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OPTIMIZATION OF THE PROCESSES PARAMETERS IN FRICTION WELDING OF DISSIMILAR COMBINATION OF METALS USING TOPSIS METHODOLOGY

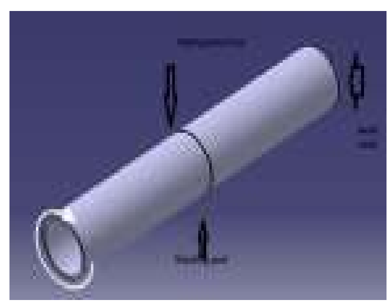
[1]Syed Sibghatullah Hussaini Quadri, [2]G.M. Sayeed Ahmed, [3]Md sadiq mohiuddin
[1]Department of Mechanical Engineering, Mewar University
[2] Department of Mechanical Engineering, College of Engineering, K.S.A
[3]Department of Mechanical Engineering, Mewar University Mewar University.

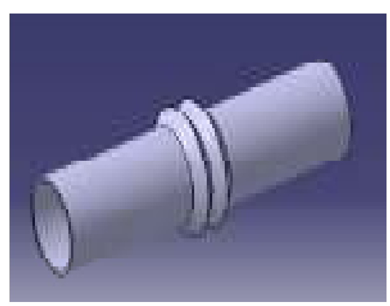
Abstract - Friction welding is used in many fields because the procedure is easily automated and it is possible to weld similar and dissimilar materials. It can be used to weld the materials which cannot be welded by resistance welding due to electrical and heat conductivity. It can also be applied to weld the materials which have the low coefficient of friction such as Aluminum, Brass, Copper and its combination.In this work, two different combinations were selected-namely Aluminum-Copper and Aluminum-Brass. An exhaustive literature survey was done to identify the areas where more work could be done. Based upon factors such as earlier work done, material cost, availability and potential use, different materials of current interest to mankind, especially the Defense and Automobile industry were studied. It was thought that if welding could be done with a minimum of flash volume, while not compromising on basic Mechanical properties of weld like Tensile Strength, hardness and Impact strength, there would be less material wastage.In this research the combination of Aluminum-brass, Aluminum-Copper was selected because it cannot be weld by resistance welding and arc welding due to high conductivity and it cannot 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. Experiments performed on manually lathe machine with different three RPM (1700, 2700, and 3700) different position of work pieces Tests were conducted with different welding process parameters. Optimization of the parameters was also studied. TOPSIS methodology has been adopted to get the best possible combination of process parameters. The strength of the welded joint was determined by Breaking Point load. Hardness values of the joints were also obtained with the HV hardness scale.

Keywords- Optimization, TOPSIS, Friction welding, Processes Parameters, Tensile strength

I. Introduction

Friction welding is a solid-state welding processes using heat generated through mechanical friction between moving work pieces, with the addition of an upsetting force to plastically displace material. Friction welding is type of forge welding, welding is done by the application of pressure. Friction generates heat, if two surfaces are rubbed together, enough heat can be generated and the temperature can be raised to the level where the parts subjected to the friction may be fused together.One component is gripped and rotated about its axis while the other component to be welded to it is gripped and does not rotate but can be moved axially to make contact with the rotating component. At a point fusion temperature is reached, then rotation is stopped and forging pressure is applied. The material used in experiment was Aluminum, Brass, and Copper. Experiments performed on manually lathe machine & special type of fixture is used on the lathe machine to estimate the manually forge pressure.





[1]Corresponding Author

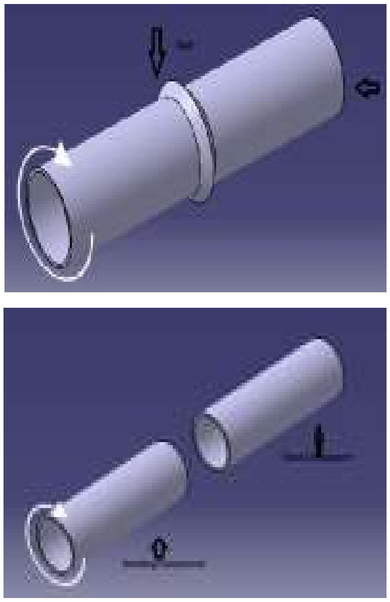


Fig 1: Stages of Friction Welding Processes

II. Objectives

Based upon literature survey, the following aspects of friction welding have been taken up

To study the friction weld ability of Aluminum to Aluminum, Aluminum to Brass, Aluminum to Copper , Brass to Copper

1. To study the welding strength with different combination of metals and determine experimentally Tensile strength
2. To study the effect of friction pressure, forging pressure on friction weld ability.
3. To study the effect of weld time for different welding parameters and to determine the optimum feasible parameters of welding.
4. Determine the optimum welding parameters using TOPSIS technique.
5. At the end of the investigation, the following objectives have been met Mechanical property data for the above mentioned dissimilar metal combinations have been generated Best welding parameters have been suggested which gives good tensile strength and good quality of weld as determined by the Tensile tests.

