Optimization of Wear Parameters of aluminium composites (AA6082/12wt%ZrO₂) utilizing Taguchi technique

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Abstract. Optimization of the wear properties of AA6082/12%ZrO₂ AMCs prepared through compo casting process using Taguchi’s S/N analysis was evaluated. Taguchi’s process was utilized and L₉ orthogonal array was elected for behaving the wear tests. Optimal process parameters are estimated to eliminate the wear characteristics of the composite. Moreover, the effect of ANOVA also demonstrates that the sliding distance, the applied force and the sliding velocity have an essential function in the reduction of wear (gram). The values of the tests are consistent with the methodology of Taguchi.

1. Introduction

1.1. Aluminium matrix composites

In aluminium based matrix composites consists of two phases such as matrix phase and another one is the reinforcement phase. In the matrix, phase contains constituent of an aluminium or aluminium alloy which is a percolating network (i.e. Al–Cu, Al–Si in addition Al–Si–Mg alloys,). The second phase is the reinforcement phase aluminium or aluminium alloy is reinforced with the non-metallic and general ceramics like as BN, AlN, B₄C, Gr, Al₂O₃ and SiC. The properties of the aluminium based MMC could be designer by changing the natural constituents and fraction of volume [1-12]. Aluminium-based MMCs are planned to substitute materials of monolithic such as polymer-based composites, alloys of titanium, ferrous alloys and aluminium alloys for meet many applications. The advantages of the aluminium based MMC is contrasted with the unreinforced materials which are mentioned below,

- Enhanced damping capabilities
- Mass of control (specific in the application of reciprocating)
- Enhanced wear resistance and abrasion
- Improved electrical performance
- Heat/Thermal supervision
• Controlled coefficient of thermal expansion
• Enhanced properties of temperature
• Low density (weight)

1.2. Taguchi Technique
The Taguchi technique is a governing tool for the design of a process based on the OA-Orthogonal Array. ANOVA is mostly used to restrict the number of trials and to increase the performance of the method. In this investigative process, the surface roughness response value and the variables are wall angle, spindle speed, feed rate. This experimental analysis is associated with the nature of the L9 orthogonal array experience. The step-by-step process conducted in the Taguchi methodology is given below.
Stage 1: Parameter detection and recognition of control variables.
Stage 2: Detection of the level of each factor.
Stage 3: Choose an orthogonal array procedure.
Stage 4: Implementation of matrix experiments through assigning control variables to the OA column.
Stage 5: Data interpretation to forecast optimum benefits and to evaluate outcomes.
Stage 6: Clarification and validation of the obtained values.

2. Experimental details
In this research work, the AA6082 aluminium alloy is considered as a primary material for the composite. The matrix and subordinate material (ZrO₂) is mixed in the proportion of 88% aluminium with 12% ZrO₂. The research methodology shall be as follows;
- Originally, the AA6082 will be melted after the insulation materials have been powdered.
- Both materials are mixed and the molten mixture is kept at a temperature of 850°C.
- The mixture is stirred continuously at 350 rpm for six minutes.
- A specific mixture is poured into a different preheated mould.
- Multiple experiments have been carried out on the produced composite. Pin on disk wear testing machine was utilized for accompanying sliding wear tests.

3. Results and Discussion
3.1. Taguchi DOE Analysis
Variables and levels are shown in Table 1. unlubricant sliding wear tests were worked by using a pin made of aluminium alloy based on AA6082 /ZrO₂ AMCs. Wear assessment was carried out using the Taguchi L-9 orthogonal sequence. The operating environment is the normal load, the sliding distance and the sliding velocity, and the wear is the response factor as can be seen in Table 2. The effect of system parameters, including normal load, sliding velocity and sliding distance, on the rate of wear, was calculated utilising S/N response analysis. The "smaller-better" state was used as an analytical model to evaluate the wear characteristics (gram) of the AMCs. Table 3. demonstrates the response table for the S/N ratio.

