 Sec, Forging pressure was 30 bar, friction pressure was 15 bar, and rotational speed was 1600 R.P.M.

Based on these results for maximized Tensile strength the factors should be set as:-

- Friction time 5 Sec
- Forging pressure- 30 bar
- Friction pressure- 15 bar
- Rotational Speed- 1600 R.P.M.

4.1 Main effects plot for Tensile Strength:-

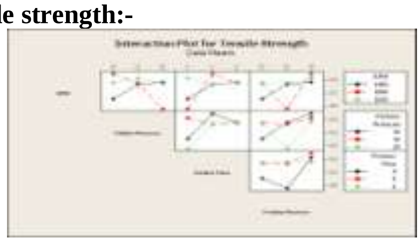


Graph 4.1: Main effect plot for Tensile Strength

4.2 Interpreting the Main effects plot for Tensile Strength:-

Examining the main effects plots confirms these results. The main effects plot shows that, with the friction time 5 Sec, forging pressure 30 bar, friction pressure 15 bar the tensile strength is maximized when the rotational speed is 1600 R.P.M.

4.3 Interaction plot for Tensile strength:-



Graph 4.2 Interaction plot for Tensile strength

Interpreting the results:-

The above plot indicates an interaction between the all levels of all factors which are considered, for high tensile strength.1500 r.p.m is better when the friction pressure is 10 to 15 bar, but the 1400 r.p.m is better when the friction pressure is 15 to 20 bar. 1500 r.p.m is better when the friction time is 4 to 5 sec. 1600 r.pm is better when the forging pressure is 20 to 25 bar and 1500 r.p.m is better when the forging pressure is 25 to 30 bar. 10bar friction pressure is better when the friction time is 4 to 5 sec. 10 bar friction pressure is better when the forging pressure is 25 to 30 bar. 6 sec friction time is better when the forging pressure is 20 to 25 bars but 5 sec friction time is better when the forging pressure is 25 to 30 bars.

4.4 The regression equation for tensile strength:-

TENSILE STRENGTH = **-** 4542 + 3.37 speed **-** 7.83 friction pressure + 620 friction time + 71.9 forging pressure **-** 0.0493 speed X forging pressure **-** 0.413 speed X friction time

Table 4.3: The regression Analysis Table for Tensile strength

Runs	Speed	Friction pressure	Friction time	Forging pressure	Tensile strength	Speed **X** Forging Pressure	Speed **X** Forging time
1	1400	10	4	20	314	28000	5600
2	1400	15	5	25	343	35000	7000
3	1400	20	6	30	347	42000	8400
4	1500	10	5	30	363	45000	7500
5	1500	15	6	20	345	30000	9000
6	1500	20	4	25	295	37500	6000
7	1600	10	6	25	346	40000	9600
8	1600	15	4	30	354	48000	6400
9	1600	20	5	20	344	32000	8000

By Minitab soft ware the values of R-Square and adjusted r-square for above table is

R-Square (R^2) = 94.3%

R-Square (adjusted) (R^2 adjusted) = 77.2%

P-value = 0.161

Interpreting the results of Table 5.9:-

The R^2 value indicates that the predictors explain **94.3% of** the variance in Tensile strength. The Adjusted R^2 is **77.2%** which accounts for the number of predictors in the model. Both values indicate that the model fits the data well. The value of R^2 and adjusted R^2 are 94.3% and 77.2% respectively which signifies that regression model provides an excellent explanation of the relationship between the independent variables (factors) and the response tensile strength. The associated P value 0.161 for the model which is in between 0-1 indicates that the model is statistically significant.

4.5 The regression analysis chart for tensile strength by Minitab soft ware:-

Table 4.4: Analysis of Variance for tensile strength

Predictor	coefficients	P-value
Constant	-4542	0.086
Speed	3.367	0.079
Friction Pressure	-7.833	0.069
Friction Time	620.2	0.069
Forging Pressure	71.90	0.171
Speed X forging pressure	0.00050	0.168
Speed X Friction time	-0.04933	0.071

Interpreting the results of Table 4.4

Each coefficient estimates the change in the mean response per unit increase in X (predictor) when all other predictors are held constant. In the output above, if the speed variable increases by 1 unit and the other variables stay the same, Tensile strength increases by about3.37units on average. If the Friction pressure variable increases by 1 unit and the other variables stay the same, Tensile strength decreases by about7.83 units, on average. If the Friction time variable increases by 1 unit and the other variables stay the same, Tensile strength increases by about 620 units, on average. If the Forging pressure variable increases by 1 unit and the other variables stay the same, Tensile strength increases by about 71.9 units, on average If the Speed X forging pressure variable increases by 1 unit and the other variables stay the same, Tensile strength increases by about 0.0005 units, on average If the Speed X Friction time variable increases by 1 unit and the other variables stay the same, tensile strength decreases by about 0.04933 units, on average If the p-value (P) of a coefficient is less than the chosen, such as 0-1, the relationship between the predictor and the response is statistically significant.

In the above table P-Values for all predictors are in between 0-1, so the relationship between the predictor and the response tensile strength is statistically significant.