III. Literature Review

Ellis et al (1977) examined the relationships between “friction time-workpiece diameter”, “shortening-upsetting pressure” and “carbon equivalent-hardness variation”. Ishibashi et al. (1983) selected stainless steel and high-speed steel as representative materials with an appreciably difficult weldability, and obtained their suitable welding conditions. In their work, distributions of alloying elements at and near the weld interfaces for joints of sufficient strength were analyzed using an X-ray micro-analyzer.

Murti and Sundaresan (1983) directed a study about parameter optimization in friction welding of dissimilar materials. Dunkerton (1986) investigated the effects of rotation speed, friction pressure and upsetting pressure in all friction welding methods for steel. Yılbas et al. (1995) investigated the mechanical and metallurgical properties of friction welded steel-aluminum and aluminum-copper bars.

Yılmaz (1993) investigated hardness variations and microstructures in the welding zone of welded dissimilar materials. As mentioned earlier, diametrical differences of the components generally create difficulties in determination of the proper welding parameters because of the differences in heating capacities of the components. Nentwig (1996) investigated the effect of cross-sectional differences in the components in on the joint quality of friction welds. It was concluded that: in comparing the friction welding of parts having different cross-sections with those of equal cross-sections using same welding parameters, the heat input is inadequate, and friction welding parameters for equal cross-sectioned parts cannot be transferred automatically to cross-sections of different sizes.Sahin and Akata (2001) investigated welding quality using tensile test results of welded parts having different cross-sections. Akata et al. (2001) conducted a detailed study about construction and controlling of friction welding set-up

IV. Experimental Setup Detail

The present study utilized a continuous drive friction welding machine. In continuous drive friction welding one work piece is rotated at nominal constant speed in action alignment with the second part under an applied pressure. The rotation and pressure are maintained for the specific period to ensure adequate thermal and mechanical conditioning of the interface region. Thereafter, the rotation is stopped often with forced braking and at the same time pressure is increased to upset parts together. The application of an axial force maintains intimate contact between the parts and causes plastic deformation of the material near the weld interface. Manually Lathe machine is used for the friction welding operation. Machine setup is done as per the principle of continuous drive friction welding machine & to measure the forge pressure hydraulic jack with pressure gauge is used in the tail stock. So that manually effort can be measured. The main condition of machine that work pieces must be ideal alignment as shown in Figure.2 otherwise work pieces may be damage.This project involves the experimental study on friction welding of similar material of brass. These similar joints thus prepared with friction welding techniques have been studied for tensile strength and upset values.As per your requirement to weld 3 work pieces.

1. Aluminium-Copper

2. Aluminium-Brass

3. Aluminium-Aluminium

4. Brass-Copper

The length of each piece will be 50mm and the diameter of 20mm. After welding the total length of the pieces may vary from 90 to 95mm.

Table 1: Base Material Chemical Composition Aluminum

Alloy	Si	Fe	Cu	Mg	Zn		Aluminum
						EACH	MIN.
1070	0.20	0.25	0.04	0.03	0.04	0.03	99.70

Table.2: Base Material Chemical Composition Brass

Element	Cu	Zn	Lead
Percentage (%)	70	28	2

Table 3: Base Material Chemical Composition Copper

Element	Cu	Zn	Lead
Percentage (%)	70	28	2

V. Specifications of Work Piece

- Diameter of Rod 20mm
- Length of Rod 50mm
- Total length 60mm
- Total welds 9 for each combination
- Total rods 9X2 =18

VI. Specifications Of Machine

The specifications of Friction welding machine which is used for friction welded joint

- F.W.M/c Type FWT-12
- Max weld area 800 mm^2
- Min weld area 70 mm^2
- Max bar capacity (solid diameter) 32 mm
- Max length of rotating component 220mm
- Max forge force 120kN
- Spindle speed variable RPM 1000-2000
- Slide stroke 350mm
- Spindle drive 15KW
- Control voltage 24VDC

Fig 2: Hydraulic System for Friction Welding Machine

VII. Experiment Procedure

First of all machine is set up as per requirement of Friction welding i.e. Fixture is arranged on the machine. High speed steel and stain less steel is used for the friction welding. Experiments performed with three different rpm 1500, 2500, and 3500. One of the components is at rpm & other stationary in the fixture. Heat is generated during the friction between the two materials. Temperature gun is used to measure the temperature during the friction welding process. Stop watch is used to measure the Friction time of welding operation of two different materials. Total Six experiments performed on three different rpm (1500, 2500, and 3500).

