Experimental Investigation of Mechanical Properties of Ni/Cu hybrid reinforced 7075 Aluminum alloy composites

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Abstract — Particle-reinforced metal matrix composites (MMC) in the form of hybrid composites are commonly used in many applications where the components are prone to wear and tear. Therefore, it is necessary to analyze various mechanical properties such as fracture toughness behavior and wear behavior of metal matrix composites. Various types of particulate metal fillers have been reported to be used as reinforcing fillers in metal matrices, but the use of metal powders for this purpose has not been fully investigated. In this study, a new class of hybrid reinforced aluminum alloy composites was developed using a nickel/copper metal powder filler. We also analyzed the effect of the weight percent of copper and nickel particles on different mechanical properties of Al 7075/Cu/Ni/matrix composites. The results show that the 4 wt% Ni and 4 wt% Cu and 4 wt% Ni and 4 wt% Cu MMCs have the highest hardness & flexural strengths among all the MMCs produced. It can be concluded that these MMCs are widely used in various industrial and technical aerospace, novel and wear applications due to their high tensile strength.

Keywords: Aluminum, Metal Matrix Composites, Copper, Nikel

I. Introduction

A composite material is a mixture of two or more components. They have different physical and chemical properties, and when these materials are combined, the properties of the composite differ from those of the individual components. When a composite is analyzed at the macroscopic level, it has two or more phases, one is the matrix and the other is the reinforcement. The reinforcement may be continuous or discontinuous. Reinforcement is more difficult and powerful than the other phase called Matrix. The support component is the reinforcement, the strength and stiffness of the matrix material [1].

The reinforcement is used in the form of fine particles, the metal is used in the form of the substrate, and the composite is called metal matrix composite (MMC). Upon mixing, these materials improve the mechanical properties of composites if the base material and reinforcement retain their physical and mechanical properties. The distribution of reinforcing particles within the matrix should modify the strain-stress behavior. These MMCs have a number of drawbacks compared to other materials in single form due to higher manufacturing costs and reduced toughness and ductility when mixed with reinforcements. Some of the important materials are Co, Be, Al, Mg, Ni, Ti and Fe, some of which are used as base materials[2]

In today's world, composite materials are using current scenario materials due to their excellent properties and various industrial applications. Due to their light weight, aluminum composites are mainly used in the automotive industry. When using composites, the net weight loss should be 20-50%. Composites have excellent weather resistance and can withstand chemical attack in a variety of applications [3][4]

II. Literature survey

Literature reviews provide various aspects of hybrid metal matrix composites, particularly relevant to erosion and wear properties and fracture analysis of hybrid metal matrix materials. Different studies have been conducted by different researchers on different conditions of composites.

Cheng et al. [5] investigated the mechanical behavior of SiCP / 6066Al composite materials and fabricated samples by powder metallurgy method. They found that the load transfer between the matrix and the reinforcement, the grain refinement of the metal matrix, and the dislocation enhancement are the main reinforcement structures of SiCP / Al composites.

Kubota et al. [6] Reported that Al - 15 at. % MgB_2 composite material was investigated and mechanically ground (MMed) using a vibrating ball mill and spark plasma sintering (SPS) to produce a composite material to prepare a sample. They examined the following properties such as hardness, compressive strength, etc. They found that the highest compressive strength is obtained by increasing the hardness of the composite material.

Nguyen et al. [7] studied the mechanical behavior of the oxidation behavior of magnesium alloy AZ 31 B and woven the sample through the solidification process. They found that the presence of fine Nano sized particles of alumina (Al2O3) increased and gradually increased the oxidation resistance of the AZ 31 B alloy. The presence of nano-Al2O3 particles tended to retard the transient oxidation step.

Sardar et al. [8] Although no samples were prepared using the ultrasonic cavitation-assisted stirring casting process, the mechanical behavior of magnesium matrix composites was studied. They studied the following properties, including mechanical properties and microstructure of composites: They found that the Mg micro/nanocomposites developed by UASC have much better tensile properties and wear resistance compared to base alloys or composites fabricated by mechanical stirring only.

Srivatsani [10] studied fracture analysis and found that microscale fracture is caused by individual decomposition or agglomeration of Al2O3 micro particles in the metal matrix and decomposition at the matrix-particle interface. I found results. Errors due to cracking and dissolution at the interface increased with the amount of matrix strengthening.

