Comparative Investigations on Al7075 MMC reinforced with wt. %6 Al2O3 and B4C

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Abstract. MMCs are finding greater applications in aerospace, auto industries owing to their typical properties with respect to wear, mechanical and temperature resistance. The present study involves evaluation of microstructure, drilling, mechanical properties for Al7075 reinforced with Al₂O₃ content of wt.% 6.MMC and compare with Al7075 - 6% B4C composite for showing effect of reinforcement on drilling, mechanical properties. The composite samples were examined for mechanical, bending strength, hardness, elongation behaviour. Results revealed that uniform circulation of particulates in matrix structure with great bonding. Al7075 reinforced with 6% B4C displays high mechanical strength, better elongation, high surface quality and low hardness is seen. Surface roughness test was carried on the basis of Taguchi’s L9 orthogonal, and analysed by ANOVA, results specify maximum influence on surface roughness is due to speed for Al₂O₃. Further with B4C the surface roughness is affected by material, confirmation tests were also conducted for validation of process parameters.

Keywords: Al₂O₃, B₄C, Al7075, Wear characteristics, Drilling Analysis

1. Introduction

The composites are playing a pivotal role in the present-day technology. Among several MMCs, Aluminium matrix composites are prominent possessing good mechanical properties and find major applications in the fields of aerospace and automobile. With the introduction of SiC, B4C, Al₂O₃ etc as reinforcement the properties have enriched in terms of hardness, wear. Based on the type of alloying element various techniques like powder metallurgy, casting by stirring, squeezing can be adopted. Several researchers have made extensive investigations in the relevant area. Some of the works done are, Senerkarabulut et al [1] conducted mechanical tests with AA7039 with SiC, B4C, Al₂O₃ as reinforcements, concluded with results showing elevated hardness, elongation, TRS, prolongation with Al₂O₃ reinforced composite exhibited better bonding better surface. K. Umanath et al [2] studies are with A16061-T6, silicon carbide (SiC), aluminium oxide (Al2O3) composite on wear safety. T. Rajmohan et al [3], M. Ramulu et al [4], A. Pramanik et al [5], A. Saravanakumar et al [10] tested

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effects of shaft speed, bolster rates, drill materials impact for cutting parameters on surface with Al356/10SiC (wt %) metal grid, Al356/10SiC-3mica (wt%) mixture composites, and discovered that PCD drills outperformed with reference to quality of drilled hole with less force. Further similar works were addressed by K.M. Shorewardi et al [6], with SiC, Al2O3, B4C (0-20 %), Sener Karabulut et al [7], AA7039/ Al2O3MMCs used powder technology and milling parameters were analysed. Most of the researchers used stir casting process and successfully obtained good results.

2. Experimental Work:

2.1 Material: For the said experimental work, materials selected are, Aluminium 7075 as grid material (composition, ref. table 1) and for reinforcements aluminium oxide (Al2O3), B4C separately (wt. rate of 6%). The specimens were prepared as per ASTM standard by stir casting process.

| Table 1. Composition of Al7075 alloy. |
|--------------------------------------|
| Aluminium 7075 content (%by weight)  |
| Aluminium  | Al  | Si  | Fe  | Cu  | Mn  | Mg  | Ch  | Zn  | Ti  | Others |
| Alloy      | Max | Max | Max | Max | Max | Max | Max | Max | Max | Max |
| 7075       | 87.1-91.4 | 0.40 | 0.50 | 1.2- | 0.30 | 2.1- | 0.18- | 5.1- | 0.20 | 0.15 |

The process, reinforcement added slowly for better dispersion to the crucible preheated to 500°C additives such as degas tablet and scum powder for degasification, prevention of oxidation of Al17075 and to remove slag/flux. Castings prepared have constant weight percentage of Al17075 and 6%Al2O3 and 6% of B4C. Later SEM study is made, wear test, surface roughness, drilling etc were conducted.

