Tribological Test on Copper based Hybrid Composite Material

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***Abstract*— The basic reason of metals reinforced with hard ceramic particles or fibers are improved properties than its original material in terms of strength, stiffness, hardness, electrical conductivity. Nickel improves the machinability of the composites and also possesses excellent corrosion resistance and electrical conductivity, thereby decreasing the wear rate of hybrid copper composite, without reducing its electrical conductivity.**

Keywords- Reinforced Composite, Stir-Casting Fabrication, Tensile Test, Optical Microscopy, Stress Strain, Young's Modulus, Shear Modulus.

1. INTRODUCTION

A composite material is made by combining two or more dissimilar materials. They are combined in such a way that the resulting composite material or composite possesses superior properties which are not possessed by individual material. So, in technical Terms, we can define a composite as a multiphase Material from a combination of materials, differing in Composition or form, which remain bonded together, But retain their identities and properties, without going into any chemical reactions1.The advantages of the composite materials are only realized when there Is a reasonable cost – performance relationship in the Component production. The use of a composite material is obligatory if a special property profile can only be achieved by application of these materials.

Copper Matrix Composite can be used in electrical switches and connecting pins due to its enhanced strength and electrical conductivity. Also it can be used in electrical applications for the brushes of DC Motor which get worn out regularly and in electrical switches where copper parts are used these composites can be used to increase the life of the Switches. The reinforcement of metals can have many different objectives. The reinforcement of light metals opens up the possibility of application in areas where weight reduction has first priority. The precondition here is the improvement of the component properties.

The development objectives for metal composite materials are:

1. Increase in yield strength and tensile strength.
2. At room temperature and above while maintaining the minimum ductility or rather toughness.
3. Increase in creep resistance at higher
4. Temperatures compared to that of conventional
5. Alloys.
6. Increase in fatigue strength, especially at
7. Higher temperatures.
8. Improvement of thermal shock resistance.
9. Improvement of corrosion resistance.
10. Increase in Young’s modulus.
11. Reduction of thermal elongation.

II. DETAILS EXPERIMENTAL

2.1. MATERIALS AND PROCEDURES

The materials used in preparing copper matrix hybrid Composite are Copper which serves the purpose of Metal matrix along with reinforcements such as Nickel and Silicon Al_2O_3 to obtain the desired properties of hybrid composite. Copper Matrix composites are widely used in electrical Sliding contacts such as in homo polar machines, railway overhead current collection system, lead Frame in large scale integrated-circuit, welding Electrodes, transfer switches, and electrical contact material. They can also be used in sliding contacts.

These can be of very different character, e.g. High speed, heavy current types: motors and generators, slip rings, brushes, commentators, current pickup contacts in electric transport. Low speed, light current types: potentiometers. The resistance to mechanical wear of the contact brushes and slip rings must be very high, since the relative speed of the contacts may reach 50 m/s or more. Dissimilar brush materials are usually employed to avoid excessive frictional wear.

The brush/commutate system is at intense pressure, because it is an amalgamation of sliding contact and make-break contact Carbon fiber reinforced copper matrix composites correspond to a fair degree of compromise between thermo mechanical properties and thermal conductivity.

Their main advantages are the following:

i. Lower density than copper
ii. Very good thermal conductivity
iii. Low coefficient of thermal expansion
iv. Good machinability.

Desirable properties of composite materials are high Stiffness and strength, low density, high electrical and thermal conductivity, flexible coefficient of thermal expansion, corrosion resistance, enhanced wear resistance etc. Wetting of the fiber by Copper is less, though due to very low solubility of Carbon, not exceeding 0.02% even at elevated temperature.

It is therefore generally essential to force impregnation to form a composite, with not entirely acceptable results. An understanding of Carbon diffusion in Copper and its behavior at the Cu/C interface is Elementary to developing successful strategies for getting better fibber-matrix composite performance.

2.2 STIR CASTING FABRICATION

Stir casting was recognized for fabrication of MMC (Metal Matrix Composite), and currently practiced commercially. Its advantages lies in its Ease, suppleness and its application in large scale production and, in principle it permits conventional metal processing route to be used, and its little cost. The cost of preparing composites materials using a Casting method is about one-third to one-half that of other methods. Normally,stircasting of MMC Involve producing a melt of the chosen matrix Material, followed by the addition of a reinforcing material into the melt, and achieving a suitable dispersion through stirring.