Correlation between Experimental and predicted tensile strength:-

Table4.5: Correlation between Experimental and predicted tensile strength

Runs	RPM	Experimental Tensile Strength	Predicted Tensile Strength	Residual
1	1400	314	315.833	-1.8333
2	1400	343	332.333	10.6667
3	1400	347	348.833	-1.8333
4	1500	363	367.667	-4.6667
5	1500	345	349.667	-4.6667
6	1500	295	299.667	-4.6667
7	1600	346	343.667	2.3333
8	1600	354	351.667	2.3333
9	1600	344	341.667	2.3333

By Minitab software the values Pearson correlation co efficient for the table 5.10 is
Pearson correlation co efficient of Experimental and predicted tensile strength = **0.971** and
P-Value = **0.000**

V. Interpreting the results:-

The correlation coefficient obtained for Experimental Tensile strength and predicted tensile strength is **0.971,** when the value of correlation is more than **0.5**, the two set of values said to be in correlation. The Pearson correlation between experimental and predicted Tensile strength is **0.971** which indicates there is direct intermediate correlation between experimental values and predicted values. Therefore the experimental tensile strength and predicted tensile strength values are said to be in correlation. The difference between an Experimental value and its corresponding Predicted value is the residual.

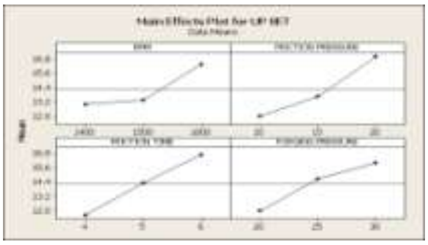
5.1 Taguchi Analysis for upset versus speed, friction pressure, friction time, forging pres sure by Minitab software:-

Table 4.6: Response Table for Means of Upset

Level	Speed	Friction pressure	Friction time	Forging pressure
1	13.00	12.00	11.67	12.00
2	13.33	13.67	14.33	14.67
3	16.33	17.00	16.67	16.00
Delta	3.33	5.00	5.00	4.00
Rank	4	2	1	3

The response tables show the average of each response characteristic (means) for each level of each factor. The tables include ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on Delta values; rank 1 to the highest Delta value, rank 2 to the second highest, and so on. Use the level averages in the response tables to determine which level of each factor provides the best result. In this Experiment the ranks indicate that Friction time has the greatest influence on the mean, friction pressure has the next greatest influence, forging pressure has the next greatest influence, followed by Rotational speed. From this Experiment, our goal is to decrease the upset or loss of length of friction welded joint for brass material, required factor levels that produce the lowest mean. From Taguchi experiments, the level averages in the response tables show that means were maximized when the Friction time was 6 Sec, Friction pressure was 20 bar, forging pressure was 30 bar, and rotational speed was 1600 R.P.M. And the Upset was minimized or reduced when the Friction time was 4 Sec, Friction pressure was 10 bar, forging pressure was 20 bar, and rotational speed was 1400 R.P.M. **Based on these results for Minimized upset should set the factors at: ,** Friction time 4 Sec , Friction pressure10 bar , Forging pressure 20 bar ,Rotational Speed 1400 R.P.M.

5.20 Main effects plot for Upset:-

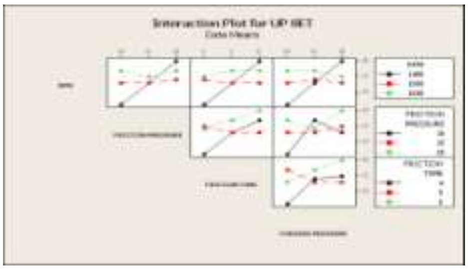


Graph 51: Main effect plot for Upset

Interpreting the Main effects plot for Tensile Strength:-

Examining the main effects plots confirms these results. The main effects plot shows that, with the friction time 6 Sec, forging pressure 30 bar, friction pressure 20 bar the upset is maximized when the rotational speed is 1600 R.P.M. And with the friction time 4 Sec, forging pressure 20 bar, friction pressure 10 bar the upset is minimized when the rotational speed is 1400 R.P.M.

Interaction plot for Upset:-



Graph 5.2 Interaction plot for Upset

Interpreting the results:

1400 r.p.m is better when the friction pressure is 10 to 15 bars and at the same 1400 r.p.m has high upset when the pressure is 15 to 20 bars.

1400 r.p.m is better when the friction time is 4 to 5 sec. and at the same 1400 r.p.m has high Upset when the friction time is 5 to 6 sec. 1400 r.p.m is better when the forging pressure is 20 to 25 bars. And at the same 1400 r.p.m has high Upset when the forging pressure is 25 to 30 bars. 15 bar friction pressure is better when the friction time is 6 to 5 sec. but at 10 bar friction pressure has low upset when friction time is 4 to 5 sec. 15 bar friction pressure is better when the forging pressure is25 to 30 bar. But at 10 bar friction pressure has low upset when the forging pressure is 20 to 25 bars. 5 sec friction time is better when the forging pressure is 25 to 30 bar.bur at 4 sec friction time has low upset when the forging pressure is 20 to 25 bar.

