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# Investigations on Mechanical Properties of Micro Titanium and CNT reinforced Copper Hybrid Metal Matrix Composites

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**Abstract**: Copper based composites plays a vital role in the field of marine, aerospace, automobile and power sector for making of components like electrical sliding contacts, gears, bearings, bushes, brakes and clutches etc. Even though promising reinforcements are available for the composites, always researchers search for the new combination of matrix and reinforcement for tailored properties and cost effectiveness. CNT is one of the effective reinforcement used in the metal matrix composites by various researches because of its excellent properties. The present work is focused on the preparation of copper/CNTs/Micro-Titanium composite through stir casting technique performance studies of the composite are made on the mechanical properties. The composite prepared with reinforcement such as CNTs and Micro-Titanium of 0.5, 1, 1.5 % and 1, 3 & 5wt. % were studied. The Tensile strength, Compression strength, was found out via experimentation.

**Keywords**: Micro-Titanium, CNT, Tensile strength, Compression strength.

## I. INTRODUCTION

A typical composite material is a system of materials composing of two or more materials (mixed and bonded) on a macroscopic scale. Generally, a composite material is composed of reinforcement (fibers, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material.

Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form.

Or

Composite materials are heterogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They can also be considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.

### 1.1 Classification of composites

Classification of composite is done based on both geometry of reinforcing material and the type of matrix material. Classification scheme for the composite is as illustrated in figure 1.2 shown below.

#### 1.1.1 Classification of composites based on Matrix Materials

a) Polymer Matrix Materials
b) Carbon Matrices
c) Metal Matrix Materials
d) Ceramic Matrix Materials

 

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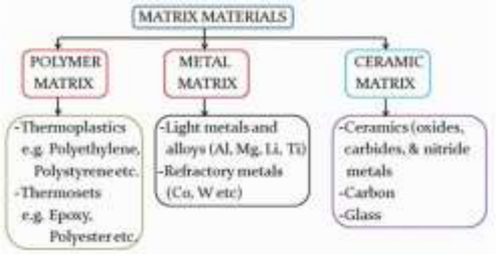


Figure 1.2 Classification of composites based on matrix.

### 1.1.2 Classification of composites based on Reinforcement

a) Fiber Reinforcement

b) Particulate Reinforced Composites

c) Structural Composites (Laminar Composites)

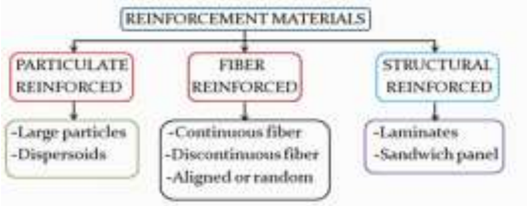


Figure 1.3 Classification of composites based on reinforcements

### 1.2 METAL MATRIX COMPOSITES

Metal matrix composite (MMC's) is engineered combination of the metal (matrix) and hard particle or ceramic (reinforcement) to get the tailored properties. Metal composite materials have found application in many areas of daily life for quite some time. Often it is not realized that the application makes use of composite materials. These materials are produced in situ from the conventional production and processing of metals. Here, the Dalmatian sword with its meander structure, which results from welding two types of steel by repeated forging, can be mentioned. Materials like cast iron with graphite or steel with high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials. For many researchers the term metal matrix composites are often equated with the term light metal matrix composites (MMCs).

### 1.3 Processing of Metal Matrix Composites

Metal-matrix composites can be processed by several techniques. Some of these important techniques are described below.

- Solid state processing
- Liquid metal processing
- In situ processing
- Vapor state processing
- Plasma/spray deposition

.

## II. MATERIALs

### 2.1 Material Selection:

In selection of matrix material such as metals or alloys the matrix should be chosen only after giving careful consideration to its chemical compatibility with the reinforcement, its ability to wet the reinforcement and to its own characteristics properties and processing behaviour. One of the very crucial issues to be considered in selection of the matrix alloy composition involves the natural dichotomy between wettability of the reinforcement and excessive reactivity with it. Good load transfer from the matrix to the reinforcement depends on the existence of a strongly adherent interface. In turn, a strong wetting and aggressive reactivity are both favored by strong chemical bonding between the matrix and reinforcement. As a rule of alloying element addition, the added element should not form inter metallic compounds with the matrix elements and should not form highly stable compounds with the reinforcing

  

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metals. The good properties can be obtained in a composite material when the reinforcement particulates and matrix are as physically and chemically compatible as possible.

