IJIRST –International Journal for Innovative Research in Science & Technology| Volume 5 | Issue 6 | November 2018
ISSN (online): 2349-6010

Experimental Investigation of Mechanical Characterization of Aluminum Metal Matrix Composite Material

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Abstract

Aluminum composite material has become the most widely used substrate within the sign and display industry due to the many benefits which this material provides. The properties of composite materials increased by adding various types of fillers as reinforcing materials. These alloy is widely used in various industrial and engineering field aerospace, novel and wear application due to their higher tensile strength, young's modulus and higher wear resistance properties. The paper deals with the development of aluminum alloy composites using Nickel/Copper metal powder filler. The main objective of this to find out the impact of % wt of copper and nickel particulates on different mechanical properties of Al 5083/Cu/Ni/ matrix composites. The result has to be shown that among all the fabricated MMCs, the MMC having 2% wt of Ni and 2% wt of Cu higher compressive strength and highest ultimate tensile strength and the MMC having 3 % wt of Ni and 2 wt % of Cu exhibited having higher impact strength, impact strength among all the fabricated MMCs.

Keywords: Aluminum, Metal Matrix Composites, Nickel, Copper

I. Introduction

Composite materials (also referred to as composites or shortened to composites) are mixtures of two or more constituent materials. They have different physical and chemical prosperity, but combining them produces materials with properties and properties different from the individual components. Individual components are separated in the finished structure and remain distinct. These new composite materials are needed for a number of reasons:

Compared to convective materials, they are stronger, lighter, or less expensive. At the macroscopic level, the composite has two or more phases, which composite material has superior mechanical properties compared to the individual components acting independently. In these two phases, one phase is matrix and the other is reinforced. The reinforcing material may be a continuous type or a discontinuous type. Reinforcement is harder and stronger than other phases called matrices. The load bearing component is reinforcement and is the strength and stiffness provided by the matrix material.

Again reinforcement is divided into two categories: fine particles and fibers. However, the substrates known as matrices can be metals, polymers and ceramics. When metal is used as the matrix and reinforcement is used as fine particles, the composite is called metal matrix composite (MMC). This matrix and micro particles maintain their chemical and physical properties, but remarkably improve the mechanical properties of the composites. These fracture mechanisms depend on the distribution of particulate reinforcement in the matrix and alter the overall stress-strain behavior of the MMC. However, MMC has several disadvantages compared to signal metal, there are increased production costs due to expensive manufacturing techniques used and their ductility and toughness are reduced. Several important materials are used as matrices such as Al, Be, Mg, Ti, Fe, Ni, Co and Ag. The use of aluminum as a matrix composite is mainly [1].

In the matrix, the particle-reinforced metal shows a large effect due to its large mechanical and physical properties. Use of reinforcing materials for the development of metal matrix composites (MMC) for producing composites which must be the highest strength to weight ratio and low weight to stiffness ratio at low cost, and the manufacture of light composite materials. Particulate reinforced aluminum matrix composites are widely used as composite materials in automotive applications [2].

II. LITERATURE REVIEW

The main aim of literature review is to study various aspects of hybrid metal matrix composites with a special reference to erosion and wear characteristics and fracture analysis of hybrid metal matrix materials. A variety of research work has been done by different researchers on different condition of composite materials like:

– Mechanical characterization of metal matrix composite materials

A. Literature Review of Various Field of Research Areas

Paper No.	*Authors*	*Materials*	*Remarks*
1.	*V.S. Aigbodion (2007)*	*Al–Si alloy/alumino-silicate composite*	*The addition of alumino- silicate particles to (Al - 6% Si) alloy increases the compressive strength of the alloy up to the addition of alumino- silicate up to 20% by weight, but with a general reduction in impact strength, increased in hardness*
2.	*Sajjad Amirkhanlou, Behzad Niroumand (2011)*	*Al356/SiCp*	*When the reinforcing material was injected as a composite powder, the porosity of the composite material decreased considerably. The maximum tensile strength, yield strength and elongation of composites produced by compo casting of (Al-SiCp-Mg)cp injected melt increased by 90%, 103% and 135%, respectively.*
3.	*L. Falcon-Franco , I. Rosales b, S. García-Villarreal , F.F. Curiel , A. Arizmendi-Morquecho (2016)*	*Magnesium metallic matrix composites with nitride addition effect*	*Hardness and modulus measurements showed an improvement of about 3 times the value due to the addition of AlN particles to the MgAZ 91 matrix.*
4.	*Joyson Abraham, S. Chandra Rao Madane, I. Dinaharan, L. John Baruch (2016)*	*quartz particulate reinforced AA6063 aluminum matrix composites*	*The quartz particles increased the micro hardness of the composite material and the quartz particles improved the wear resistance of the composite material. The wear rate decreased as the volume fraction of quartz particles increased.*
5.	*Hossein Abdizadeh , Maziar Ashuri , Pooyan Tavakoli Moghadam , Arshia Nouribahadory , Hamid Reza Baharvandi (2011)*	*aluminum/zircon composites*	*With increasing zircon content of composites, the hardness of specimens increases to a maximum value of 75 BHN. Yield stress and compressive strength change with increasing zircon content.*
6.	*N. Nemati , R. Khosroshahi , M. Emamyb, A. Zolriasatein (2011)*	*Al–4.5 wt.% Cu–TiC Nano composites*	*The hardness of the nano-particle reinforced composite material was higher than the hardness of the micron size TiC reinforcement material. The wear resistance of all samples reinforced with nano-sized TiC was higher than micron sized TiC reinforced composites and matrix alloys.*
7.	*S. Mohan Kumar, R. Pramod, H K Govindaraju (2017)*	*Aluminium AA430 Reinforced with SiC and Mgo*	*As the addition of reinforcing particles increased, the strength of the metal matrix such as tensile strength, yield strength and Young's modulus increased. However, the ductility of the matrix is compromised by the presence of hard reinforcing particles and gradually decreases as these particles increase in the metal matrix.*
8.	*Barbara Previtali, Dante Pocci, Cataldo Taccardo (2008)*	*Aluminum matrix composites*	*Due to the high volume content of SiC particles and absence of weak brittle compounds, the wear resistance of Al - 20% SiC is higher than that of Al - 7.5% B 4 C and above all extremely superior to that of A359 + 1% non-reinforced Mg Alloy.*
9.	*Y. Wang, H.Y. Wang, Y.F. Yang, Q.C. Jiang (2015)*	*TiB2 particulate reinforced Mg composites*	*Compared with the AZ91 alloy, the TiB2/AZ91 composite shows that the nucleation temperature of the primary Mg is lower and the TiB2 particles cannot act as the nucleus of the primary Mg. The grain refinement effect in the TiB2/AZ91 composite can be attributed to the growth restriction effect exerted by the TiB 2 fine particles.*
10.	*Hulya Kaftelen, Necip Unlu, Gultekin Goller, M. Lutfi Ovecog˘lu , Hani Henein (2012)*	*Al–Cu matrix composites reinforced with TiC particulates*	*The hardness and wear resistance of the cast and sintered composites were significantly improved compared to the hardness and abrasion resistance of Al4Cu matrix alloys.*

Aigbodion [3] investigated the mechanical behavior of the Al - Si alloy / aluminosilicate composite material, and made samples using powder metallurgy method. They investigated the following properties such as linear shrinkage, porosity, density, hardness, impact energy, compressive strength and microstructure of the composite material. As the weight fraction of the alumino ilicate addition in the alloy increases, impact energy and porosity decrease, hardness values and linear contraction increase. Compressive strength increased up to 20% by weight addition of reinforcement. Sajjad Amirkhanlou and Behzad Niroumand [4] investigated the mechanical behavior of the Al 356/SiCp cast composite material, injected the particles into the molten material, and cast the obtained composite slurry by the stir casting and compo casting method to prepare a sample. They found that the distribution of

SiC particulates in the matrix improved the porosity of the composite material. Rosales et al. [5] investigated the mechanical behavior of magnesium metal matrix composites and fabricated samples by self-infiltration technique without pressure. They found that mechanical property evaluation such as Young modulus and hardness test evaluation shows positive strengthening behavior in composite materials. Abraham et al. [6] examined the mechanical behavior of quartz fine particle reinforced AA 6063 aluminum matrix composite and these samples were prepared the friction stir processing. They found the result of quartz particles that we uniformly redistributed in the aluminum matrix. Dispersion of quartz particles improved AMC of micro hardness and abrasion resistance. Hossein [7] investigated the mechanical properties of aluminum/zircon composite materials and made samples by powder metallurgy method. They found that the most improved compressive strength was obtained on specimens containing 5% of zircon sintered at 650 ° C.