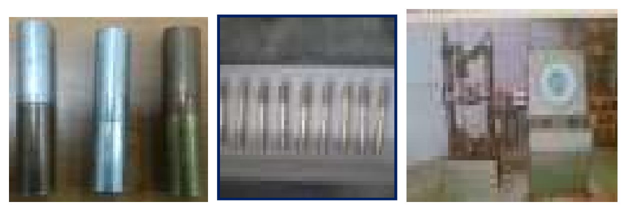


Fig 3: Experimental Friction Welding Samples and Specimens before tensile strength test and tensile testing machine

The variables in the Friction welding process are Rotational speed, Heating pressure, Forging pressure, Heating time, Braking time, Forging time High quality friction weld between various material joints can be obtained within a certain range axial pressure and rotational speed.

Table 4: Experimental Readings.

Work Piece	Forging Pressure, Kg/cm^2	Friction Time, Sec	Forge Time Sec	R.P.M	Temperature
W1	120	10	30	1500	900
W2	150	10	25	2500	950
W3	175	10	40	3500	1020
W4	320	15	65	2500	1015
W5	225	15	50	2500	990
W6	115	15	75	1500	950

VIII. Optimization Using AHP and Topsis

Multi Attribute Decision Making (MADM) is generally employed for evaluating and ranking finite numbers of alternative involving several attribute. MADM approach may be employed to evaluate and outrank best alternate from the multi objective optimization results. Analytic Hierarchy Process (AHP) has been employed to decide the importance of weight, later on Technique for Order Preference by Similarity to Ideal Solution has been used to optimize the selection. Combined approach of AHP and TOPSIS is briefly described as follows:

Step 1: Using pairwise comparison, relative importance may be established with respect to the objective to formulate pair-wise comparison matrix. Assuming N attributes, the pair-wise comparison of attribute i with attribute j yields a square matrix A_{NxN} where a_{ij} denotes the comparative importance of attribute i with respect to attribute j. In the matrix, a_{ij}, when i = j and a_{ij}= 1/a_{ij}.This can be obtained as Eq.(1), subsequently Geometric Mean(GM) can be obtained by Eq. (2) and finally weights is obtained by Eq. (3) such that $A_3 = A_1 \times A_2$ and $A_4 = A_3/A_2$, where

$$A_2 = \left[W_{1,} W_{2,} W_{N,}\right]^T$$

$$A_{NxN} = \begin{bmatrix} a_{11} & a_{12} & \cdots a_{1N} \\ a_{21} & a_{22} & \cdots a_{2N} \\ a_{M1} & a_{M2} & \cdots a_{MN} \end{bmatrix} (1)$$

$$GM_i = \frac{[\prod_{j=1}^{N} a_{ij}]}{N} (2)$$

$$W_j = \frac{GM_i}{\sum_{i=1}^{n} GM_i} (3)$$

Step 2: Calculate the maximum Eigen value (λ_{max}), which is the average of matrix A_4. Obtain the consistency index (CI), and consistency ratio (CR) using Eq. (4) and (5).Random Index (RI) indicates standard values.

$$CI = \frac{\lambda_{max} - N}{N-1} (4)$$

$$CR = CI/RI \ (5)$$

Step 3: After finalizing the objective and criteria for the optimization. Material removal Rate, depth of cut and speed are beneficial criteria whereas tool overhang is considered as non-beneficial attributes.

Step 2: All the collected data are transformed into decision matrix.

Step 3: The normalized matrix N_{ij} may be calculated using formula:

$$N_{ij} = \frac{x_{ij}}{\sqrt{\sum x_{ij}{}_{ij}^2}} \ (6)$$

The normalized decision matrix, N9×3, may be calculated using equation is calculated using Eq. (6) given as

Step 4: The weighted normalized decision matrix is obtained using weights.

$$W_{ij} = N_{ij} X \, W_j \ (7)$$

Where N_{ij} is the normalized matrix and W_j is the weight criteria. The criteria weight (W_j) is obtained by AHP method as discussed.