Fig.1. Graphite crucible furnace

Base material: Hybrid Copper Composite
Nano particle: Hard Ceramic Particles
Nano particle size: 40nm.
Fabrication method: stir casting
(at atmospheric condition)
Pre heating temperature: 950^0C

The subsequent step is the solidification of the melt containing suspended particles to obtain the desired distribution of the dispersed phase in the cast matrix. In the composites formed through this method, particle distribution will vary significantly depending on process parameters during both the melt and solidification stages of the process .The addition of particles to the melt drastically changes the viscosity of the melt, and this has outcomes for casting processes. It is vital that solidification occur before considerable settling has been allowed to take place. The process is generally attained out at two dissimilar ranges of temperature of the melt, beyond the liquids temperature or at the melt temperature controlled within the partially solid range of the alloy the technique concerning the latter range of temperature is called the compo-casting process and it is very efficient in making cast composites with elevated particle content.

ELEMENT	MASS (gm)	VOLUME (cc)	VOLUME FRACTION
COPPER	95	10.603	0.879
NICKEL	2.5	0.32	0.053
Al_2O_3	2.5	0.779	0.064

Table 1: Volume fraction for different Components in 5% reinforcement

The most important condition when using a stir casting technique is continuous stirring of the melt with a motor driven agitator to prevent settling of particles.

ELEMENT	MASS (gm.)	VOLUME (cc)	VOLUME FRACTION
COPPER	**90**	**10.045**	**0.749**
NICKEL	**5**	**1.266**	**0.094**
Al_2O_3	**5**	**1.558**	**0.116**

Table 2: Volume fraction for different Components in 10% reinforcement.

ELEMENT	MASS (gm.)	VOLUME (cc)	VOLUME FRACTION
COPPER	**85**	**9.487**	**0.685**
NICKEL	**7.5**	**1.899**	**0.137**
Al_2O_3	**7.5**	**2.336**	**0.168**

Table 3: Volume fraction for different components in 15% reinforcement

2.3 OPTICAL MICROSCOPY

Optical microscopy is performed to view the grain structure of composite at various percentages. It was performed as it shows the kind of correlation between different components of composites and how are they distributed, whether continuous or discontinuous which is not visible through naked eye. It is done using optical microscope at 100X magnification.

Fig.2 Microstructure of 15%vol of Nano-particles of composite

III. RESULTS AND DISCUSSION

3.1. YOUNG'S MODULUS (E)

From the law of composite mixtures we can find the Young's Modulus for the 5%, 10% and 15% (mass) Reinforced composite

3.1.1 YOUNG'S MODULUS FOR 5% REINFORCED COMPOSITE.

Volume Fraction of reinforcements for
5% Reinforcement from **Table 1**= 0.117
Thus we get can find the Young's Modulus for the
5% Reinforced composite
E = 145.01 GPa

3.1.2 YOUNGS MODULUS FOR 10% REINFORCED COMPOSITE.

Volume Fraction of reinforcements for 10%
Reinforcement from **Table 2**= 0.21
Thus we get can find the Young's Modulus for the
10% reinforced composite E = 163.523 GPa

3.1.3 YOUNGS MODULUS FOR 15% REINFORCED COMPOSITE.

Volume Fraction of reinforcement for
15% Reinforcement from **Table 3**= 0.305
Thus we get can find the Young's Modulus for the
15% reinforced composite E = 188.956 GPa

3.2 SHEAR MODULUS (G)

From the law of composite mixtures, the shear Modulus has been determined for different percentage Reinforcements. Shear Modulus for 5%, 10% and 15% reinforcement Was found to be 48.918 GPa, 55.06 GPa and 57.60 GPa respectively.

