Experimental investigation and modeling of drilling process parameters for surface roughness of Al6061/SiC/Gr hybrid composite using RSM

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Abstract. Surface quality and material removal rate (MRR) are two significant factors in the manufacturing which influence precision thus mirrors the productivity of the industry. Objective of this work is motivated to determine the optimum operating parameters for the drilling Aluminum hybrid composite. The metal hybrid composite of Aluminum was fabricated by stir casting process. Silicon carbide and graphite particles were added to improve material properties. The main cutting parameters, namely, spindle swiftness, feed amount and type of coolant are considered in this study. In this work, the experimentations were planned by a Box-Behnken design (BBD) method. The impact of procedure parameters on the reactions are assessed and ideal cutting conditions for limiting surface roughness and boost the MRR were resolved utilizing reaction tables, reaction charts, association tables, 3-D surface plots and attractive quality investigation. To approve, affirmation tests have been completed and anticipated outcomes have been seen as in great concurrence with experimental discoveries.

1. Introduction

Metal Matrix Composites (MMC) is generally utilized composite materials in aviation, car, gadgets and medical industries. The common issue with MMCs is that they are hard to appliance, because of the hardness and grating nature of the strengthening particles. There are various routes which are employed to fabricate metal matrix composites. This includes solidification processing, deformation processing and powder metallurgy. Among them, the stir casting method is the cheapest one in which the reinforcing particles are stirred into the molten alloy and the resultant melt is used to obtain cast ingots of composites. AL 6061 is widely used aluminum alloy in commercial industries due to its low density, electrical conductivity and corrosion resistance properties. The significant worry with the machining of AMMC is the extraordinary instrument wear brought about by the grating activity of the fortified particles, which prompts high machining cost [1-3]. The specialized challenges related with accomplishing a uniform appropriation of fortification, great wettability among substances, and a low porosity material are introduced and talked about.

Sharma et al. [4], seen that during boring of graphite fortified aluminum grid mixtures, instrument life of HSS boring apparatus gets expanded contrasted with the base amalgam as graphite being strong oil decreases the erosion device work interface. Kunz et al. [5] found that joining of graphite atom into aluminum MMCs improve the machinability of the composites during infiltrating of Al/SiCp, Al/SiCp–Gr and Al/Al2O3–Gr composite. Muniaraj et al. [6], researched the infiltrating action on
Al/20%SiC/5%Gr and Al/20%SiC/10%Gr blend composites made by vortex methodology and contemplated that for each and every cutting condition, Al/20%SiC/10%Gr composite has lower surface repulsiveness regards than Al/20%SiC/5%Gr composite. Results exhibited that consolidation of graphite as additional help in Al/SiCp-fortified composite reduces the cutting force and further it is seen that more development of graphite diminishes the surface completion.

Pradeepkumar and Packiaraj [7] used the Taguchi method to examine the impacts of penetrating boundaries, for example, cutting speed (5, 6.5, 8 m/min), feed (0.15, 0.20, 0.25mm/rev) and drill apparatus distance across (10, 12, 15mm) on surface roughness, device wear by weight, MRR and gap breadth blunder in boring of OHNS material utilizing HSS winding drill.

The present work is to present an effective approach for optimizing drilling parameters with response surface methodology. The experiment was carried out by varying spindle swiftness, feed amount and changing the coolant fluid. High speed steel was used as drill material. Kerosene, diesel and vegetable oil were used as coolant material. Surface roughness (SR) was measured after the experiment. Experiments were designed by response surface methodology and there were 17 experiments.

2. Experimental work

Aluminum alloy of AA6061 is utilized as a metal material. The graphite particles of size 20 μm and silicon carbide (SiC) Particles of normal size 20 μm are used as the help materials for produce. The composites creation is finished with fixed measure of 5 wt.% of SiC and with 5 wt.% of graphite. The composites were created by utilizing stir castin g technique at ideal speed which guarantees the uniform circulation of the fortifications in lattice alloy. The analyze was directed in outspread drilling machine. The procedure parameters picked dependent on literature review and conversation with subject specialists. The three controllable boundaries level and structure matrix are given underneath in the Table 1. Estimation of material ejection rate and surface brutality were recorded for each penetrating action. The surface unpleasantness was estimated on the Surface analyzer and MRR calculated from measuring weight of work piece before and after the drilling process. Surface roughness and MRR values were represented in Table 2.

The drilling test was directed under wet cutting conditions on a traditional vertical drilling machine. The machining tests were set up as 100 × 80 × 10 mm rectangular plates, Figure 1 shows the experimental set-up used. Three different cutting fluids were utilized, namely Kerosene, Diesel & vegetable oil. The tests were done using HSS drill, and performed at different cutting speeds and feed rates. Subsequently, the surface roughness of drilled holes was evaluated using the Federal Surf analyzer System 400.

| Table 1. Design factors and their levels. |
|------------------------------------------|
| **Factors** | **Parameters** | **Levels** | |
| SS | Spindle speed (RPM) | -1 | 0 | 1 |
| FEED | Feed rate (mm/min) | 0.20 | 0.25 | 0.30 |
| CF | Cutting fluid | kerosene | Diesel | Vegetable oil |

-1
0
1
Table 2. Experimental results SR.

