CNC Machining parameters optimization of AA7050 with reinforcement of ZrO$_2$ composites

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Abstract. The foremost target of this evaluation is to optimize the impacts of Computer Numerical Control (CNC) machining factors of CNC turning machine for the AA7050/ZrO$_2$ AMCs with response of material removal rate (CMRR) by utilizing Taguchi approach. The CNC turning aspects of this evaluation are Depth of cut, Speed and Feed rate. Taguchi route as L16 orthogonal array and 3 levels of machining factors are employed to guess the output like CMRR. The 16 samples of experiments are employed to determine the CMRR.

1. Introduction
The Metal Matrix Composites (MMCs) have two constituents the first constituent acts as the matrix component or base metal and the second constituent acts as the reinforcement metal. The characteristic properties are merged among two constituents after the preparation of the composition. Aluminium is one of the most used metals in industrial application. But the aluminium based matrix composites are heavier for some application, especially aerospace [1-5]. In automotive and aerospace applications, the aluminium based MMC is maximum normally utilization MMC. The aluminium based MMC have individual properties such as enhanced wear resistance, controlled thermal expansion, enhanced temperature properties, deduction of density, enhanced stiffness in addition to higher strength [6-8].

Particulate MMC offers numerous potential preferences contrasted and traditional titanium alloys including expanded firmness, great creep execution, wear resistance, and fatigue resistance. A great part of the work on mechanical properties has focused on the tensile execution and a portion of this information is introduced in this outline. Different properties, for example, creep, fatigue, and wear
resistance have been referenced quickly as they speak to a lower extent of the information accessible [9-12].

The CNC machine is regulated by codes such as G and M. Preparatory features like the geometry of tool motions and working condition of machine controller features. The CNC uses miscellaneous parts called M codes to monitor on/off signals for machine functions. MRR is an essential attribute for the component’s consistency, as it has a profound impact on the operation of the mechanical components. The goal of this study is to notice the optimum factors for the chosen control factors in order to maximize the metal removal rate (MRR) by employing the Taguchi method. In this work, the CNC machining trials have been performed on the CNC turning machine considering the three parameters such as feed, speed and depth of cut. The configuration of experiments action has been systematized to use the Taguchi’s L_{16} orthogonal array. This follows research study of the significance of the parameters utilizing the ANOVA approach.

2. Experimental details
In this research work, the AA7050 aluminium alloy is considered as a primary material for the composite. The matrix and subordinate material (ZrO$_2$) is mixed in the proportion of 90% aluminium with 10% ZrO$_2$. The research methodology shall be as follows;

- Originally, the AA7050 will be melted after the insulation materials have been powdered.
- Both materials are mixed and the molten mixture is kept at a temperature of 750°C.
- The mixture is stirred continuously at 400 rpm for four minutes.
- A specific mixture is poured into a different preheated mould.
- Multiple experiments have been carried out on the produced composite

After, the machining work was carried out on CNC turning center employing high speed steel (HSS) drill bit. Fig. 1 reveals the CNC machine setup. The tool employed for this research is 18 mm HSS drill bit. In this study, each aspect has three levels. L$_{16}$ orthogonal array is followed. Table 1. reveal the process parameter for CMRR.

| Table 1. Process parameters and their levels |
|-------------------------------------------|
| S. No | Factors               | Level 1 | Level 2 | Level 3 | Level 4 |
|-------|-----------------------|---------|---------|---------|---------|
| 1.    | Cutting speed (rpm)   | 200     | 400     | 600     | 800     |
| 2.    | Feed (mm/min)         | 20      | 40      | 50      | 60      |
| 3.    | Depth of cut (mm)     | 0.4     | 0.8     | 1.2     | 1.6     |
3. Results and Discussion

Turning based composite materials removal rate (CMRR) is utilized as an empirical feature. The larger is better performance attribute of Taguchi is adopted to enhance the objective feature (i.e., CMRR). These tests were conducted on CNC turning of AA7050/ZrO$_2$ composites using the Taguchi approach parametric method and measured using S/N Analysis for optimum CMRR. In CNC machining process, developing the CMRR is the primary goal to enhance the output yield. The S/N ratio for CMRR is also revealed in the Table 2. The CMRR was estimated based on the weight and turning period by employing the below equation.

