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# MACHINING CHARACTERISTICS ON SURFACE ROUGHNESS OF (MgO) REINFORCED IN (AL-7075) MMC'S

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## ABSTRACT

Metal matrix composites possess significantly improved properties including high tensile strength, hardness, low density and good wear resistance compared to alloys or any other metals.
In this work the composite metal matrix material is developed by reinforcing of Magnesium oxide Nano powder (Mgo) in Aluminum alloy (Al-7075) fabricated by Stir Casting Machine. The MMC's specimens are prepared by varying the percentage of weight fraction of the reinforced particles as 5%, 10% of magnesium nano powder (Mgo) and the remaining aluminum alloy respectively. The machining characteristics that influence the surface roughness such as Feed rate, Depth of cut and cutting speed were studied. The methodology based on orthogonal array Taguchi's Experimental Technique and Analysis of Variance (ANOVA) and Signals to Noise ratio (S/N Ratio) were employed to optimize the surface roughness.

***Keywords:*** *Aluminum 7075, Magnesium Oxide Nano Powder, Stir Casting Technique, ANOVA*

## I. INTRODUCTION

A composite material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications. Modern composite materials are usually optimized to achieve a particular balance of properties for a given range of applications. Composite is a multiphase material that exhibits a significant proportion of the properties of both constituent phases such that a better combination of properties is realized. This is termed as the principle of combined action. The term "composite" broadly refers to a material system which is composed of a discrete constituent (the reinforcement) distributed in a continuous phase (the matrix), and which derives its distinguishing characteristics from the properties of its constituents, from the geometry and architecture of the constituents, and from the properties of the boundaries (interfaces) between different constituents. Composite materials are usually classified on the basis of the physical or chemical nature of the matrix phase, e.g., polymer matrix, metal-matrix and ceramic composites.

## II. SELECTION OF MATERIALS

Work Materials which are used in the experiment.

- ❖ Matrix Material
- Aluminum (Al7075)
- ❖ Reinforcement Materials
- Magnesium Oxide Nano powder

**Matrix Material**

***Aluminum 7075:***
The matrix material to be used was chosen as Al7075 which is a precipitation hardened aluminum alloy, containing zinc, magnesium, copper, and chromium as its major alloying elements. It has good mechanical properties and it is strong with strength comparable to many steels, has good fatigue strength and less resistance to corrosion and many others.

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***Table.1.Chemical Composition of Al 7075***

| Element | % Weight | Element | % Weight |
|---|---|---|---|
| Si | 0.4 | Cr | 0.28 |
| Cu | 2.0 | N | - |
| Mg | 2.9 | Zn | 6.1 |
| Mn | 0.3 | Ti | 0.2 |
| Fe | 0.5 | Zr | - |
| | | Al | Remainder |

***Table.2.Properties of Aluminum 7075***

| Properties | Density | Melting Point $^0C$ | Tensile Strength MPa | Fatigue Strength MPa | Hardness HB |
|---|---|---|---|---|---|
| Al7075 | 2.8 | 627 | 572 | 160 | 60 |

***Reinforcement Material:***

Magnesium Oxide is selected as Reinforcement. It is physically and chemically stable at high temperatures. It has two attributes: high thermal conductivity and low electrical conductivity. Magnesium oxide (MgO) has elastic modulus of approximately 300GPa, shear modulus of 122 GPa and CTE (coefficient of thermal expansion) of 12 µm/m-$^oC$. The MgO nanoparticles have high surface reactivity and high chemical and thermal stability, which make MgO a hopeful material for applications in fields of sensors, semiconductors, etc.

***Fig1: MgO Nano Powder***

***Properties of Magnesium Oxide:***

| Properties | Density | Melting Point | Boiling Point |
|---|---|---|---|
| MgO | 3.58 g/cc | $2852^0C$ | $3600^0C$ |

***Rule of Mixture:***

**Density:** dc = dm*Vm + df*Vf

Where,

- dc, dm, df – densities of the composite, matrix and dispersed phase respectively;

Vm,Vf – volume fraction of the matrix and dispersed phase respectively.