Nemati et al. [8] Investigated the mechanical behavior of Al - 4.5 wt% Cu - TiC nanocomposites and prepared samples using powder metallurgy technique with ball mill mixing. They investigated the following properties such as hardness and wear resistance of composites, lowering of density, grain size and distribution homogeneity and abrasion resistance. They found TiC particle size as reinforcement and addition of contents. Relative density, particle size and distribution uniformity decrease, hardness value and abrasion resistance increase. The use of 5 to 10 wt% micron size reinforcing particulates results in a significant hardness reduction of 174 to 98 HVN of the composite. The abrasion surface was observed by scanning electron microscope observation and the superiority of the wear mechanism was recognized as abrasion wear accompanying delamination wear mechanism. Mohan Kumar et al. [9] Investigated the mechanical behavior of aluminum AA 430 reinforced with SiC and Mgo. They made samples using stir casting technique. It was also revealed that as the load and the sliding distance increased, the wear rate of the specimen increased. As the volume content of the reinforcement increased, the coefficient of friction decreased slightly. Previtali et al. [10] Investigated the mechanical behavior of aluminum matrix composites (20% SiC or 7.5% B 4 C carbide) and made them by double stir casting method. They found the result that components in aluminium alloy with SiC as reinforcement have uniform distribution of ceramic particles, sound interface without fragile compounds and wear resistance higher than that of components reinforced with B4C particles. Wang et al. [11] Investigated the solidification behavior of the TiB2 particle-reinforced Mg composite material and compared it with the AZ 91 alloy. The grain refinement effect in the TiB2/AZ91 composite is due to the growth limiting effect brought about by TiB2 micro particles and the faster cooling rate. Kaftelen et al [12] examined the mechanical properties of Al - Cu matrix composite reinforced with TiC particulates and produced samples by powder metallurgy (PM) and casting. They found that both the wear resistance and the hardness of the cast composite were improved with TiC content. Sintered composites containing smaller TiC particles (0.6 - 3.5 μm) showed higher hardness than those coarsened with coarser TiC (0.8 - 6.6 μm) particles.

III. MATERIALS & METHODS

A. *Matrix Material*

Aluminum 5083 is known for exceptional performance in extreme environments. Aluminium 5083 is highly resistant to attack by both seawater and industrial chemical environments. Aluminum 5083 also retains exceptional strength after welding. It has the highest strength of the non-heat treatable alloys but is not recommended for use in temperatures in excess of 65°C [13]

Table – 1
Chemical Composition for Aluminum Alloy 5083

Element	*Si*	*Fe*	*Cu*	*Mn*	*Mg*	*Zn*	*Ti*	*Cr*	*Al*
%	*0.4*	*0.4*	*0.1*	*0.4-1.0*	*4.0-4.9*	*0.25*	*0.15*	*0.05-0.25*	*Balance*

B. *Compressive Strength*

Tensile tests were performed on samples prepared according to ASTM (Instron 1195) using UTM. It is named D3039-76. Flat test specimens are generally used for tensile testing. Into In this test, a uniaxial load is applied from both ends. The size of the specimen is 30 mm × 10 mm × 10 mm. particulate filled reinforced metal matrix composite in which 1.0 wt%, 2.0 wt%, 3.0 wt% and of the reinforced material. The crosshead speed shall be 10 mm / min.

1) *Test Parameters*

– Size of composite samples = 30 mm*10 mm*10 mm
– Crosshead speed = 10 mm/min

C. *Tensile Test*

Tensile tests were performed on samples prepared according to ASTM (Instron 1195) using UTM. It was named D3039-76. A flat specimen is generally used for the tensile test. Into In this test, a uniaxial load is applied from both ends. Sample size is 140 mm × 10 mm × 10 mm. Particulate packed reinforced metal matrix composite 1.0% by weight, 2.0% by weight, 3.0% by weight of reinforcing material. The crosshead speed shall be 10 mm / min.

