Study of Al-Cu-ZnO NP composite for EDM Applications

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Abstract - *Electro discharge machining is a manufacturing process whereby a desired shape is obtained using electrical discharges. Material is removed from the work piece by a series of rapidly recurring current discharges between two electrodes separated by a dielectric liquid and subject to an electric voltage. In this study the electrode tool is made up of Al-Cu-ZnO NP composite for Electro discharge machining process. The composite is made using powder metallurgy method with aluminum matrix and copper, ZnO nano particles reinforcement. Synthesis of zinc oxide nano particles is achieved from combustion method. By varying zinc oxide nano particles by 3, 5 and 7% in composite its mechanical properties, electrical properties, and wear properties are studied. From the experimentation, it is observed that hardness strength and thermal conductivity increases as percentage of zinc oxide NP increases whereas electrical conductivity and spark erosion rate decreases.*

Key Words: EDM, Powder metallurgy, SEM, nano particles.

1. INTRODUCTION

Metal matrix composites (MMCs) generally consist of lightweight metal alloys of aluminum, magnesium, or titanium, reinforced with ceramic particulate, whiskers, or fibers. The reinforcement is very important because it determines the mechanical properties, cost, and performance of a given composite. Composites reinforced with particulate can have costs comparable to unreinforced metals, with significantly better hardness, and somewhat better stiffness and strength. Continuous reinforcement can result in dramatic improvements in MMC properties, but costs remain high. Continuously and discontinuously reinforced MMCs have very different applications. MMCs can be designed to fulfill requirements that no other materials, including other advanced materials, can achieve. There are a number of applications in aerospace structures and electronics that capitalize on this advantage. Current markets for MMCs are primarily in military and aerospace applications. Experimental MMC components have been developed for use in aircraft, satellites, jet engines, missiles, and space shuttle. [1]

There have been studies on Al doped ZnO thin films and ZnO reinforced magnesium matrix nano composites [2][3]. Thus Gull et el. [2] finds that hardness and thermal stability found increased gradually with increase in ZnO. Selvam et el. [3] find that Mg/ZnO nano composites find their application in automotive and aerospace industries due to their superior specific properties.

2. EXPERIMENTAL WORK

1.1 Materials

For the preparation of composite, first atomized aluminum powder (180, 250 grit size added in 50:50 ratio of total aluminum weight) and atomized electrolytic copper powder (325 grit size) was obtained.

1.2 Synthesis of Zinc oxide nano particles

In this work, the ZnO nano particles were synthesized by combustion method. Analytic grade zinc nitrate (0.5 gm) and organic fuel urea (1.0 gm) were directly mixed at a desired molar ratio. From experiment, it was found that zinc nitrate possesses absorbent property. The reactant mixture is easy to absorb moisture from the air to become transparent slurry. Therefore, the fuel was directly mixed at a specific molar ratio with a starting solution in a peter dish, stirred for 2 minutes, which gives homogeneous mixtures. This clear solution was kept in muffle furnace for 1 hour to produce ZnO nano particles. During combustion process, evolution of a large volume of gases occurs; the clear solution dries thus producing a loose white cloud foam product. It was found that, the combustion reaction is depending on the molar ratio of fuel to oxidation [4]. The synthesized zinc oxide nano particles are in the range of 100 nm as shown in Fig 1.

Fig -1: synthesis of zinc oxide nano particles

1.3 Mixing of powders by Ball milling theory

The object of mixing is to provide a homogeneous mixture and to obtain desired uniformity of density from top bottom of the compact. Mixing adversely affect both green and sintered strengths. Over-mixing should be avoided, since this increases the apparent density of the mix thus affecting the green strength. For this, the mixing process is carried out in ball mill. The process can be carried out with or without binder (lubricant).

1.4 Green compacting

The mixed powders are compressed to shape in a rigid steel die under pressures of 15- 90 MPa. The inner surface of die is coated with grease. At this stage, the compacts maintain their shape by virtue of cold-welding of the powder grains within the mass. The compacts must be sufficiently strong to withstand ejection from the die and subsequent handling before sintering. Compacting is a critical operation in the process, since the final shape and mechanical properties are essentially determined by the level and uniformity of the pressed density. Fig 2 shows the split die and green compact.

Fig -2: Split die and green compact

1.5 Sintering

Sintering is a key part of the operation as compact acquires the strength needed. The thermal treatment of a compact carried at a temperature below the melting point of the Aluminum i.e. at 550^{0}c. The sintering cycle was carried out for 5 hours. The sintering cycle is shown in chart 1.