## III. EXPERIMENTAL PROCEDURE

Stir-casting is the simplest and most commercial method of production of MMCs. This approach involves mechanical mixing of the reinforcement particulate into a molten metal bath and transferred the mixture directly to a shaped mould prior to complete solidification. In this process, the crucial thing is to create good wetting between the particulate reinforcement and the molten metal. The stir casting technique was used to fabricate the composite specimen as it ensures a more uniform distribution of the reinforcing particles. This method is most economical to fabricate composites with discontinuous fibres or particulates. In this process, matrix alloy (Al 7075) was first superheated above its melting temperature. Then keep the matrix alloy in the semisolid state. At this temperature,

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the preheated Mg particle of 5%, 10% (by weight) were dropped into the slurry and mixed using a graphite stirrer. The composite slurry temperature was increased to fully liquid state and automatic stirring was continued to about five minutes at an average stirring speed of 300-350 rpm under protected organ gas. The Mg particles help in distributing the particles uniformly throughout the matrix alloy. The melt was then superheated above liquids temperature and finally poured into the cast iron permanent mould for testing specimen.

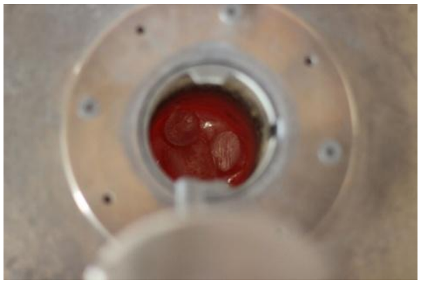

*Fig.2: Melting of Al 7075 in Stir Casting*

**Important Parameters Used in stir casting:**

***Particulate Preheating Temperature:***

Preheating of particulate is necessary to avoid moisture from the particulate otherwise chances of agglomeration of particulate occurs due moisture and gases. The preheated temperature in a furnace is made up to $800^0$C and maintained at that temperature before mixing with Aluminum melt. Along this MgO particles were heated to form a oxide layer on the MgO particles which make it chemically more stable and by the oxide layer formation wet ability will increase so particles will effectively embedded in aluminum matrix and will result in less number of porosities in casting.

***Stirring Speed:***

In stir casting process stirring speed is very important parameter for consideration. In the process stirring speed was 500 rpm which was effectively producing vortex without any spattering. Stirring speed is decided by fluidity of metal if metal having more fluidity then stirring speed will be low. It is also found that at less speed, dispersion of particulates is not proper because of ineffective vortex.

*Fig.3: Stir Casting Equipment*

## IV. EXPERIMENTATION

The experimental arrangement has been assembled by the coupling gear-box motor and mildsteel four blade stirrer is used. The melting of the aluminum (100%) scraps and Magnesium Nano powder (Mgo– 20nm size) is carried out in the graphite crucible into the electricfurnace. First the scraps of aluminum were preheated for 2 to 3 hours at

450°C and Mgo powder also heated with 800°C and both the preheated mixtures is then mechanically mixed with each other below their melting points. This metal-matrix Al - Mgo is then poured into the graphite crucible and put in to the electric furnace at 830°C temperature. The furnace temperature was first increases above the composites completely melt the scraps of aluminum and then cooled down just below the components temperature and keep it in a semi-solid state. At this stage the preheated Mgo were added with manually mixed with each other. It is very difficult to mix by machine or stirrer when metal-matrix composites are in semi molten state with manual mixing taking place. When the manual mixing is complete then automatic stirring will carried out for ten minutes with normal 400 rpm of stirring rate the temperature rate of the electric furnace should be controlled at 760 ± 10°C in final mixing process. After completing the process the slurry has been taken into the sand mould within thirty seconds allow it to solidify. This experiment should repeatedly conducted by varying the compositions of the composite powder of Mgo (5%, 10%), weight of aluminum scraps in grams plus weight in grams of Mgo powder as shown in the following chart.