1) *Test Parameters*

– Size of composite samples = 140 mm*10 mm *10 mm
– Crosshead speed = 10 mm/min

D. *Impact Strength*

Impact tests are performed on sample specimens using an Izod impact machine. The size of the impact test specimen is 65 mm × 10 mm × 10 mm in the case of the metal matrix reinforced composite material. The V notch is generated on a 2 mm sample.

The pendulum impact tester crushes the V-notch specimen with a pendulum hammer, measures the energy used and gives the notch impact strength of the specimen by relating it to the cross section of the specimen. The impact strength of the specimen is given as the impact energy in Joules divided by the cross section of the specimen in the notch. The machine's dial indicator directly gives the energy absorbed by the sample. The notch impact strength is calculated using the following equation[17].

$$I = \frac{K}{A}$$

Where, K = Impact energy in Joules and A = Cross sectional area at notch in mm^2

1) *Test Parameters*

- Size of composite samples = 65 mm*10 mm * 10 mm
- Notch length = V notch of 2 mm
- Sample orientation = cantilever

IV. RESULT & DISCUSSION

A. *Physical, Mechanical & Analysis of Nickel Metal Powder Particulate Filled 5083 Aluminum Alloy Composites*

1) *Effect of Compressive Strength on Ni Metal Powder Filled Al 5083 Alloy Composites*

Figure 1: shows the effect of nickel metal powder content on compressive strength of 5083 aluminum alloy / nickel particle composite. It has been shown that the compressive strength linearly increases with the particle content of the nickel powder in the alloy matrix. A pure aluminum alloy exhibits a compressive strength of 244 MPa without adding a filler content in the matrix material on addition of 1.0 wt.% filler content leads to increase in compressive strength by 22.9% to 300 MPa. Furthermore, 2.0 wt. % the percentage for pure alloy composite results in a compressive strength increases of 32.7% to 324 MPa[17].

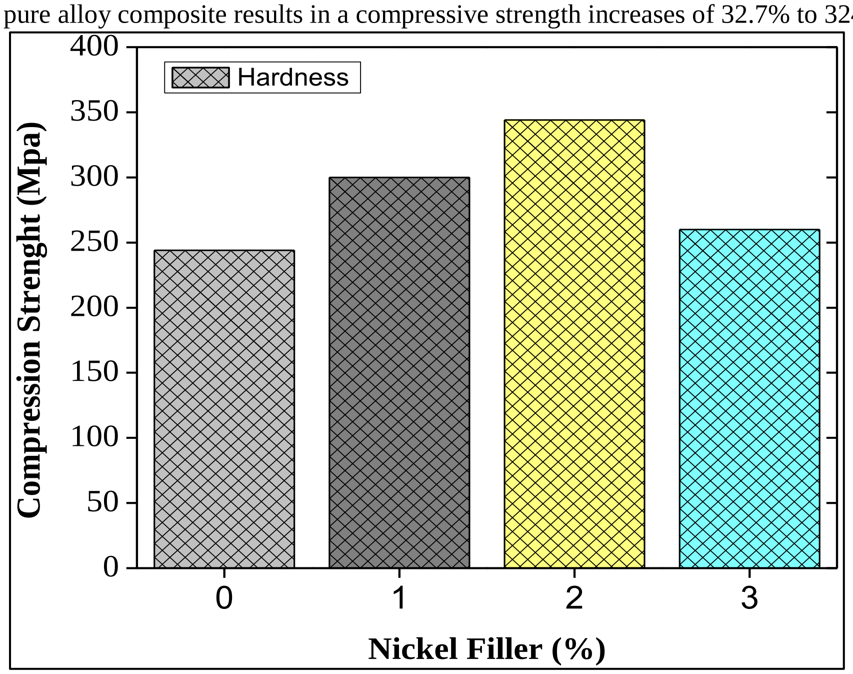

Fig. 1: Effect of Compressive Strength on Ni Metal Powder Filled Composites 5083 Aluminum Alloy Composites

Further, increase in the 3.0 wt. % of the filler content in the metal matrix, compressive strength decrease by 19.7 % to 260Mpa and compared with the neat alloy increase by the 6.5 % to 260Mpa [17] [14].