Reinforcements: CNT and Micro-Titanium Matrix: Copper

### 2.1.1 Copper (Cu)

The word copper comes from the Latin word 'cuprum', which means 'ore of Cyprus'. This is why the chemical symbol for copper is Cu. Copper and copper alloys are widely used in a variety of products that enable and enhance our everyday lives. They have excellent electrical and thermal conductivities, exhibit good strength and formability, have outstanding resistance to corrosion and fatigue, and are generally nonmagnetic. They can be readily soldered and brazed, and many can be welded by various gas, arc and resistance methods. They can be polished and buffed to almost any desired texture and luster. Pure copper is used extensively for electrical wire and cable, electrical contacts and various other parts that are required to pass electrical current. Coppers and certain brasses, bronzes and copper nickels are used extensively for automotive radiators, heat exchangers, home heating systems, solar collectors, and various other applications requiring rapid conduction of heat across or along a metal section. Because of their outstanding ability to withstand corrosion, coppers, brasses, bronzes and copper nickels are also used for pipes, valves and fittings in systems carrying potable water, process water or other aqueous fluids, and industrial gases. Copper alloys are also ideally suited where it is important to minimize bacterial* levels on touch surfaces.

Figure 2.2. Copper

### 2.1.2 Carbon Nanotubes (CNT)

Carbon nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure. Nanotubes have been constructed with length-to-diameter ratio of up to 132,000,000:1, significantly larger than for any other material. These cylindrical carbon molecules have unusual properties, which are valuable for nanotechnology, electronics, optics and other fields of materials science and technology. Nanotubes are members of the fullerene structural family. Their name is derived from their long, hollow structure with the walls formed by one-atom-thick sheets of carbon, called graphene.

**Types of carbon nanotubes and related structures**

There is no consensus on some terms describing carbon nanotubes in scientific Literature: both "-wall" and "-walled" are being used in combination with "single", "double", “triple" or "multi", and the letter C is often omitted in the abbreviation; for example, Multiwalled carbon nanotube (MWNT)

- Single-walled carbon nanotubes (SWNTS)
- Multi-walled nanotubes (MWNTS)
- Double-walled carbon nanotubes (DWNTS)

Figure 2.3 CNT

### 2.1.3 Micro-Titanium (μ-Ti):

Titanium can be alloyed with iron, copper, aluminum, vanadium, and molybdenum, among other elements, to produce strong, lightweight alloys for aerospace (jet engines, missiles, and spacecraft), military, industrial processes (chemicals and petrochemicals, desalination plants, pulp, and paper), automotive, agri-food, medical prostheses, orthopedic

 

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implants, dental and endodontic instruments and files, dental implants, sporting goods, jewelry, mobile phones, and other applications. The two most useful properties of the metal are corrosion resistance and strength-to-density ratio, the highest of any metallic element. .

Figure: 2.4. Micro-Titanium

**2.2 Manufacturing Process.**

One of the most important issues to prepare CNT metal matrix composite is the CNTs dispersion in composites, the main purpose of many research and experiments is to improve it. Another issue need to be considered is the reinforcement of CNTs, which depend on the interfacial wettability between CNTs and metal matrix. Also chemical reaction should be avoided during composites manufacture process.

**2.2.1 Stir casting**

Stir casting set-up mainly consists a furnace and a stirring assembly as shown in Figure 4.6. In general, the solidification synthesis of metal matrix composites involves a melt of the selected matrix material followed by the introduction of a reinforcement material into the melt, obtaining a suitable dispersion. The next step is the solidification of the melt containing suspended dispersoids under selected conditions to obtain the desired distribution of the dispersed phase in the cast matrix. In preparing metal matrix composites by the stir casting method, there are several factors that need considerable attention, including The difficulty in achieving a uniform distribution of the reinforcement material. Wet ability between the two main substances.