***Table.3: Weight in grams for composition of AlMgo casting:***

| Percentage | Al 7075 | MgO |
|---|---|---|
| 100 | 100 | 0 |
| 95 | 95 | 5 |
| 90 | 90 | 10 |

***Fig.4. Casted Specimens***

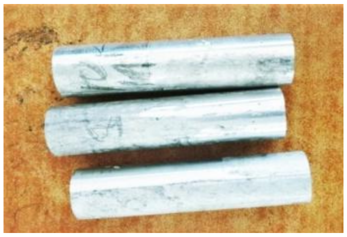

***Fig.5. after Machining Specimens***

***Fig.6. after Turning Operations***

Using Taguchi's orthogonal array the experiments are planned in the design of experiments (DoE), which helps in reducing the number of experiments. The experiments were conducted according to orthogonal array L9. In the present investigation the three cutting parameters are selected as cutting speed (v), feed (f) and depth of cut (d). Since the considered factors are multi-level variables and their outcome effects are not linearly related, it has been decided to use three level tests (Table 4) for each factor. Taguchi's orthogonal array of L9 is most suitable for this experiment as shown in Table and the S/N ratio results and analysis as shown in table.

***Table.4. Three Level Tests***

| Contol Parameters | Unit | Symbol | Levels | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| **Cutting Speed** | **mm/min** | **v** | **19** | **30** | **47** |
| **Feed Rate** | **mm/rev** | **f** | **0.53** | **0.58** | **0.64** |
| **Depth of Cut** | **mm** | **d** | **0.3** | **0.6** | **0.9** |

## V. RESULTS

**Machining values by using dry turning:**

| CUTTING SPEED | FEED RATE | DEPTH OF CUT | MATERIAL% | ROUGHNESS VALUES | S/N RATIOS | MEAN VALUES |
|---|---|---|---|---|---|---|
| 19 | 0.53 | 0.3 | 100 | 1.97 | -5.8893 | 1.97 |
| 19 | 0.58 | 0.6 | 95 | 1.5 | -3.5218 | 1.5 |
| 19 | 0.64 | 0.9 | 90 | 2.46 | -7.8187 | 2.46 |
| 30 | 0.53 | 0.6 | 90 | 2.25 | -8.2659 | 2.59 |
| 30 | 0.58 | 0.9 | 100 | 2.5 | -7.9588 | 2.5 |
| 30 | 0.64 | 0.3 | 95 | 2.2 | -6.8484 | 2.2 |
| 47 | 0.53 | 0.9 | 95 | 1.6 | -4.0823 | 1.6 |
| 47 | 0.58 | 0.3 | 90 | 2.05 | -6.235 | 2.05 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | 0 | |
| 47 | 0.6<br>4 | 0.6 | 100 | 3.10 | -<br>9.993<br>7 | 3.16 |

**Taguchis method for dry turning:**

***Responsible table for S-N ratios***

| Levels | Cutting Speed | Feed Rate | Depth of Cut | Material% |
|---|---|---|---|---|
| 1 | -5.743 | -6.076 | -6.324 | -7.440 |
| 2 | -7.691 | -5.905 | -7.261 | -4.818 |
| 3 | -6.770 | -8.220 | -6.620 | -7.947 |
| Delta | 1.948 | 2.315 | 0.936 | 3.130 |
| Rank | 3 | 2 | 4 | 1 |

***Response table for means of surface roughness (Ra):***

| Levels | Cutting Speed | Feed Rate | Depth of Cut | Material% |
|---|---|---|---|---|
| 1 | 1.977 | 2.053 | 2.073 | 2.367 |
| 2 | 2.430 | 2.017 | 2.417 | 1.767 |
| 3 | 2.270 | 2.607 | 2.187 | 2.573 |
| Delta | 0.453 | 0.590 | 0.343 | 0.777 |
| Rank | 3 | 2 | 4 | 1 |

***Analysis of variance for Ra Values:***

| Source | Degree of Freedom | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| Cutting Speed | 2 | 0.3172 | 0.3172 | 0.15858 | * | * |
| Feed Rate | 2 | 0.6556 | 0.6556 | 0.32781 | * | * |
| Depth of cut | 2 | 0.1836 | 0.1836 | 0.09181 | * | * |
| Material% | 2 | 0.9944 | 0.9944 | 0.49721 | * | * |
| Residual Error | 0 | 0 | 0 | * | | |
| Total | 8 | 2.1508 | 2.1508 | | | |

***Regression Equation***

Roughness Ra = 2.226 - 0.2489 Cutting Speed_19 + 0.2044 Cutting Speed_30 + 0.04444 Cutting Speed_47 - 0.1722 Feed Rate_0.53 - 0.2089 Feed Rate_0.58 + 0.3811 Feed Rate_0.64 - 0.1522 Depth of Cut_0.3 + 0.1911 Depth of Cut_0.6 - 0.03889 Depth of Cut_0.9 + 0.1411 Material %_90 - 0.4589 Material %_95 + 0.3178 Material %_100