3. Results and Discussion:

3.1 Microstructure Study: Figure 1 shows the SEM microstructure of Al17075 with 6%wt.Al2O3. From morphological review, homogeneous dissemination of Al2O3 is observed in the grid. Some porosity is also observed in the microstructures of the moulding. The following picture (Figure 2) depicts the EDS analysis.

![Figure 1: SEM Image of Al17075+6%wt.Al2O3.](image-url)
Figure 2: EDS analysis of A17075+6%wt. A12O3.

3.2 Micro structure of Al7075+6%B4C:
From the below SEM microstructure of A17075 with 6% wt.B4C, morphological review, homogeneous dissemination of B4C in Al7075 grid is observed. A few spots in Al7075 grid are distinguished without B4C reinforcing particles.

Figure 3: SEM Image of A17075+6%wt. B4C.
4. Test results:
A comparison table shows tensile strength peak loads and max. Bending load for A17075 with 6% of Al₂O₃ and B₄C.

Table 2 Strength test analysis of A17075

| PARAMETER                        | Al 7075 + Al₂O₃ wt. (6%) | Al 7075 + B₄C wt. (6%) |
|----------------------------------|--------------------------|------------------------|
| Vickers hardness                 | 61.3                     | 59.7                   |
| Yield stress (N/mm²)             | 162.374                  | 212.204                |
| Tensile strength (N/mm²)         | 178.862                  | 275.225                |
| Max Bending Strength in (N/mm²)  | 450.38                   | 549.79                 |

From the table 2 the Vickers hardness value recorded shows marginal higher value with 6% wt. of Al₂O₃ compared to same percent of B₄C reinforcements. Table also reveals interesting values with respect to yield stress, tensile strength with B₄C are 212.204 N/mm² and 275.225 N/mm² much higher compared to the Al₂O₃ (162.374, 178.862 N/mm² respectively) addition in Al7075. Further maximum bending strength also increased by 100N/mm² with 6% B4C resulting in worthy composite.

4.1 Drilling Parameters:
To determine surface roughness at different surface areas Taguchi technique is applied for drilled work piece (table3) and mean work roughness values are presented in table4 with optimal drilling properties for both Al₂O₃ and B₄C.

Table 3. Surface Roughness Test of A17075

| Experiment | Material     | Speed (RPM) | Feed (mm) | Thrust force(N) | Torque(N-m) |
|------------|--------------|-------------|-----------|-----------------|-------------|
| 1          | Al7075+6%Al₂O₃ | 355         | 0.05      | 245.25          | 0.784       |
| 2          | Al7075+6%Al₂O₃ | 560         | 0.08      | 274.68          | 0.882       |
| 3          | Al7075+6%Al₂O₃ | 710         | 0.12      | 353.16          | 1.0791      |
| 4          | Al7075+6%B₄C  | 355         | 0.05      | 333.54          | 0.7848      |
| 5          | Al7075+6%B₄C  | 560         | 0.08      | 457.26          | 1.1772      |
| 6          | Al7075+6%B₄C  | 710         | 0.12      | 529.74          | 1.3734      |
From the above Table 3, constant speed, feed values were selected and for speed 560 rpm and feed 0.08mm the thrust force value required for the B4C reinforcement is much higher than Al₂O₃; this is a significant observation.

4.2 Response table for Surface roughness:

Table 4. Surface roughness measurement results - Al7075

| Material               | Surface Roughness Results |          |          |
|------------------------|---------------------------|----------|----------|
|                        | Ra₁(µm) | Ra₂(µm) | Mean Ra(µm) |
| A17075+6%A1₂O₃         | 1.60     | 1.23     | 1.415     |
| A17075+6%A1₂O₃         | 2.48     | 1.94     | 2.21      |
| A17075+6%A1₂O₃         | 1.33     | 3.28     | 2.305     |
| A17075+6% B₄C          | 1.91     | 1.65     | 1.78      |
| A17075+6% B₄C          | 2.15     | 1.90     | 2.025     |
| A17075+6% B₄C          | 2.52     | 2.04     | 2.28      |

From the above table 4, results show that there is marginal improvement in surface roughness for A17075+6%A1₂O₃ as compared with A17075+6% B₄C composite. The mean surface gauge is raising in drilling work component as rate of speeds are raising.

