INVESTIGATION OF MECHANICAL BEHAVIOUR OF TUNGSTEN REINFORCED COPPER COMPOSITE MATERIALS

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ABSTRACT
Purpose: The purpose of this work is to investigate the mechanical behaviour of tungsten reinforced copper composite materials.

Design/Methodology/Approach: In this study, Composite materials were engineered or naturally occurring materials made from two or more constituent material with significantly different physical or chemical properties which remain separate and distinct at the macroscopic scale within the finished structure .Composite highlighted how different material can work in synergy. Combination of copper and tungsten elements optimized some properties such as strength, corrosion resistance and wear resistance .ASTM number was B702 for this composite. Copper tungsten composite fabrication by liquid state method involved incorporation of dispersed phase into molten matrix metal followed by its solidification. Good interfacial bonding should be obtained by this liquid state method. Liquid state method was cost effective one for MMC fabrication. This composite gained great importance in the automotive ,electrical, thermal, military, aerospace because of their high and excellent electrical conductivity ,low thermal expansion.

Findings: The Mechanical properties of composite are evaluated .Properties are those characteristics of material that describe its behavior under the action of external forces .Moreover the composite is characterized with the help of microstructural analysis.

Originality/Value: This paper explains the effect of mechanical properties of tungsten reinforced copper composite materials

Paper Type: Research paper

Keywords - *Copper, Impact, mechanical behavior, Tensile, Tungsten.*

INTRODUCTION

Materials are made up of matter .Materials are anything that have weight and occupy some space. Every materials having its own characteristics ,applications, advantages and limitations. The field of engineering concerns with the optimum use of materials. The engineers are required to select the most suitable materials for their jobs. In order to make the optimum selection of materials, engineer should have the fundamental principles of materials. Classification of materials are metals, plastics, ceramics, composites. Composite is a combination of two or more materials which are used in combination to rectify a weakness in one material by strength in another. Two materials are combination may process the desired properties and provide a feasible solution to the materials selection problems. Theses materials are referred as composites. Constituents of composites are of matrix phase ,dispersed phase. The properties of composites are functions of the properties of both the constituent phase their relative amount and the geometry of the dispersed phase .The geometry of the dispersed phase means the shape of the particles and particle size distribution and orientation. Classification of composites are particle reinforced composites, fibre reinforced composites, structural reinforced composites. Fibre properties (Tungsten), if the composite is to be used at elevated temperature, the fibre should have a high melting temperature. To achieve better mechanical properties one should use fibres that have higher specific strength and specific modulus. Matrix properties (copper),The matrix usually provides the major control over electrical properties ,chemical behavior and elevated temperature use of the composites.The FRC should have following characteristics are good resistance to corrosion ,good fatigue resistance ,low co-efficient of thermal expansion. Laszlo J et.al assessed fine grained ,high density (97%+ of theoretical density [TD]),80 Tungsten -20 copper weight percent (80W-20Cu[58W-42Cu atomic percent])composites prepared using nonconventional alloying techniques. Basawaraj B et.al researched over electrical ,mechanical and physical properties of Cu-WC composites were presented .The composites of copper alloy containing 0-8 weight % WC were prepared using liquid metallurgy route by stirring molten alloy to obtain vortex using a steel stirrer coated with alumina and rotated at 500rpm.Zhou Q et.al discussed about a novel approach for producing tungsten copper composites were investigated. This approach combined high temperature preheating technique and underwater shock consolidation. Ghaderihamidi et.al activated sintering of tungsten used to have in filtrable skeletons. Mostafaroosta et.al assessed the feasibility of fabricating W-Cu composite by hot press studied and the best parameters for hot pressing were acquired.Aditya anil bothate et.al assessed the binary system of tungsten copper lacks mutual solubility between its components. The refractory properties of tungsten and the high conductivity of copper were used to produce functionally graded composites.