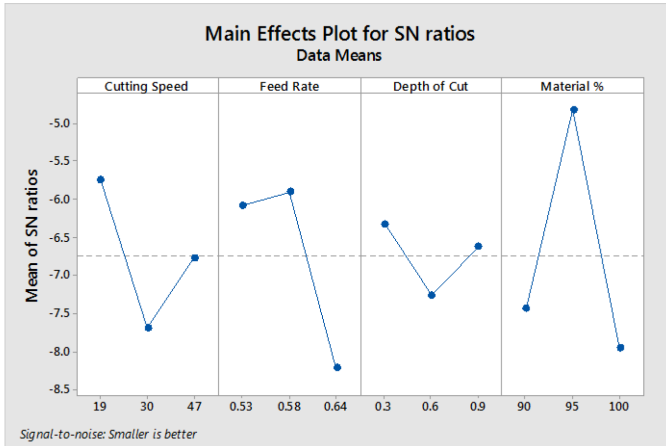


*Fig.7. Main effects plot for SN ratios*


*Fig.8. Main effects for means*

**Machining values by using wet turning:-**

| CUTTING SPEED | FEED RATE | DEPTH OF CUT | MATERIAL% | ROUGHNESS VALUES | S/N RATIOS | MEAN VALUES |
|---|---|---|---|---|---|---|
| 19 | 0.53 | 0.3 | 100 | 2.45 | -7.7833 | 2.45 |
| 19 | 0.58 | 0.6 | 95 | 2.3 | -7.2345 | 2.3 |
| 19 | 0.64 | 0.9 | 90 | 1.82 | -5.2014 | 1.82 |
| 30 | 0.53 | 0.6 | 90 | 2.46 | -7.8187 | 2.46 |
| 30 | 0.58 | 0.9 | 100 | 2.21 | -6.8878 | 2.21 |
| 30 | 0.64 | 0.3 | 95 | 3.31 | -10.396 | 3.31 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 47 | 0.53 | 0.9 | 95 | 2.1 | -6.4443 | 2.1 |
| 47 | 0.58 | 0.3 | 90 | 2.83 | -9.0357 | 2.83 |
| 47 | 0.64 | 0.6 | 100 | 2.24 | -7.0049 | 2.24 |

**Taguchi's Method for Wet Turning:**

***Responsible Table for S – N Ratios***

| Levels | Cutting Speed | Feed Rate | Depth of Cut | Material% |
|---|---|---|---|---|
| **1** | **-6.740** | **-7.349** | **-9.072** | **-7.352** |
| **2** | **-8.368** | **-7.719** | **-7.353** | **-8.205** |
| **3** | **-7.495** | **-7.534** | **-6.178** | **-7.225** |
| **Delta** | **1.629** | **0.371** | **2.894** | **0.800** |
| **Rank** | **2** | **4** | **1** | **3** |

***Response Table for means of surface Roughness (Ra)***

| Levels | Cutting Speed | Feed Rate | Depth of Cut | Material% |
|---|---|---|---|---|
| **1** | **2.190** | **2.337** | **2.863** | **2.370** |
| **2** | **2.660** | **2.447** | **2.333** | **2.570** |
| **3** | **2.390** | **2.457** | **2.043** | **2.300** |
| **Delta** | **0.470** | **0.120** | **0.820** | **0.270** |
| **Rank** | **2** | **4** | **1** | **3** |

***Analysis of Variance for S/N Ratios***

| Source | Degree of Freedom | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| **Cutting Speed** | 2 | 0.3380 | 0.3380 | 0.16690 | * | * |
| **Feed Rate** | 2 | 0.02660 | 0.02660 | 0.01330 | * | * |
| **Depth of cut** | 2 | 1.03740 | 1.03740 | 0.51870 | * | * |
| **Material%** | 2 | 0.11780 | 0.11780 | 0.05890 | * | * |
| **Residual Error** | 0 | * | * | * | | |
| **Total** | 8 | 1.51560 | | | | |