$$MRR = \frac{\pi}{4}(d^2) \times L$$  \hspace{1cm} \text{Where } d = \text{diameter of the hole in mm } L = \text{length of the specimen in mm}$$

3.1. Novel Taguchi exploration for CMRR

For CMRR, HSS tool rotating speed (TOS) is the highly impacting factor for CMRR followed by feed rate (FR) and depth of cut (DOC). Chart for S/N ratio exposed in Fig. 2 reveals there is high range of deviation for difference in tool speed where as there is slight level of modification for change in FR for CMRR (Tables 3 and 4, Fig. 3).

3.2. Analysis of Variance for CMRR

TOS is the highly influencing factor for CMRR followed by FR and DOC. Interaction Plots for MRR shown in Fig. 4 and Table 5.

| Exp. No | Cutting speed (rpm) | Feed Rate (mm/min) | Depth of cut (mm) | CMRR (m$^3$/min) Avg | S/N Ratio |
|---------|---------------------|---------------------|-------------------|-----------------------|-----------|
| 1       | 200                 | 30                  | 0.4               | 525.050               | 54.4040   |
| 2       | 200                 | 40                  | 0.8               | 540.460               | 54.6553   |

Table 2. Input factors for CMRR and S/N ratio for CMRR
## Table 3. Response Table for Means

| Level | Cutting speed (rpm) | Feed Rate (mm/min) | Depth of cut (mm) |
|-------|---------------------|-------------------|------------------|
| 1     | 551.4               | 400.6             | 352.9            |
| 2     | 424.3               | 445.5             | 372.0            |
| 3     | 327.0               | 426.7             | 467.8            |
| 4     | 328.1               | 358.0             | 438.1            |
| Delta | 224.5               | 87.5              | 115.0            |
| Rank  | 1                   | 3                 | 2                |

## Table 4. Response table for S/N Ratios

| Level | Cutting speed (rpm) | Feed Rate (mm/min) | Depth of cut (mm) |
|-------|---------------------|-------------------|------------------|
| 1     | 54.48               | 51.69             | 50.53            |
| 2     | 52.50               | 52.81             | 51.06            |
| 3     | 49.82               | 51.54             | 52.53            |
| 4     | 50.07               | 50.82             | 52.74            |
| Delta | 4.66                | 1.98              | 2.22             |
| Rank  | 1                   | 3                 | 2                |

Larger is better
Figure 2. Main effect chart for means CMRR of AA7050/ZrO$_2$ AMCs

Figure 3. Main effect chart for S/N ratio CMRR of AA7050/ZrO$_2$ AMCs
**Figure 4.** Interaction plot for CMRR of AA7050/ZrO$_2$ AMCs

**Table 5.** Analysis of Variance for CMRR

| Source                | DF | Seq SS  | Adj MS  | F-Value | P-Value | Contribution |
|-----------------------|----|---------|---------|---------|---------|--------------|
| Regression            | 3  | 146720  | 48907   | 3.33    | 0.056   | 45.44%       |
| Cutting speed (rpm)   | 1  | 117730  | 117730  | 8.02    | 0.015   | 36.46%       |
| Feed (mm/min)         | 1  | 4292    | 4292    | 0.29    | 0.599   | 1.329%       |
| Depth of cut (mm)     | 1  | 24697   | 24697   | 1.68    | 0.219   | 7.649%       |
| Error                 | 12 | 176155  | 14680   |         |         | 54.55%       |
| Total                 | 15 | 322875  |         |         |         | 100.00%      |

4. **Conclusion**

In the present work, all the sixteen samples were positively machined via the turning machine and the CMRR value of the AA7050/ZrO$_2$ AMCs were obtained through optimization process, the outcomes were drawn as:

- Taguchi approach of experimental design has been efficaciously applied for optimizing multi-response process parameters for CNC Turning AA7050/ZrO$_2$ AMCs with L16 orthogonal array.
- Experimental Outcomes achieved from Taguchi technique exactly matches with analysis of Variance.
From the analysis the cutting speed has 36.46% of contributed and followed as DOC is 7.649% and FR is 1.329%.

5. References

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