2. MATERIALS AND METHODS

2.1. MATERIALS

Copper is one of the oldest and widely used nonferrous metals in industry. copper have very high thermal and electrical conductivity, excellent corrosion resistance, ductile and malleable. Melting point:1083^{0}C, Structure: FCC, Density: 8.93x10^3 Kg/m^3, Young's modulus: 122.5gpa,Tensile strength:220Mpa.Tungsten's atomic number :74,Atomic weight:183.86,Group number :6,Atomic volume:9.53, Structure :BCC , Density: 10.3gm/cm^3,Melting point:3400^{0}C, Boiling point: 5530^{0}C, Poisson's ratio:0.284, Recrystallization temperature:1300-1500^{0}C,Working temperature <1700^{0}C,Co efficient of expansion:4.3x10^{-6},Vickers hardness:3430,Tensile strength:1x10^{5}Mpa to 5x10^{5}Mpa,Electrical resistivity:10.5micro ohm- cm , Brinnel hardness:2570,Real name: Wolfram.

2.2. FORMULATION AND DESIGNATION OF THE MATERIAL

Metal matrix composites are also known as MMC. Composite material with atleast two constituent parts, one being metal other material may be different material. When three materials are present is called hybrid composites. An MMC is complementary to a cremates. The other material may be a different material such as ceramic organic compound. Composition, MMCs are made by dispersing a reinforcing material into metal matrix. Reinforcement surface can be coated to prevent a chemical reaction with the matrix. The properties of composites are a function of the properties of the both constituent phase their relative amounts and the geometry of the dispersed phase. Matrix is the monolithic material into which the reinforcement is embedded and is completely continuous .This means that there is a path through the matrix to any point in the material unlike two materials sandwiched together. For higher temperature application tungsten-copper composites are common. Characteristics of composites are artificially made, consist of atleast two different species with a well defined interface, properties are influenced by the volume percentage of ingredients. Performance of the composite depends on the properties of matrix and reinforcements, size and distribution of constituents, shape of constituents, Nature of interface between constituents. Manufacturing method of composites are solid state, liquid state and vapour deposition. Application of MMCs in engine cylinder liners, space systems, missiles, gliders, forks, space hardware, marine application, pedal crank arms, boutique sports equipments.

2.3. HEAT TREATMENT

It is the controlled heating and cooling of metals for the purpose of altering their properties .It is very essential in order to obtain the optimal results. It is most important and widely used manufacturing process. Purpose of heat treatment is to change chemical composition, soften the material, refine the grain size, relieve internal stresses. Types of heat treatments are annealing ,normalizing ,homogenizing, tempering, hardening, solution hardening, austempering. For copper tungsten combination homogenizing, annealing, solution hardening were well preferred heat treatment process. It depended upon the composition of the secondary phase. Homogenizing was suitable for 10-30% of secondary phase. It was a process in which prolonged high temperature soaking also known as “coaring”. This process was applied slowly improve the properties time and temperature required for the homogenization vary with grain size, composition and desired degree of homogenization. Soaking period was 3h.Temperature normally were above the upper annealing range (475-525^{0}C).

2.4. GENERAL FABRICATION METHODS OF MMC

Squeeze infiltration was the most successful form for MMC production. In this technique the molten metal was forced –infiltrated into fiber bundles or preformed ,expelling all absorbed and trapped glass. This method involved placing a preheated perform of reinforcement into a preheated die, filling the die with molten matrix metal, squeezing the molten into the perform using a hydraulic press with a preheated ram ,holding the pressure during solidification ,releasing the pressure and ejecting the resulting composite. The preheated reinforcement, usually in the form of a precompacted and inorganically bonded perform was placed in a preheated metal die, super heated liquid metal was introduced into the die and pressure was applied to drive the metal into the interstices between the reinforcing materials. The pressure required to combine matrix and the reinforcement was a function of the friction effects due to viscosity of the molten matrix asit fills the ceramic perform squeeze casting produces components, which were free from gas or shrinkage porosity. Solid state processes were generally used to obtain the highest mechanical properties in MMCs, particularly in discontinuous MMCs. This was because segregate on effects and brittle reaction product formation were at a minimum for these processes, especially when compared with liquid state processes. Powder metallurgy (PM) was the common method for fabricating DRMMC (Discontinuous reinforced metal matrix composites).