III. MATERIAL & METHODS

This section highlights the materials, manufacturing techniques and methods used to achieve the proposed research results. In the current study, aluminum 7075 alloy was used as the base material and nickel and copper were used as the reinforcing material. For the production of hybrid reinforced aluminum alloy composites, liquid agitation casting technique was used. The experiment includes deta
ils of physical properties (density, porosity), mechanical properties (hardness, flexural strength) of hybrid reinforced aluminum alloy composites.

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A. Matrix Material

Aluminum 7075 is known for its superior performance in extreme environments. Aluminum 7075 is extremely durable in both saltwater &industrial chemical environments.

Aluminum 7075 retains excellent strength after welding. It has the highest strength of any non-heat treated alloy, but is not recommended for use above 65ºC. Copper and nickel with different amounts of fillers are used as reinforcement [11].

Element	Wt %
Si	0.4
Fe	0.5
Cu	3.7-4.7
Mn	0.3-.08
Mg	1-1.7
Zn	0.24
Ti	0.15
Al	Remaining

Table 1: Chemical composition of alloy Al7075 in % wt.

B. Hardness

Hardness is measured using a Rockwell hardness tester. A diamond cone indenter with an angle of 120° between opposing surfaces is pressed into the test material under a light load of usually 20 kgf and another heavy load of 160 kgf is applied to the lever and a dial showing the Rockwell hardness number as a "B" scale indicator.

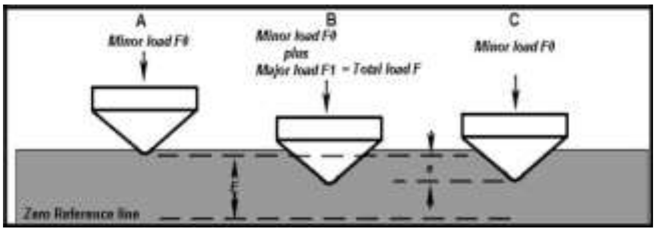

Fig. 1: Steps in Rockwell hardness tester

Figure 1 shows the principle of Rockwell. Repeat the test on all metal matrix reinforced composite samples

Following are the test parameters:

- Minor load = 20 kgf
- Major load = 160 kgf
- Indenter = 120 degree diamond cone indenter
- Size of test samples (EA-1 to EA-4) = 30 mm*30 mm*

C. Flexural Strength

The interlaminar shear strength (ILSS) of the composite is the short beam shear (SBS) test. The SBS test is a three-point bend test performed using the same UTM as ASTM Standard D 2344 – 84. Sample size is 75 mm × 15 mm × 15 mm.It was measured at a cross head speed of 12 mm/min. MMC reinforced metal matrices 0 wt%, 2 wt%, 4 wt% and 6 wt%, so the sample thickness varies from 1 to 4 mm. Length and width of the particulate filler composite .It is the same as the unfilled composite, but the thickness is a fairly constant 2 mm .Particulate filler composite material.

The ILSS value is evaluated using the following equation

$$F.S = \frac{3PL}{2bt^2}$$

Where P is the maximum load, b is the width of the specimen; t is the thickness of the test

Sample. Evaluate using the same three-point bending test with the same bending strength. The flexural strength of the composite is evaluated using the following formula. Where L is the span length of the specimen.

D. Test parameters

- Size of composite samples = 100 mm*20 mm*
- Crosshead speed = 10 mm/min
- Span length = 60 mm

IV. RESULT AND DISCUSSION

A. Analysis of mechanical and fracture toughness of 7075 aluminum alloy composites filled with powder nickel powder

1) Effect of hardness on 7075 aluminum alloy composites filled with nickel powder

Figure 2 shows the Rockwell hardness values of aluminum alloy composites filled with different weight percentages of nickel metal powder. It can be seen that the hardness continue
sly increases with the addition of nickel powder and decreases after a certain time.