***Regression Equation***

Roughness Ra = 2.413 - 0.2233 Cutting Speed_19 + 0.2467 Cutting Speed_30- 0.02333 Cutting Speed_47 - 0.07667 Feed_0.53 + 0.03333 Feed_0.58 + 0.04333 Feed_0.64 + 0.4500 Depth of Cut_0.3 - 0.08000 Depth of Cut_0.6- 0.3700 Depth of Cut_0.9 - 0.04333 Material %_90 + 0.1567 Material %_95 - 0.1133 Material %_100

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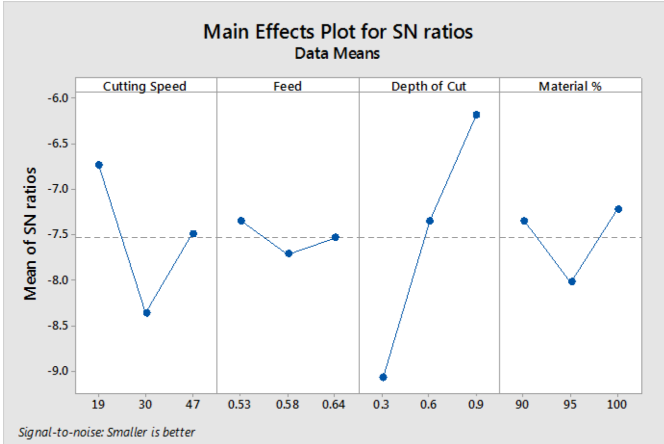


***Fig.10. Main effects for SN ratios***

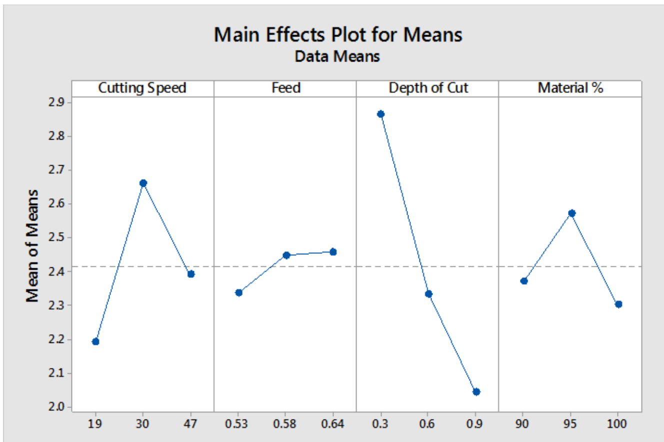


***Fig.11: Main effects for means***

## VI. CONCLUSIONS

The surface roughness in the turning process has been investigated for machining of aluminum (Al-7075) MMC with reinforcements of nano particles with 5%,10% MgO under different cutting conditions with a HSS tool of 1600 grade using Taguchi's orthogonal array. Based on the experimental and analytical results, the following conclusions are drawn:

a) With the help of Taguchi method the effect of machining parameters on the surface roughness has been evaluated and optimal machining conditions would be arrived at to minimize the surface roughness.

b) It is found that the depth of cut is the dominant parameter for surface roughness followed by the cutting speed. Compared to other parameters the material%, feed rate shows minimal effect on surface roughness.

i) The results of the analysis of variance revealed that minimal surface roughness could be arrived at significantly for composite wet turning operations through the specified machining conditions: v = 19 m/min, f = 0.53 mm/rev and d = 0.3 mm.

The optimal cutting parameters and the percentage contribution may be established as follows:-
Cutting speed (v): 19 m/min & Percentage contribution: 15.694%
Feed rate (f): 0.53 mm/rev. & Percentage contribution: 80.379%
Depth of cut (d): 0.3 mm & Percentage contribution: 1.375%

c) It is found that the material% is the dominant parameter for surface roughness followed by the feed rate. Compared to other parameters depth of cut, cutting speed shows minimal effect on surface roughness.

i) The results of the analysis of variance revealed that minimal surface roughness could be arrived at significantly for composite dry turning operations through the specified machining conditions: v = 19 m/min, f = 0.53 mm/rev and d = 0.3 mm.

The optimal cutting parameters and the percentage contribution may be established as follows:-
Cutting speed (v): 19 m/min & Percentage contribution: 14.745%
Feed rate (f) : 0.53 mm/rev. & Percentage contribution: 30.48%
Depth of cut (d): 0.3 mm & Percentage contribution: 8.537%

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