2) *Effect of Impact Strength on Nickel Powder Filled Al 5083 Alloy Composites*

Figure 2: shows the influence of the nickel metal powder content on the impact strength of the 5083 alloy nickel particle composite. It is shown from the graph that the impact energy increases to 92 J with 1.0 wt% nickel powder in the matrix not filled with 80 J of nickel metal powder with 0 wt% filler content. The extra addition of impact strength nickel metal powder is 114 J at 2.0 wt% of nickel metal powder and 130 J at 3.0% nickel metal powder.

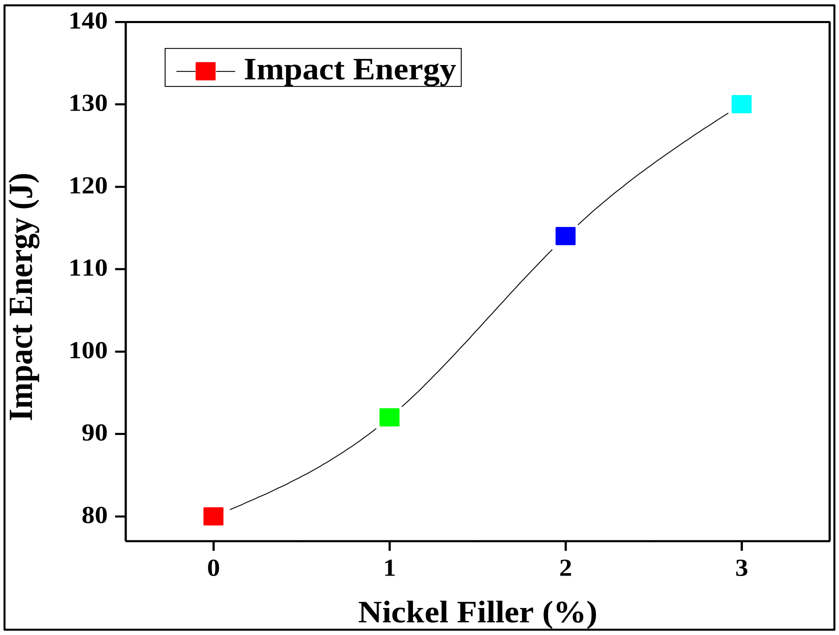

Fig. 2: Effect of Impact Strength on Nickel Powder Filled 5083 Aluminum Alloy Composites

Therefore, by the end of this alloying complex, the addition of nickel metal powder reinforcement accompanied by an improvement in impact strength must demonstrate the resistance ability in aluminum alloyed composites. By increasing the particle size, significant impact strength increases and the hot extrusion ratio also has to increase [17] [18] [14].

3) Effect of Tensile Strength on Ni Metal Powder Filled 5083 Aluminum Alloy Composites

The tensile strength of nickel metal powder filled with 5083 aluminum alloy composite material is shown in Figure 3. From this analysis it is observed that the tensile strength increases with increasing filler content. The tensile strength value of the unfilled alloy is 228MPa with a nickel metal powder content of 0% by weight. However, when a filler content of 1.0 % by weight is further added, the tensile strength is 268 MPa. By addition of 2.0 wt% of nickel metal powder again, the content of tensile strength was 335 Mpa. Similarly, the addition of tensile strengths of nickel metal powder content of 2 % by weight is 337 Mpa. As the filler content increases the resistance to tensile loading / stress on the specimen increases. The reason for increasing the load is when particles (Ni) in the alloy matrix are pulled from the matrix and are transferred and maintained in particulate during loading. Better mixing and better interfacial bonding between filler and matrix further improves tensile strength [17] [14] [15].