Step 5:Obtain the positive ideal solution (A^+) and the negative ideal solution (A^-) using Eq. (8) and Eq. (9):

$$A^+ = \{(maxW_{ij} \backslash j \in J), (minW_{ij} \backslash j \in J')\} \ (8)$$

$$A^- = \{(min \, W_{ij} \backslash j \in J), (max \, W_{ij} \backslash j \in J')\} \ (9)$$

J = 1, 2, 3,n, where J is associated with the benefit criteria J' = 1, 2, 3,n, where J′ is associated with the cost criteria Eq.(10) and (11):

Step 6: Obtain the separation measure using:

$$S_i^+ = \sqrt{\sum (W_{ij} - A_j^+)^2} (10) j=1, \quad \text{where i=1.2.3,…,m.}$$

Step 7: The relative closeness is calculated to the ideal solution using Eq (12).

$$C_i^* = \frac{S_i^+}{S_i^+ + S_i^-} \ (12)$$

The larger C_i^* value indicates the better performance of the alternatives.

IX. Results & Discussion

Table 5: Load at Breaking Point

Work piece Samples	Load at Breaking point, KN
W1	10.15
W2	10.25
W3	4.5
W4	5.4
W5	3.5
W6	4.6

The Breaking point Test of friction welded specimens was performed on the Universal Testing Machine 75 TONS, U.T.M Breaking point value given in Table, When RPM is increased from 1700 to 2700 Aluminum RPM and Brass constant breaking load value is decreased from 9.5-9.15KN and when further RPM is increased from 2500 to 3750RPM. Then breaking load value simultaneously decreased up to 3.50 (KN). When RPM is increased from 1700 to 2700 for Aluminum RPM and Brass RPM breaking load value is decreased from 4.5-3.5KNand when further rpm is increased from 2700 to 3700 then breaking load value is increased up to 5.4 KN. Hardness measurement of the specimens was done along the weld and at the cross section of base metal. Aluminum and

Brass was taken along the weld hardness. On hardness was taken at a constant distance of 0.2 mm from the interface in all samples. Total of 12 readings were taken, one on intersection, 6 on Aluminum and 6 on Brass side as shown in table 5 and 6. Higher Hardness values are observed next to interface but they dramatically decreased with increase distances.As RPM is increases temp is also increases and hardness is also increases. But hardness is decreases with increases the upset time.

Table 6: Hardness H.V

Work piece Samples	HARDNESS-HV
W1	310-325
W2	300-320
W3	315-330
W4	320-345
W5	330-350
W6	320-360

Table 7: Normalized Weighted Eigen Value

	RPM	Forging pressure	Friction Time	Forging Time	Temperature	Eigen value
RPM	1	1/2	1/2	1/2	1	0.1193
Forging pressure	2	1	1	3	2	0.3114
Friction Time	2	1	1	1/2	1/2	0.1743
Forging Time	2	1/3	2	1	2	0.2294
Temperature	1	1/2	2	1/2	1	0.1655
TOTAL	8.000	3.333	6.500	5.500	6.500	1.0000
	λ_{Max}	5.4375		RI	1.1200	
	CI	0.1094		CR	0.0977	

Table 8: TOPSIS Ranking of Processes Parameters

		RPM	Forging pressure	Friction Time	Forging Time	Temperature
SN		C1	C2	C3	C4	C5
1	A1	1500	120	10	30	850
2	A2	2500	150	10	25	880
3	A3	3500	175	10	40	920
4	A4	2500	320	15	65	965
5	A5	2500	225	15	50	895
6	A6	1500	115	15	75	870

X. Conclusion

The present work uses multi-objective techniques of AHP and TOPSIS to optimize parameters related to Friction Welding. AHP has been used to find the relative importance among Forging Pressure, Friction Time, Forging Time, Temp and RPM. Using TOPSIS relative closeness has been obtained. The relative closeness is also used to determine the optimum parameter for Friction welding. The best result is obtained when RPM is 3500, Friction time is 14, Forge Time is 65 and Forging Pressure is 320.The change of phase of the motions of the mating parts can be accomplished with highly precision and speed than are possible when alignment of the parts is dependent on stopping the motion of one or both the parts. Friction welding has been successfully employed to weld dissimilar metals. Strength of the joints obtained was good. Mechanical behavior of friction welded joint for Aluminum, Brass and Copper is studied by the TOPSIS and observed that friction processed joint exhibited comparable strength. Developed knowledge of Optimization of welding Parameters. There is a provision of improving the Tensile strength of the work samples by adding hard metallic powders like Carbon, TiO_2 in the work pieces during casting and after making the pieces it can be friction welded and covers future scope which has large potential commercial applications.

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