Diffusion bonding in the form of foils and a dispersed phase in the form of fibers were stacked in particular order and then pressed at elevated temperatures. The finished laminate composite material had a multilayer structure. This was used for fabricate simple shape parts. Sintering was mixed with a powder of dispersed phase particles, fibers for subsequent compacting and sintering. It involved consolidation of powder grains by heating “green compact” part to high temperature below the melting point. When the material of the separate particles diffused to the neighbouring powder particles. Sintering was enhanced when liquid phase takes part in the process. It was a phenomenon where by compacted powders will bond when heated to temperature above half their melting point. Sintering was occurs with pressing in the HIP,HDP (Hot Isostatic pressing, Hot die pressing).In stir casting, The matrix metal was commercially available with 99.99% purity. This metal was initially melted above 1080^{0}C in a graphite crucible. The reinforcement phase was tungsten with 99.95% purity. This reinforcing phase was preheated to 1023^{0}C and poured slowly, continuously into liquid matrix that was being stirred with a steel impeller at 800rpm.In order to improve the fluidity of the mixed powders the temperature was increased and a small portion of liquid was cast into a steel mould for the purpose of investigating microstructure.

2.5. DISTRIBUTIVE MIXING

A stirring process with a steel impeller had been employed to premix the CU melt with tungsten.It was known that the densification of tungsten with copper was not good. So it was essential to mix in dilatometric rang to improve the densification and there by to improve the spatial homogeneity of reinforcement. As the impeller rotated of moderate speeds a VORTEX was generated in the melt that draws the reinforcement particles into the melt from the surface. Creation of high level of shear force was necessary in order to produce adequate melt circulation and homogeneous distribution of the reinforcement throughout the matrix material. The impeller design played a crucible role.High turbulent flow in the axial direction was necessary to obtain fairly uniform particle distribution. The stirring condition ,melt temperature ,type and amounts of particles were the main factors that were being investigated further .The degree of mixing was governed by the momentum transfer from the position of the stirrer. It could seen that tungsten particles were dispersed in copper.

2.6. DISPERSIVE MIXING

To break agglomerates into individual particles were in liquid metal the applied shear stress to overcome the average cohesive force. Absence of chemical reaction was highly desirable from the physical property point of view.

3. RESULTS AND DISCUSSIONS

3.1. TENSILE TEST

The specimen to be tested was fastened to the two end jaws of the UTM.Now the load was applied gradually on the specimen by means of the movable cross head, till the specimen fractures. During the test, the magnitude to the load was measured by the load measuring unit. A strain gauge or extensometer was used to measure the elongation of the specimen between the gauge marks when the load was applied. Total length of specimen is 120mm,Initial diameter of specimen is 12.5mm,Final diameter of specimen is 10.70mm,Initial area is 122.65mm^2,Final area is 89.87mm^2,Initial gauge length is 50mm.Original area of cross section of cu-90%w-10% is 122.65mm^2,yield stress is 171.218Mpa,UTS is 236.44Mpa,Percentage of elongation is 19%,Percentage of reduction is 26.72%,Modulus of toughness is 45N/mm^2,Breaking stress is 214Mpa,Young's modulus is 1.5x10^{3}N/mm^2,Yield stress of cu80%-w20% is 195.67Mpa,Tensile strength is 287.81Mpa,Percentage of elongation is 15.9%,Percentage reduction is 16.8%,Modulus of toughness is 45.7Mpa,Fracture stress is 264.166Mpa,Young's modulus is 2.2x10^{3}N/mm^2. The details about the tensile strength values are show through by graph fig.1.Tensile test reports are indicated through by table 1.The tensile strength of the CU-80%W-20% is higher than with CU-90%W-10%.The tensile strength values are 236.44Mpa for CU-90%W-10% and 287.81Mpa for CU-80%W-20%.