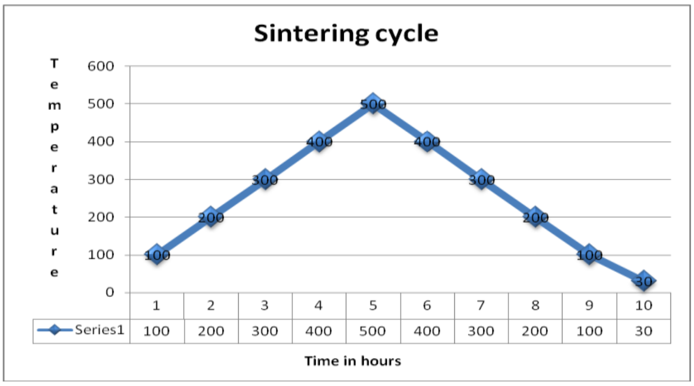

Chart -1: Sintering cycle

3. SEM ANALYSIS OF COMPOSITE

The morphology of prepared Al-Cu-ZnO NP composites are illustrated in Fig 3, 4, 5 for 3, 5 and 7% composition of ZnO NP. The result shows that ZnO NP in the range of 80-100nm. The powders compacted are in well dispersed phenomenon with lower percentage of porosity. The Aluminum, copper are in micron size with well placed nano particles of ZnO. It is clear from figures that all constituents are well sintered but the only complexity is non uniform distribution of particles of Al, Cu and ZnO NP.

Fig -3: synthesis of zinc oxide nano particles

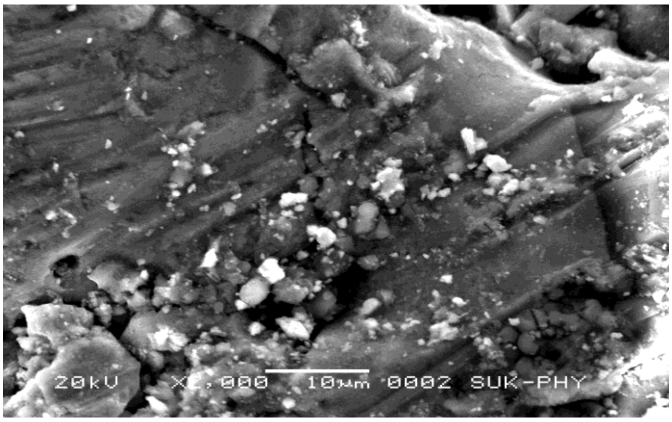

Fig -4: synthesis of zinc oxide nano particles

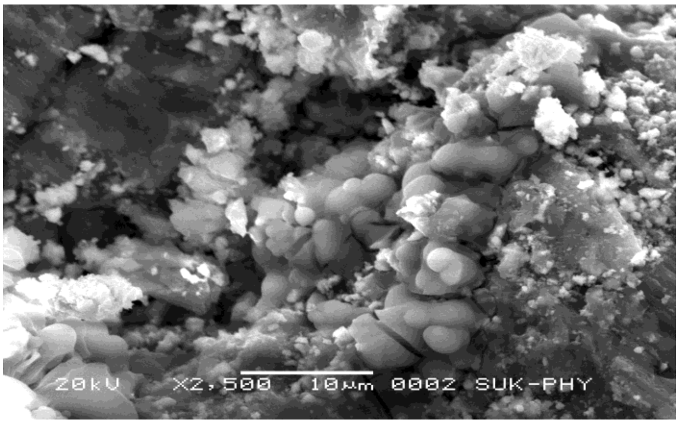

Fig -5: synthesis of zinc oxide nano particles

4. RESULTS AND DISCUSSION

4.1 Hardness test

The specimens are subjected to Brinell hardness test where specifications are: Load P = 187.5 kg, Indenter D = 2.5 mm.

Table -1: BHN obtained from hardness test

	3% of ZnO NP	5% of ZnO NP	7% of ZnO NP
Specimen 1	54.55	82.45	95.49
Specimen 2	58.335	82.45	95.49
Specimen 3	54.55	82.45	93.49