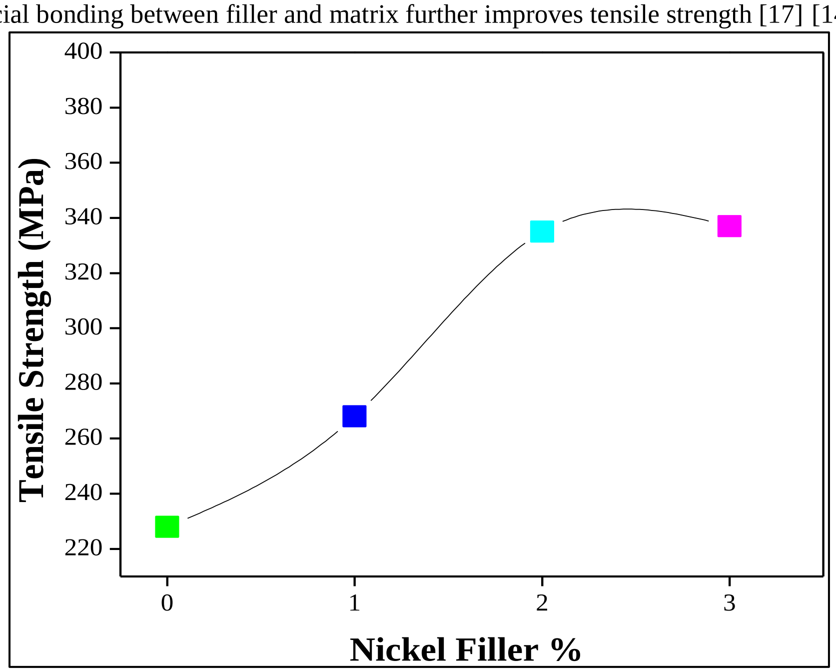

Fig. 3: Effect of Tensile Strength on Copper Metal Powder Filled 5083 Aluminium Alloy Composite

B. Physical, Mechanical & Analysis of Copper Metal Powder Particulate Filled 5083 Aluminum Alloy Composites

1) Effect of Compressive Strength on Copper Metal Powder Filled Al 5083 Alloy Composites

Figure 4 shows the effect of copper metal powder content on compressive strength of 5083 aluminum alloy / copper particle composite. It has been shown that the compressive strength increases linearly with the particle content of the copper powder in the alloy matrix. A pure aluminum alloy exhibits a compressive strength of 250 MPa without adding a filler content in the matrix material, on addition of 1.0 wt.% filler content leads to increase in compressive strength by 32% to 330 MPa. After that again increasing the copper metal powder in the metal matrix up to 2.0 wt. % result in a compressive strength increase of 44% to 360Mpa, when compared with the pure matrix metal [17].

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

Fig. 5 shows the influence of the copper metal powder content on the impact strength of the 5083 alloy copper particle composite material. According to the graph, it was shown that 0 wt% of copper metal powder and impact energy was 110 J. At that point, the percentage of copper metal powder of 0 to 1.0, the impact energy was 131 J. Again increase the copper metal powder in the alloyed composite, at the wt. % of 2.0 impact energy increase up to 159 J. again increment of the copper metal powder in the composite matrix the impact strength is 130 J at the wt. % of 3.0.

Again increase the copper metal powder in the alloyed composite, at the wt. % of 2.0 impact energy increase up to 159 J. again increment of the copper metal powder in the composite matrix the impact strength is 130 J at the wt. % of 3.0[17].

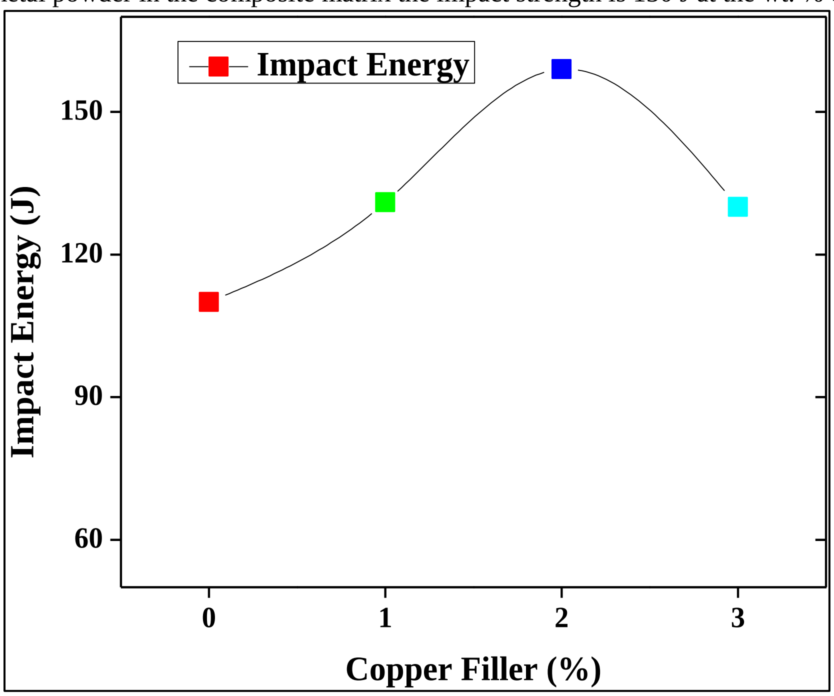

Fig. 5: Effect of Impact Strength on Copper Powder Filled 5083 Aluminum Alloy Composites