3.2. HARDNESS TEST

It is defined as the ability of material to resist permanent indentation or deformation when in contact with an indenter of known geometry and mechanical properties into the test materials. Since the indenter is pressed into the test material during testing hardness is also viewed as the ability of a material to resist compressive loads .The intender may be spherical(brinnel), pyramidal or conical .In Rockwell tests the depth of indentation at a prescribed load is determined and converted into a hardness number ,which is inversely related to depth .For metals hardness number is directly proportional to the uni-axial yield stress at the strain imposed by the indentation .This statement may not apply in the case of polymers ,since their yield stress is ill defined .Hardness testing is perhaps the simplest and the least expensive method of mechanically charactering a material since it does not require an elaborate specimen preparation involves rather inexpensive testing equipment and is relatively. Types of hardness tests are brinnel hardness test, rockwell hardness test, vickers hardness test, knop hardness test, mohs hardness test.

3.3. BRINNEL HARDNESS TEST

One of the earlier standardized methods of measuring hardness was the brinnel test, In this test, A hardened steel ball indenter was forced into the surface of the metal to be tested. The diameter of the resulting impression was measured with the help of calibrated microscope. During a test the load was maintained constant for 10 to 15 seconds. The measured diameter is converted into the equivalent brinnel hardness using the following relation, BHN=load on the ball/area of indentation of steel ball. Limitations are not valid for case hardened surface, Not valid for thin specimen. The diameter of the intender is 10mm.Standard load range between 500Kg to 3000Kg in increments. The hardness test is performed by pressing a steel ball also known as indenter into the specimen.

3.4. ROCKWELL HARDNESS TEST

The test piece was raised by turning the hand wheel ,till it just touches the indenter .A minor load of 10Kg was applied to seat the specimen. Then the dial indicator was set zero. Now the major load was applied to the intender to produce a deeper indentation. After the indication pointer had come to rest the major load was removed .With the major load removed the pointer now indicate the rockwell hardness number to appropriate scale of the dial. The material to be tested was held on the anvil of the machine. The Rockwell hardness is probably the most widely used methods of hardness testing. The principle of the rockwell test differs from that of the others in that the depth of impression is related to the hardness rather then the diameter or diagonal of the impression. Rockwell are widely used in industries due to its accuracy ,simplicity and rapidity. In this test the dial gives a direct reading of hardness no need for measuring indentation diameter or diagonal length through microscope. Rockwell scales are B-scale (1/16inch diameter steel ball indenter;100kg load)used to measure the hardness of nonferrous metals, C-scale (120 degree diamond cone indenter called BRALE ;150 kg load) usually to measure the hardness of steels. The details about the hardness values are show through by graph fig.2.Hardness test reports are indicated through by table 2 .The hardness of the CU-80%W-20% is higher than with CU-90%W-10%.The hardness values are 61HRB for CU-90%W-10% and 80HRB for CU-80%W-20%.