| S.NO | Spindle speed (RPM) | Feed rate (mm/min) | Cutting fluid  | SR (microns) |
|------|---------------------|--------------------|----------------|-------------|
| 1    | 400                 | 0.3                | kerosene       | 2.38        |
| 2    | 300                 | 0.2                | Diesel         | 3.64        |
| 3    | 400                 | 0.25               | Diesel         | 3.18        |
| 4    | 400                 | 0.25               | Diesel         | 3.28        |
| 5    | 400                 | 0.2                | kerosene       | 2.92        |
| 6    | 400                 | 0.30               | Vegetable oil  | 3.76        |
| 7    | 400                 | 0.3                | Diesel         | 3.16        |
| 8    | 500                 | 0.2                | Diesel         | 2.66        |
| 9    | 500                 | 0.3                | Diesel         | 3.12        |
| 10   | 400                 | 0.25               | Diesel         | 3.16        |
| 11   | 500                 | 0.25               | Vegetable oil  | 3.14        |
| 12   | 300                 | 0.25               | Vegetable oil  | 4.4         |
| 13   | 300                 | 0.3                | Diesel         | 3.52        |
| 14   | 400                 | 0.3                | Vegetable oil  | 3.68        |
| 15   | 300                 | 0.25               | Kerosene       | 2.94        |
| 16   | 500                 | 0.25               | Kerosene       | 2.46        |
| 17   | 400                 | 0.25               | Diesel         | 3.46        |
3. Result and discussion

3.1. The effect of process parameters on Surface Roughness

A run of the mill checks for typicality supposition that is made by developing an ordinary likelihood plot of the residuals. Every remaining is plotted against its normal incentive under ordinariness. The lingering dispersion is discovered ordinary, as this plot is a straight line appeared in Figure 2. It very well may be seen from Figure 3 that the anticipated qualities and the genuine qualities have a straight graph. The reaction surface is plotted to examine the impact of procedure factors on the material expulsion rate and is appeared in Figures 4 & 5. From the figure 4 & 5, it is observed that SR decreases when the spindle increases. [4-7].

Figure 1. Drilling Experimental setup.

Figure 2. Normal plot of residuals.
Figure 3. Predicted vs. Actual value.

This is because of volume cleared by the drill excessively directionally corresponding to encourage rate. So as to measurably investigate the outcomes, ANOVA was performed. Procedure factors having \( p \)-value. From ANOVA results, it was observed that spindle speed and cutting fluid were significant parameters for surface roughness.

Figure 4. Contour plot for SR.
Feed rate is certifiably not an unmistakable parameter which impacts the SR. The maximum predicted value of MRR observed for spindle swiftness of 500 rpm. Confirmation experiments were conducted and the results were validated with predicted values.

![Figure 5. 3D Surface Graph plot for SR.](image)

3.2. **Confirmation experiment**

Regression equation is to anticipate the surface roughness and MRR values. The normal estimations of the qualities were gotten and contrasted and the anticipated qualities. Anticipated and exploratory qualities were plotted and it was appeared in figure 10 and 11 for SR and MRR. The variety among trial and anticipated qualities were little. To approve the outcomes got, three affirmation tests were directed for every single of the reaction qualities (SR and MRR) at ideal degrees of the procedure factors. The normal estimations of the attributes were acquired and contrasted and the anticipated qualities. Table 3. Gives the values of experimental and predicted values.

![Figure 6. Experimental Vs Predicted SR.](image)
### Table 3. Experimental results SR

| Standard Order | Actual value | Predicted value |
|----------------|--------------|-----------------|
| 1              | 2.92         | 2.82            |
| 2              | 3.18         | 3.25            |
| 3              | 3.12         | 2.98            |
| 4              | 2.66         | 2.72            |
| 5              | 3.16         | 3.25            |
| 6              | 3.76         | 3.86            |
| 7              | 4.4          | 4.36            |
| 8              | 2.94         | 2.89            |
| 9              | 2.46         | 2.5             |
| 10             | 3.64         | 3.79            |
| 11             | 3.52         | 3.47            |
| 12             | 3.46         | 3.25            |
| 13             | 3.16         | 3.25            |
| 14             | 3.68         | 3.58            |
| 15             | 3.28         | 3.25            |
| 16             | 3.14         | 3.18            |
| 17             | 2.38         | 2.48            |

### 4. Conclusion

After the test directed, reaction factors were arranged, and examination was led. Single target advancement was performed on Taguchi's Technique. After the parameters are optimized, ANOVA was performed to decide the general extent of every parameter. The accompanying ends are drawn from the exploratory examination of boring of Al6061-SiC-Graphite cross breed metal grid composites. Increment in shaft diminishes the surface unpleasantness of the gaps. The surface unpleasantness esteem increments with increment in feed rate. Sort of cutting liquid is additionally a critical parameter on surface unpleasantness. Increment in shaft builds the material evacuation rate. Cutting liquid is certainly not a noteworthy parameter on MRR. The surface unpleasantness (SR) and material evacuation rate (MRR) could be anticipated viably by applying Spindle speed, feed rate, and sort of cutting liquid and their communication in the frequent relapse models. Feed rate is the most critical parameter used to forecast the surface unpleasantness.

### 5. References

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