So by the end of this alloyed composite has to be shown makeable growing resistance ability in the aluminum alloyed composite by the addition of copper metal power reinforcement with improvement of impact strength and slightly decreased at the wt. % of 3.0 of copper metal powder . By increasing the particle size remarkable impact strength has to be increased and hot extrusion ratio also [18] [14].

3) Effect of Tensile Strength on Cu Metal Powder Filled 5083 Aluminum Alloy Composites

Tensile strength of copper metal powder filled with 5083 aluminum alloy composite material is shown in Figure 6 from this analysis; it is observed that the tensile strength increases as filler content increases. The tensile strength value of the unfilled alloy is 225 MPa and the content of the nickel metal powder is 0% by weight. However, when 1.0% by weight of filler is further added, the tensile strength is 260 MPa. By adding again the 2.0 wt% copper metal powder, the tensile strength content was 332 Mpa. Similarly, the tensile strength addition of 3 wt% copper metal powder content is 329 Mpa [16]. As the filler content increases the resistance to tensile load / stress on the specimen increases. The reason for increasing the load is that the particles (Cu) in the alloy base material are pulled up from the base material and transferred into the load to be maintained in the form of particles. Better mixing and good interfacial bonding of the filler and the matrix further improves the tensile strength [14] [18] [15].

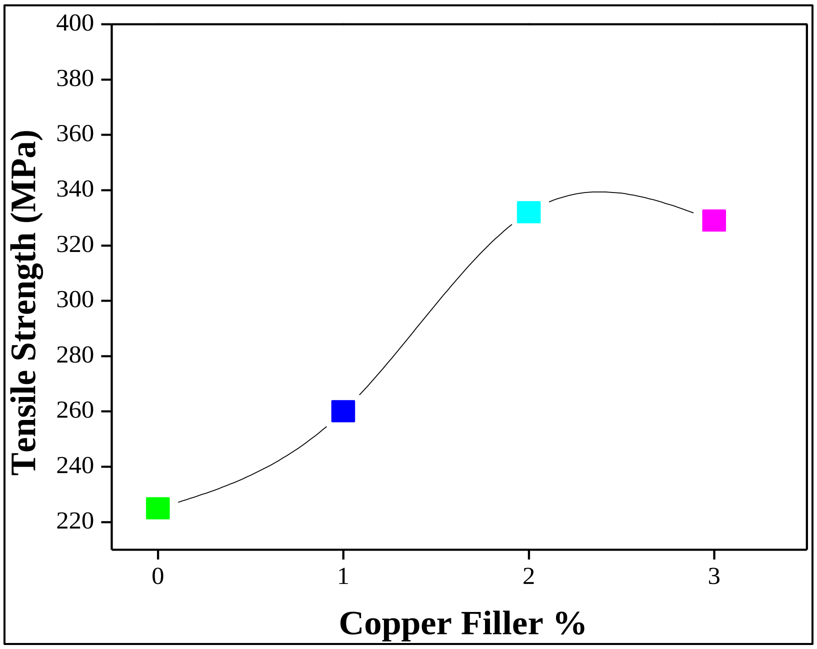

Fig. 6: Effect of Tensile Strength on Copper Metal Powder Filled 5083 Aluminum Alloy Composite

V. CONCLUSION

The following conclusion have been drawn from present research work

- For both copper and nickel reinforcement the maximum compressive strength shown by matrix on 2.0 wt. %.
- Further increase the wt. % of copper and nickel in aluminum matrix the compressive strength decreases.
- As the wt. % of nickel reinforcement increases in aluminum matrix first tensile strength increase and decrease.
- As the wt. % of copper and nickel reinforcement increases in aluminum first tensile strength increases and then decrease.
- The impact strength of the aluminum increases when increase the wt. % of nickel in aluminum matrix.
- The impact strength of the aluminum increases first and decreases when wt % of copper increases in aluminum matrix.

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