3.5. IMPACT TEST

The impact was performed to study the behavior of the materials under dynamic load or suddenly applied load. It also indicated the notch sensitivity refers to the tendency of some normal ductile materials to behave like a brittle materials in the presence of notches .A notch was cut in a test piece which is struck by a single blow in a impact testing machine. Then the energy absorbed in breaking the specimen could be measured from the scale provided on the impact testing machine. The capacity of metals to withstand blows without fracture is known as impact strength or impact resistance. The impact test indicates the toughness of the material during “PLASTIC DEFORMATION”. Plastic deformation is the deformation of a body which remains even after removing the external load from the body. It does not obey the hook’s law,It takes place after the elastic deformation has stopped. Types of impact tests are izod test, charpy test. Charpy test is widely used in industries. It is very useful in determining the temperature range of ductile to brittle transition .Many type of impact test have been used to evaluate the notch toughness of metals ,plastics and ceramics. In general the categories of impact test can be classified in terms of” loading method” and the notched specimen. Specimen types are charpy v notch, charpy u notch, Izod specimen. Charpy testing requires good calibration methods. Machine belting should be examined regularly for looseness and broken specimen should be examined for unusual side markings. Most of the charpy impact machines are pendulum type. They must be very rigid in construction to withstand the repeated hammering effect of breaking specimen without affecting the operation of pendulum mechanism. The pendulum should swing freely with a minimum friction. Any restriction in movement of the pendulum will increase the enegy required to fracture specimen. There will always be small effects of this type and they are usually compensated for, along with the wind age friction effects by scale reading adjustments built into the equipment. Test criterias are minimum impact energy value, shear appearance fractured test bars expressed in percent, lateral expansion. Advantages of v notch are high degree of constraint, good tri axiality. Once the equipment has been properly setup and calibrated and the specimens have been correctly prepared testing can be done prior to each testing session the pendulum should be allowed at least one free fall with no test specimen present. To confirm that zero energy is indicated. The pendulum is cocked and the specimen is carefully positioned in the anvil using special tongs that ensures centering of the notch .The quick release mechanism is actuated and the pendulum falls and strikes the specimen generally causing it to break. The amount of energy absorbed is recorded .Specimen temperature can be drastically affect the result of impact testing .Testing should be done at temperature from 21 to 32^0C.Material of the specimen is CU-W, Length of the specimen is 55mm,Type of notch is v groove, Breadth of the specimen is 10mm,Depth of the specimen is 10mm,Depth of groove is 3mm,Area is 55mmx10mmx10mm. Impact test reports are indicated through by table 3.The impact of the CU-80%W-20% is higher than with CU-90%W-10%.The impact values are 24J for CU-90%W-10% and 27J for CU-80%W-20%.

3.6. SCANNING ELECTRON MICROSCOPY

The quality and resolution of SEM images were function of three major parameters, instrument performance ,selection of imaging parameters (e.g. operator control),nature of the specimen. One of the most surprising aspects of scanning electron microscopy was the apparent ease with which SEM images of three dimensional objects could be interpreted by any observer with no prior knowledge of the instrument .This was some what surprising in view of the unusual way in which image was formed ,which seemed to differ greatly from normal human experience with images formed by light and viewed by the eye. In order to produce images the electron beam was focused into a fine probe ,which was scanned across the surface of the specimen with the help of scanning coils. Each point on the specimen that was struck by the accelerated electrons emits signal in the form of electromagnetic radiation. Selected portions of this radiation, usually secondary (SE)and /or backscattered electrons (BSE) were collected by a detector and the resulting signal was amplified and displayed on a TV screen or computer monitor .The resulting image was generally straight forward to interpret, at least for topographic imaging of objects at low magnifications .The electron beam interacted with the specimen to a depth approximately 1 µm.The main components of a typical SEM are electron column ,scanning system, detector, display, vacuum system and electronics controls. The electron column of the SEM consists of an electron gun and two or more electromagnetic lenses operating in vacuum. The electron gun generates free electrons and accelerates these electrons to energies in the range 1-40KeV in the SEM. The purpose of the electron lenses is to create a small, focused electron probe on the specimen. Most SEMs can generate an electron beam at the specimen surface with spot size less than 10nm in diameter while still carrying sufficient current to form acceptable image. Typically the electron beam is defined by probe diameter (d) in the range of 1nm to 1 µm,probe current(ib)-pA to µA,and probe convergence (α)-10-4 to 10-2 radians. Complex interactions of the beam electrons with atoms of the specimen produce wide variety of radiation .The need of understanding of the process of image formation for reliable interpretation of images arises in special situations and mostly in the case of high magnification imaging. In such case knowledge of electron optics, beam specimen interactions ,detection ,and visualization processes is necessary for successful utilization of the power of the SEM. SEM analysis images are shown in figure 3,4,5,6,7.