| Sl.No | Sliding Distance (m) | Applied Load (N) | Sliding Velocity (m/s) |
|-------|---------------------|------------------|------------------------|
| 1     | 1000                | 5                | 1                      |
| 2     | 1000                | 10               | 2                      |
| 3     | 1000                | 15               | 3                      |
| 4     | 1500                | 5                | 2                      |
| 5     | 1500                | 10               | 3                      |
Table 2. Experimental outcomes

| Sl. No | Sliding Distance (m) | Load (N) | Velocity (m/s) | Wear (gram) | S/N Ratio |
|--------|----------------------|----------|----------------|-------------|-----------|
| 1      | 1000                 | 5        | 1              | 0.097       | 20.2646   |
| 2      | 1000                 | 10       | 2              | 0.105       | 19.5762   |
| 3      | 1000                 | 15       | 3              | 0.129       | 17.7882   |
| 4      | 1500                 | 5        | 2              | 0.174       | 15.1890   |
| 5      | 1500                 | 10       | 3              | 0.238       | 12.4685   |
| 6      | 1500                 | 15       | 1              | 0.237       | 12.5050   |
| 7      | 2000                 | 5        | 3              | 0.265       | 11.9720   |
| 8      | 2000                 | 10       | 1              | 0.298       | 11.5351   |
| 9      | 2000                 | 15       | 2              |             | 10.5157   |

Table 3. Response table for S/N ratios

| Level | Sliding Distance (m) | Load (N) | Velocity (m/s) |
|-------|----------------------|----------|----------------|
| 1     | 19.21                | 15.81    | 14.77          |
| 2     | 13.39                | 14.53    | 15.09          |
| 3     | 11.34                | 13.60    | 14.08          |
| Delta | 7.87                 | 2.21     | 1.02           |
| Rank  |                      | 1        | 2              |

Table 4. Summary of Analysis of Variance

| Source                  | DF | Seq SS   | Contribution | Adj MS | F-Value | P-Value |
|-------------------------|----|----------|--------------|--------|---------|---------|
| Sliding Distance (m)    | 1  | 0.039043 | 87.35%       | 0.039043 | 85.94   | 0.000   |
| Load (N)                | 1  | 0.003314 | 7.41%        | 0.003314 | 7.29    | 0.043   |
| Velocity (m/s)          | 1  | 0.000067 | 0.14%        | 0.000067 | 0.15    | 0.717   |
| Error                   | 5  | 0.002271 | 5.08%        | 0.000454 |         |         |
| Total                   | 8  | 0.044694 | 100%         |        |         |         |
3.2. Analysis of Variance

ANOVA is mostly employed to determine the importance of the control variables (wear) to an effective response. This test is conducted with a 95% level of confidence, i.e., an importance rate of 5 percent. If the p-value for this attribute is less than 0.05, the factor can be typically considered essential. ANOVA’s key intention is to evaluate the control factors (load, duration, speed) to the response (wear). Figure 1. reveals the chief effect chart for mean and S/N ratios. Table 4 indicates the ANOVA for the level of wear. The sliding range and the sliding speed were found to have a substantial effect on the AMC. The third column of Table 4 indicates the percentage of respondents of each variable to the total variance and each aspect’s impact on the response parameter.

Figure 1. (a) Main effect plot for S/N ratio and (b) Main effect plot for Mean

Figure 2. Effects of applied load and sliding distance on wear
Surface plot of wear characteristics following sliding distance and load, as shown in Figure 2. The surface plot indicates the wear values improved by increasing the sliding distance. Wear rate enhancement is mainly depended on the significant frictional heat triggered to boost the sliding distance, but the load also enhances wear. The amount of heat will lead to the composites' drastic deterioration, slightly shifted from materials to the steel counterface. Also, the smallest spinning distance and load, material wear was marginally less.

4. Conclusions
The AA6082/ZrO$_2$ composite was tested using a pin-on-disk wear investigation unit. Taguchi DOE organized the trials, and the outcomes were assessed using chart results and variance analysis. Following the performance of the high impact variables used to specify a method such as sliding speed, applied load, sliding distance, the following conclusions were drawn.

- AA6082/ZrO$_2$ (12%) AMCs were made through compo casting method.
- Wear studies on the influence of process variables has been explored using the Taguchi method.
- Sliding distance is a notable factor that improves wear properties, has less effect on applied load and sliding speed. It is obvious from the results that the optimized values for the wear characteristics are the sliding distance: 1000 m, the normal load: 5 N and the sliding velocity: 2 m/s.
- From the evaluation, the sliding distance attributed 87.35 percent, followed by a normal load of 7.41 percentage and a sliding velocity of 0.14 percentage.

5. References
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