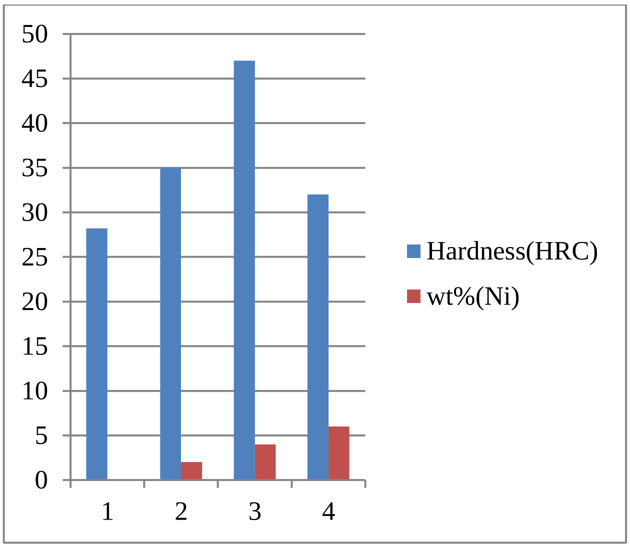

Fig. 2: Effect of hardness on Al 7075 alloy composites filled with nickel powder

Hardness (Rockwell hardness on 'C' scale (HRC) of the specimen samples are evaluated on Rockwell hardness gadget as consistent with ASTM E-ninety two at carried out load of one hundred sixty KN. it may be seen that the base material with 6 % Cu have 28.2 HRC hardness on addition of zero wt.% Ni and whilst adding the filler content material the hardness improved in regularly. once more boom in filler content of 2 wt. % over neat alloy composite hardness extended with 35 HRC. once more increase in filler content of one.2 wt. % to 4.0 wt. % hardness elevated by 37 HRC. again increase in filler content of 4 wt. % to6 wt.% hardness reduced via 32 HRC. within the alloyed composite when adding the hard nickel

Metallic reinforcement particles may additionally will increase the micro hardness of the composite by means of the increase of dislocation density of the alloyed composite. as the number of dislocations within the base matrix will increase, by way of the addition of nickel powder particles and their interaction in between dislocation and reinforcement.

2) Effect of Flexural Strength on Al 7075 alloy composites filled with nickel powder

Figure 3 shows the change in flexural strength of Al7075 alloy composites reinforced with nickel metal powder. Flexural strength was found to increase linearly, and the last it was fixed by adding nickel metal reinforcement in two samples. Composite shows 120 MPa. When adding 0 weight. % filler content and it increased to 144 MPa by adding weight. % 2 Now lift the weight. % nickel metal powder in the composite, the bending strength of the composite is increase with 220 MPa. At 4.0%. After that it has to be shown that when increasing further the nickel metal powder in the alloyed composite the its didn't show any change in the value and it has to be 220 MPa for the wt. % of 6.0 [13].

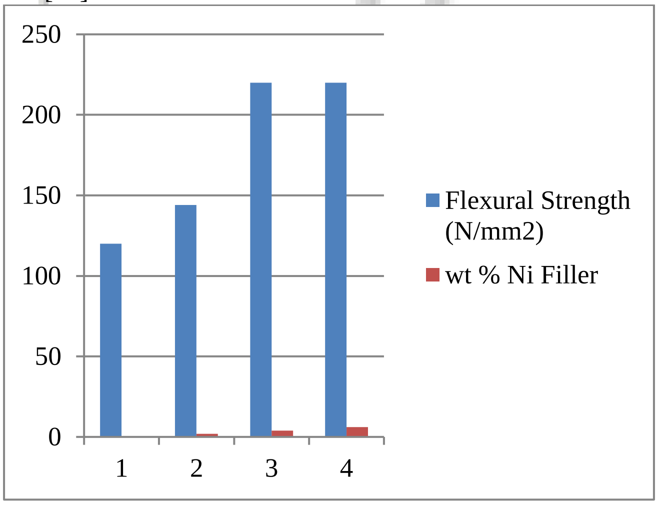

Fig. 3: Effect of flexural strength on nickel powder filled 7075 aluminum alloy composites

B. Analysis of mechanical and fracture toughness of 7075 aluminum alloy composites filled with copper powder

1) Effect of hardness on 7075 aluminum alloy composites filled with copper powder

Figure 4 indicates the Rockwell Brinell hardness values of the aluminum alloy composites filled with various weight percentage of copper metal powder. It can be seen that by the addition of Copper powder hardness will be increased gradually and after some point it will reduce.