CONCLUSION:

The tungsten reinforced copper composite materials were tested for various properties. Based on the test results the following inferences were drawn:

- Copper tungsten composite were fabricated by distributive mixing or stir casting process. The distribution of the reinforcement in the metal matrix was improved significantly when the composite were produced via compo casting process .
- Microstructure analysis revealed the improved particle distribution of the composite. The composite with ductile matrix through the bond strength was good.
- The tensile strength was found to be dependent on the fibre volume fraction. Mechanical tests were carried out to find the engineering characters suitable for designing particular mechanical system of constitution.
- The tensile properties, impact, hardness increased with the increase in volume fraction of the reinforcement. These results of the engineering characters made it possible react under the load .

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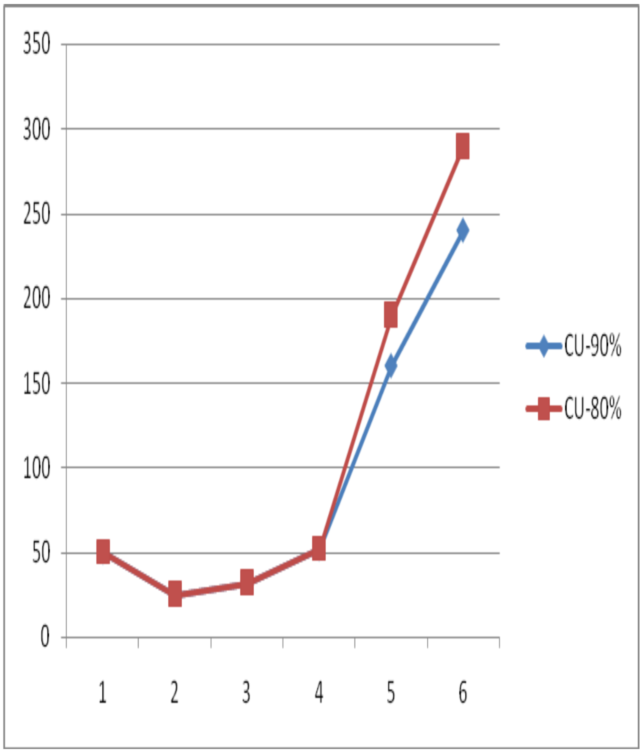