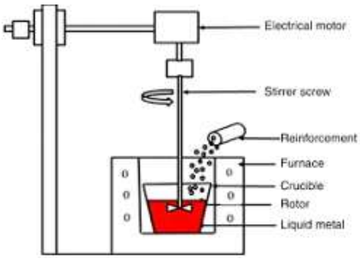


Figure 2.5:- Stir Casting

**III.EXPERIMENT**

**1. TENSILE TESTING**

Apparatus used: Universal Testing Machine

Figure 3.1 Universal testing machine Apparatus

Figure 3.2 Tensile specimen before and after test

**2. COMPRESSION**

Apparatus used:

- Universal Testing Machine (UTM)

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Figure 3.4 Compression Specimens before and after test

## IV. CONCLUSION

The copper reinforced with CNT and Micro-Titanium (µ-Ti) composites are cast, machined according to ASTM standard and tested to explore its hidden physical, Mechanical, Tribological corrosion and thermal properties. The obtained values are tabulated and plotted.

**Tensile test results**

Table 4.1. Tensile test results of µ-Ti and CNT reinforced Copper matrix MMC

| Specimen Designation | % CNT | % µ-Ti | YS | UTS | %Elongation |
|---|---|---|---|---|---|
| C1 | 0 | 0 | 176.312 | 245.8425 | 9.22 |
| C2 | 0.5 | 1 | 198.468 | 278.808 | 7.4 |
| C3 | 0.5 | 3 | 212.066 | 297.902 | 6.66 |
| C4 | 0.5 | 5 | 232.41 | 321.67 | 5.32 |
| C5 | 1 | 1 | 217.532 | 298.472 | 4.7 |
| C6 | 1 | 3 | 234.56 | 323.21 | 5.52 |
| C7 | 1 | 5 | 258.57 | 344.29 | 4.24 |
| C8 | 1.5 | 1 | 234.58 | 317.1 | 5.52 |
| C9 | 1.5 | 3 | 248.61 | 336.85 | 4.52 |
| C10 | 1.5 | 5 | 264.22 | 358.5 | 3.64 |

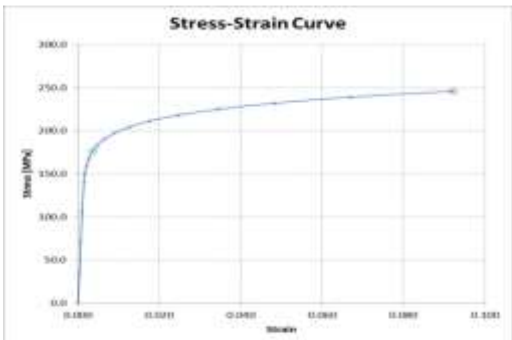


Fig 4.1. Stress-Strain curve of Pure Copper (C1)


Fig 4.2 Stress-Strain curve of copper hybrid composite(C2).

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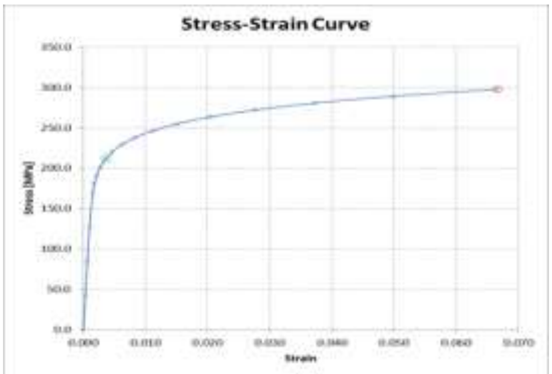


Fig 4.3 Stress-Strain curve of copper hybrid composite(C3).

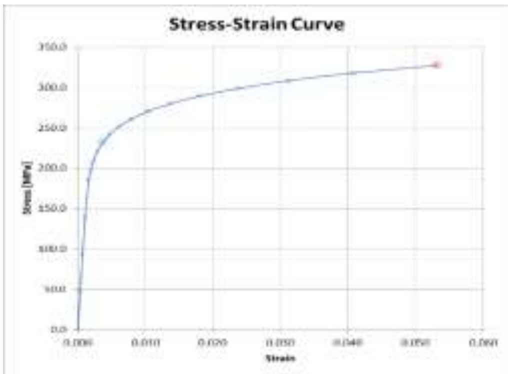


Fig 4.4. Stress-Strain curve of copper hybrid composite(C4).