Table 5. Response table for surface roughness.

| Level | Material | Speed | Feed  | Material | Speed | Feed  | Material | Speed | Feed  |
|-------|----------|-------|-------|----------|-------|-------|----------|-------|-------|
| I     | A1₂O₃    | -7.187| -2.454| B₄C      | -2.882| -5.619| A1₂O₃    | -6.099| -9.020|
| II    | A1₂O₃    | -4.710| -6.798| B₄C      | -13.126| -7.468| A1₂O₃    | -10.243| 3.401 |
| III   | A1₂O₃    | -5.719| -8.364| B₄C      | -5.897 | -9.020| A1₂O₃    | 10.243 | 3.401 |
| DELTA | A1₂O₃    | 2.477 | 5.909 | B₄C      | 10.368 | 3.401 | A1₂O₃    | 10.243 | 3.401 |
| RANK  |          | 2     | 1     | B₄C      | 1     | 2     | B₄C      | 1     | 2     |
Table 6. Anova table surface roughness for Al7075+6%Al₂O₃.

| Source     | Degree of freedom | Sum of squares | Mean of squares | F-test | P-test | Contribution |
|------------|-------------------|----------------|-----------------|--------|--------|--------------|
| Material   | 2                 | 0.7030         | 0.3515          | 0.067  | 0.0548 | 18.15%       |
| Speed      | 2                 | 2.735          | 1.3676          | 7.22   | 0.025  | 70.64%       |
| Feed       | 2                 | 0.03201        | 0.01600         | 0.03   | 0.975  | 0.83%        |
| Error      | 6                 | 8.14677        | 1.35776         | -      | -      | -            |
| Total      | 12                | 11.6168        | 3.09286         | -      | -      | -            |

Table 7. Anova table surface roughness for Al7075+6%B₄C.

| Source     | Degree of freedom | Sum of squares | Mean of squares | F-test | P-test | Contribution |
|------------|-------------------|----------------|-----------------|--------|--------|--------------|
| Material   | 2                 | 18.218         | 9.1089          | 12.38  | 0.007  | 80.49%       |
| Speed      | 2                 | 2.414          | 1.207           | 0.36   | 0.713  | 10.67%       |
| Feed       | 2                 | 0.9969         | 0.4985          | 0.14   | 0.874  | 4.40%        |
| Error      | 6                 | 46.2717        | 7.7.12          | -      | -      | -            |
| Total      | 12                | 67.9006        | 18.5265         | -      | -      | -            |

4.3 SN ratio values for surface roughness.

Figure 6: SN ratio for surface roughness for Al7075 with (a) 6% Al₂O₃ and with (b) 6% B₄C. The experimental values were authenticated by application of ANOVA. The tables 4 to 7 illustrate the contribution of the drilling parameters and their ratings. It is recorded that the speed rate has contributed to the extent of 70% and feed paid off very small contribution with Al₂O₃ as reinforcement and 80% contribution of material is made whereas the feed and speeds contributed very little when B₄C is added, correspondingly they are raked one, two, three. The S/N ratio values were also displayed in the Figure 6.
5. Conclusions

The following concluding remarks are made from comparative investigations on castings Al7075 alloyed with 6% Al2O3 and 6% B4C are, the SEM micro graphs of composite examples show uniformly conveyed interfacial bonding and individual effects on mechanical, drilling properties were observed. 6% Al2O3 shows better hardness property than 6% B4C. Yield strength with 6% B4C is much greater comparatively. Those 6% Al2O3 particles improved ductility for Al7075 matrix, expanded flexural strength. Taguchi Technique was used to achieve better-quality surface finish from optimizing required parameters. Further chip formation was affected by mechanical & morphological properties of work materials.

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