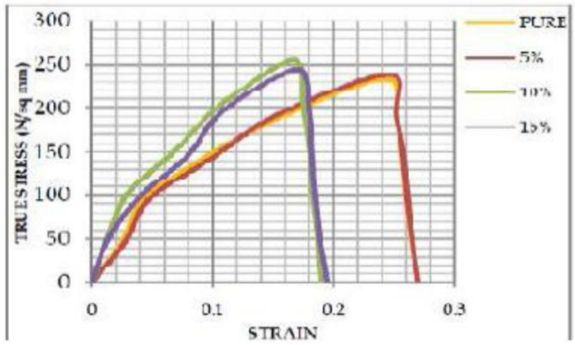

Fig.3 Graph between Stress (N/sq. mm) and Strain for different Reinforcements

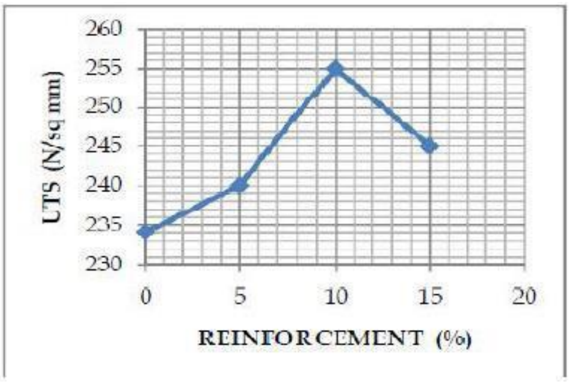

Fig.4 Graph depicting Ultimate Tensile Strength (N/sq.mm) for different percentage reinforcements.

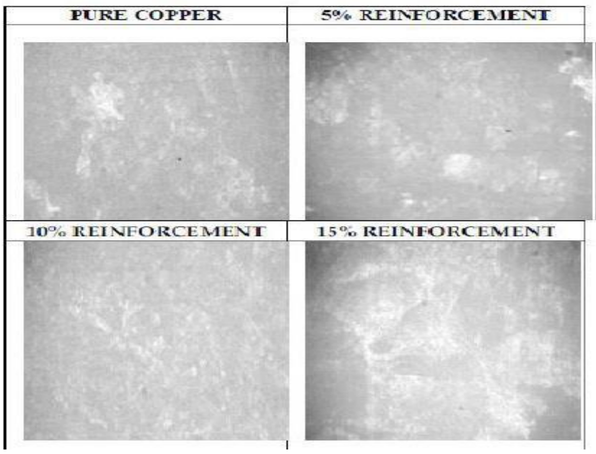

Fig.5 Optical Microscopy at 100X

IV CONCLUSIONS

Hybrid Copper Composite with nano-sized Hard Ceramic Particles was successfully fabricated via stir casting method. Mechanical behaviour of composite has been experimentally analyzed, leading following conclusions.

1. Through stress strain curves obtained after tensile test it can be inferred that the value of the ultimate strength and yield strength are enhanced, although the rise is not very steep.

2. Through load deformation curves it can be inferred that the ability of material to carry load got improved with increase in reinforcement percentage.

3. Young's modulus and shear modulus improved. (They have direct relation with reinforcement %).

4. Poisson's ratio and density of the material got reduced with increasing reinforcement percentage (they have inverse relation with reinforcement %)

Fig.6 Fabricated and tested composites.

5. There is tremendous improvement in hardness of the component.

6. With increase in the percentage value of the reinforcement the value of strength of the Composite increased, it rises from 234.1 at 0% to 240 at 5% and to 255 at 10% but with further increase in the reinforcement percentage the value of strength decreased to 245 at 15%.

7. In microstructure the aluminum oxide, silicon carbide and carbon phases are clearly visible but the mixing is not homogenous, so the composite obtained is of discontinuous type.

Hence from above observations it can be inferred that,

- ➢ High stiffness and strength is achieved in the
- ➢ Composite which is not present in Copper?
- ➢ Increased mechanical strength.
- ➢ Improved electrical and thermal conductivity
- ➢ Because of presence of graphite.
- ➢ Increased wear resistance.
- ➢ Increased machinability and surface finish.

V FUTURE WORK

Composite of Hybrid Copper Composite with different volume fraction of Hard Ceramic Particles (40 nm) which is preheated at different temperature is produced by stir casting method.

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