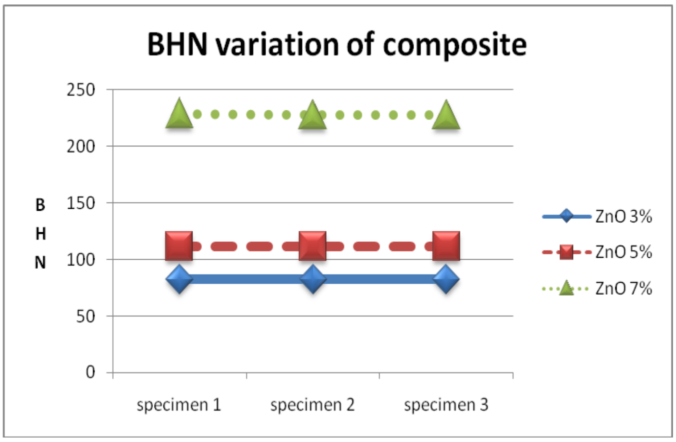

Chart -2: BHN comparison for 3, 5 and 7%

Chart 2 shows hardness comparison from 3% to 7%. The hardness of specimen goes on increasing as ZnO NP increases. The hardness of composite increases with reduction in porosity as ZnO NP acquires the voids in composite providing much more compactness to composite [5].

4.2 Electrical conductivity test

The electrical conductivity on specimen is measured by Wheatstone bridge circuit where combinations of voltage source, Wheatstone bridge, multi meter and wiring connections is used. From this setup resistance of specimen (R) can be measured.

Table -2: Resistivity obtained from conductivity test

	3% of ZnO NP	5% of ZnO NP	7% of ZnO NP
Specimen 1	0.0153	0.08773	0.2011
Specimen 2	0.0157	0.08773	0.19625
Specimen 3	0.0157	0.09235	0.19625

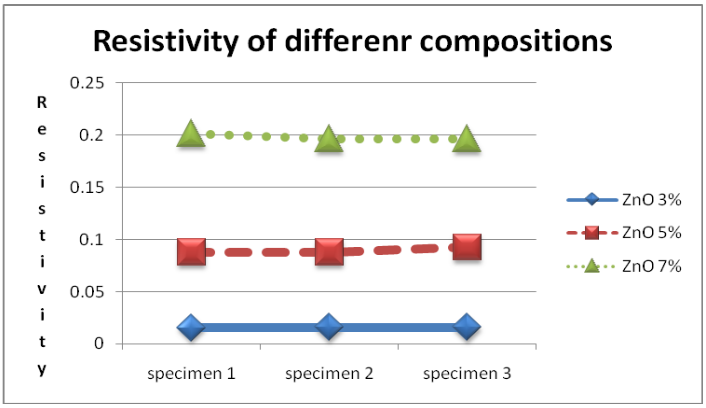

Chart -3: Resistivity comparison for 3, 5 and 7%

As shown in Chart 3 percentage of Zinc oxide NP affects the conductivity of specimen, which increases resistivity of specimen thereby decreasing conductivity. This is mainly because the property zinc oxide as it is good semiconductor with oxide layers which resist the flow of current thus conductivity decreases.

4.3 Spark erosion test on EDM

Specimen erosion is obtained by using specimen as electrode tool in EDM. The tool is made of Al-Cu-ZnO NP composite with different compositions. The work piece was mild steel. The test is conducted for 5 minutes.

Table -3: Erosion rate

	Erosion rate (gm/sec)
3% ZnO	0.001328
5% ZnO	0.00143466
7% ZnO	0.0015723

In this test erosion rate increases as percentage of zinc oxide increases. Since ZnO has a relatively large direct band gap at room temperature, thus erosion rate increases for same material removal rate.

4.4 Thermal conductivity test

The thermal conductivity setup was used for test. In this setup specimen is kept to attain uniform temperature, then its bottom and upper surface temperature was measured. Then water initial temperature and final temperature of water after specimen immersion was measured.

Table -4: Thermal conductivity

	Thermal conductivity
ZnO NP 3%	236.36 (W/m-K)
ZnO NP 5%	315.1489 (W/m-K)
ZnO NP 7%	472.72 (W/m-K)

Table 4 shows thermal conductivity results of of composite. It showed that as the ZnO NP percentage increases thermal conductivity of the specimen increases.

5. CONCLUSIONS

In this paper, the study of microstructure, mechanical and electrical properties of Al-Cu-ZnO NP composite was studied by preparing composite using powder metallurgy method. The following are the conclusions.

1. By analyzing Scanning electron microscope results it concluded that zinc oxide nano particles were agglomerated.

2. As Zinc oxide nano particles increases, the hardness of composite increases with reduction in porosity as Zinc oxide nano particles acquires the voids in the composite providing much more compactness to composite.

3. Zinc oxide is semiconductor with oxide layers, so by increasing percentage of zinc oxide nano particles in composite the conductivity decreases. It is common phenomenon as oxide layers resist the flow of current.

4. As percentage Zinc oxide nano particles increases in composite the erosion rate increases.

5. As percentage Zinc oxide nano particles the thermal conductivity increases.

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