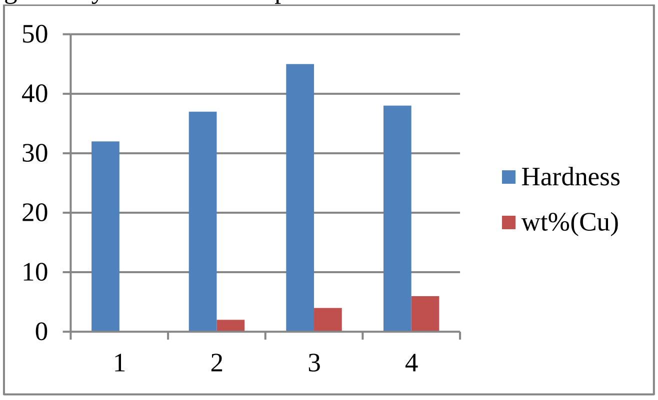

Fig. 4: Effect of Hardness on Copper Metal Powder Filled Al 7075 Alloy Composites

Hardness (Rockwell Brinell hardness on the sample "C" scale (HRC)) is evaluated according to ASTM E-92 using a Rockwell Brinell hardness tester with a load of 160 kN. This alloy is found to be 32 HRC at 0% addition. The hardness increased gradually according to the amount of filler added. The filler content is again increased by 2 wt% and the hardness of the alloy composite is increased by 37 HRC. Increase the filler content again by 2.0% by weight. % to 4.0 wt% hardness increased by 45 HRC. Again, increase the filler content by 4.0 wt%. % to 6.0 wt% hardness decreased by 38 HRC. Adding hard copper metal reinforcement particles to alloy composites can increase the microhardness of the composites by increasing the dislocation density of the alloy composites.

It can be seen that the dispersion of the hard metal particulate in the soft and ductile matrix increases the strength of the alloyed composite. By adding a reinforcing material to the composite material, the capacity and bond strength of the matrix must be increase.

2) Effect of Flexural Strength on Copper Powder Filled Al 5083 Alloy Composites

Figure5 shows the change in flexural strength of copper metal powder reinforced Al 5083 alloy composites. Flexural strength was found to increase linearly with the addition of copper metal reinforcement and decrease in the final sample. Flexural strength 96 MPa. When adding 0 weight. % filler content, increased to 198 MPa with theaddition of 2.0 wt%. Now lift the weight. % of copper metal powder in the composite, the bending strength of the composite should increase with a weight of 230 MPa. 4.0%. It should then be shown that adding more copper metal powder in the alloyed composite does not change its value and should be 140 MPa with respect to weight. 6.0% [14][13].

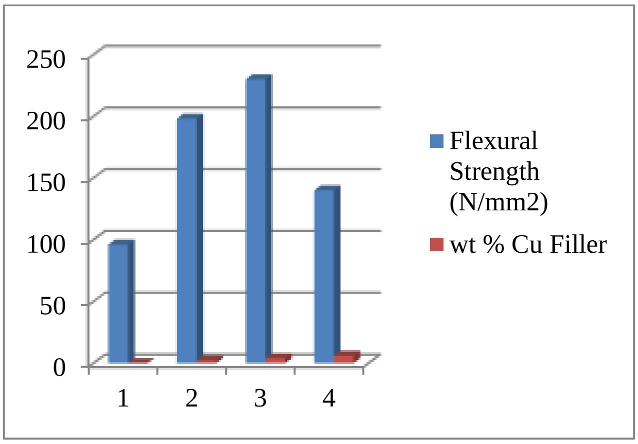

Fig. 5: Effect of flexural strength on nickel powder filled 5083 aluminum alloy composites

V. Conclusion

The following conclusion have been drawn from present research work

- For the weight wt. % of Cu-Ni in aluminum matrix the hardness of the MMC is increase with the increasing of the Cu-Ni reinforcement maximum at 4 wt. % and then decreasing when increasing the Cu-Ni content.
- For the weight wt. % of Cu-Ni in aluminum matrix the flexural Strength of the MMC is increase with the increasing of the Cu-Ni reinforcement maximum at 4 wt. % and then decreasing when increasing the Cu-Ni content.
- Finally it can be concluded that increasing the copper reinforcement in MMC, affect the hardness as well as flexural strength first it will increase and then decrease.

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