Figure 1. Result of tensile test

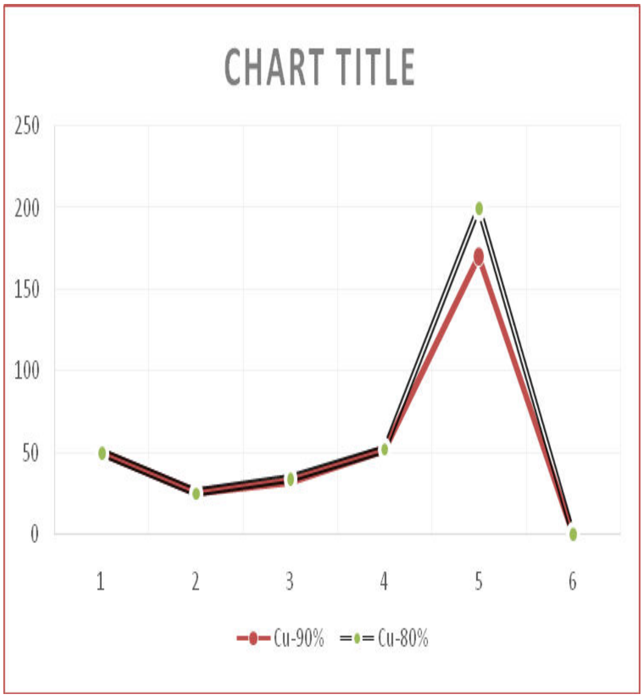

Figure 2.Result of hardness test

Figure 3.SEM analysis

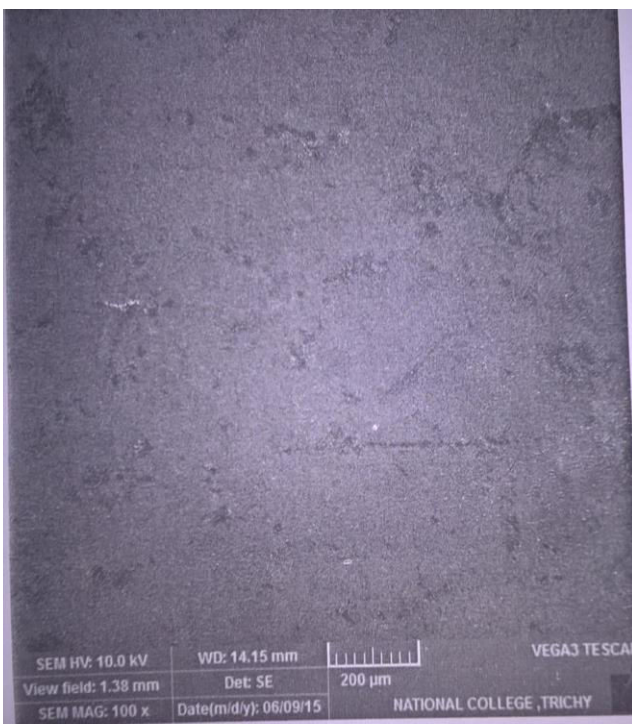

Figure 4.SEM analysis

Figure 5.SEM analysis

Figure 6.SEM analysis

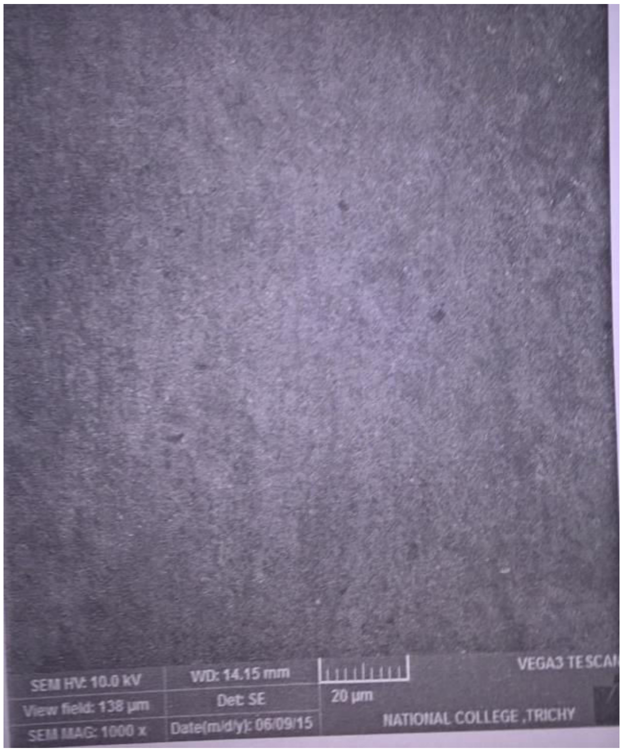

Figure 7.SEM analysis

Table 1.Tensile test reports

Composition of metals	Initial gauge length (mm)	Yield load(KN)	Tensile load(KN)	Final gauge length(mm)	Yield strength (Mpa)	Tensile strength(Mpa)
CU-90% W-10%	50	21	29	59.50	171.21	236.44
CU-80% W-20%	50	24	35.3	57.95	195.678	287.81

Table 2.Result of hardness test

S.NO	Material	Scale	Load(KG)	Indenter	Hardness
1	CU90-W10	B	150	1/16 inch dia	61HRB
2	CU80-W20	B	150	1/16 inch dia	80HRB

Table 3.Result of Impact test

Material	Size of specimen	Energy observed
CU90-W10	10X10mm^2	24J
CU80-W20	10X10mm2	27J