The regression equation for Upset:-

UPSET= **-** 40.8 + 0.0167 speed + 0.500 friction pressure + 2.50 friction time
+ 0.400 forging pressure

Table 5.3: The regression Analysis Table for Tensile strength

Runs	Speed (R.P.M)	Friction pressure (bar)	Friction time (sec)	Forging pressure (bar)	Upset (mm)
1	1400	10	4	20	6
2	1400	15	5	25	13
3	1400	20	6	30	20
4	1500	10	5	30	13
5	1500	15	6	20	13
6	1500	20	4	25	14
7	1600	10	6	25	17
8	1600	15	4	30	15
9	1600	20	5	20	17

By Minitab soft ware the values of R-Square and adjusted r-square for above table is

R-Square (R^2) = 95.2%
R-Square (adjusted) (R^2 adjusted) = 90.3%
P-value = 0.007

Interpreting the results of Table 5.3:-

The R^2 value indicates that the predictors explain 95.2**% of** the variance in Upset The Adjusted R^2 is 90.3% which accounts for the number of predictors in the model. Both values indicate that the model fits the data well. The value of R^2 and adjusted R^2 are 95.2% and 90.3% respectively which signifies that regression model provides an excellent explanation of the relationship between the independent variables (factors) and the response Upset. The associated P value 0.007 for the model which is in between 0-1 indicates that the model is statistically significant.

5.3 The regression analysis chart for Upset by Minitab soft ware:-

Table 5.4: Analysis of Variance for Upset

Predictor	**coefficients**	**P-value**
Constant	-40.08	0.008
Speed	0.0167	0.028
Friction Pressure	0.500	0.007
Friction Time	2.500	0.007
Forging Pressure	0.400	0.016

Interpreting the results of Table 5.4:-

Each coefficient estimates the change in the mean response per unit increase in X (predictor) when all other predictors are held constant. In the output above, if the speed variable increases by 1 unit and the other variables stay the same, upset increases by about 0.0167 units on average. If the Friction pressure variable increases by 1 unit and the other variables stay the same, upset increases by about 0.500 units, on average. If the Friction time variable increases by 1 unit and the other variables stay the same, upset increases by about 2.500 units, on average. If the Forging pressure variable increases by 1 unit and the other variables stay the same, upset increases by about 0.400 units, on average.

Correlation between Experimental and predicted Upset:-

Table5.5: Correlation between Experimental and predicted Upset

Runs	RPM	Experimental Upset	Predicted Upset	Residual
1	1400	6	5.55	0.44
2	1400	13	12.55	0.44

3	1400	20	19.55	0.44
4	1500	13	13.72	-0.72
5	1500	13	14.72	-1.72
6	1500	14	14.22	-0.22
7	1600	17	15.88	1.11
8	1600	15	15.38	-0.38
9	1600	17	16.38	0.611

By Minitab software the values Pearson correlation co efficient:-
Pearson correlation co efficient of Experimental and predicted Upset = **0.975**
P-Value = **0.000**

Interpreting the results:-

The correlation coefficient obtained for Experimental and predicted Upset is **0.975,** when the value of correlation is more than **0.5**, the two set of values said to be in correlation. The Pearson correlation between experimental and predicted is **0.975** which indicates there is direct intermediate correlation between experimental values and predicted values. Therefore the experimental upset and predicted Upset values are said to be in correlation. The difference between an Experimental value and its corresponding Predicted value is the residual.

VI. Conclusion

Mechanical behavior of the friction welded joint for brass is studied by the Taguchi design of experiment and observed that the friction processed joint exhibited comparable strength with the base material and joint strength increased with increase in forging pressure at high and moderate levels of rotational speeds, and the optimal value of process variables for a higher tensile strength from the Taguchi design is 1600 R.P.M Speed, 5 sec friction time, 15 bar friction pressure and 30 bar forging pressure It is observed that the Upset is decreased by all factors which are considered in friction welding process. It is found that the optimum values for less upset is 1400R.P.M Speed, 4 sec friction time, 10 bar friction pressure and 20 bar forging pressure. A study of the regression analysis for both tensile and upset was done and the regression equation for both tensile and upset to predict the values of tensile and upset at any levels of process variables is studied and the correlation between experimental values and predicted values of both tensile and upset was established with a correlation co-efficient of 0.971 and 0.975 respectively which is more than 0.5 and hence Satisfactory as per the Taguchi standards. Studied the main affect, interaction and contour plots with the help of ANOVA for both tensile and upset and observed that at all levels of variables, There is an interaction between each other. And from the main affect plots it is observed that the level of factors that have more effect on the tensile strength and upset. From the Taguchi design of experiment it is observed that the factor that has more effect on the tensile strength is forging pressure, and on the upset, the effect of all the process variables is uniform. The microstructure at heat affected zone and weld zone was observed and it is found that the friction welded joint is excellent without any internal defects like blow holes, cracks ,voids, impurities and grade size is fine towards the weld zone.

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