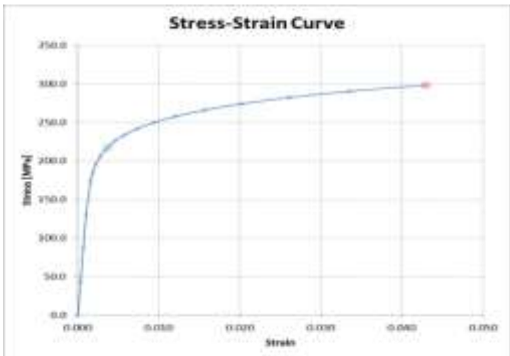


Figure 4.5. Stress-Strain curve of copper hybrid composite(C5).

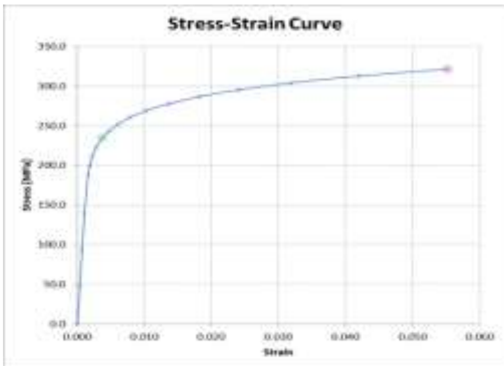


Figure 4.6. Stress-Strain curve of copper hybrid composite(C6) .

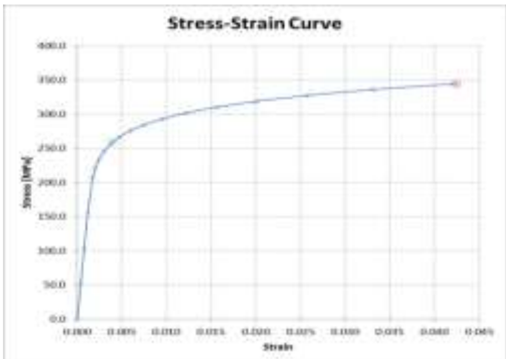


Figure 4.7. Stress-Strain curve of copper hybrid composite(C7)

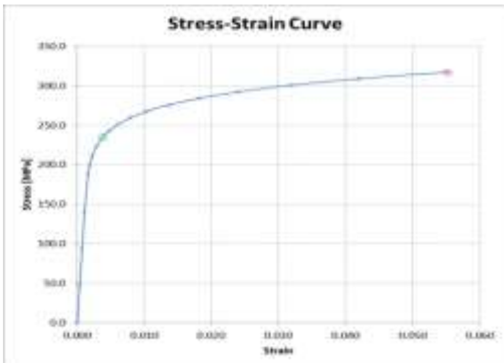


Figure 4.8. Stress-Strain curve of copper hybrid composite(C8)

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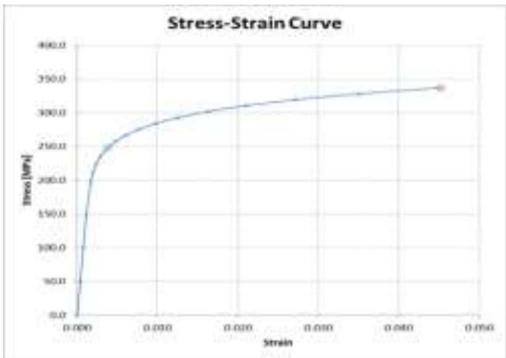


Fig4.9. Stress-Strain curve of copper hybrid composite(C9)

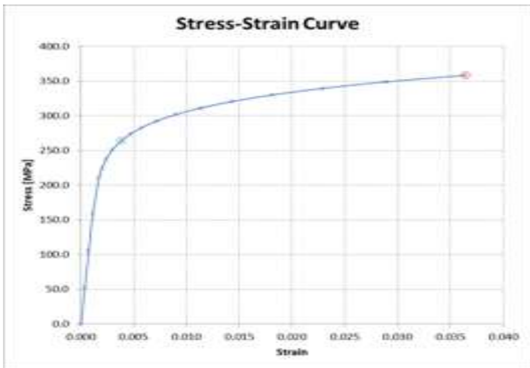


Fig 4.10. Stress-Strain curve of copper hybrid composite(C10)

Ultimate tensile strength (UTS) and elongation are summarized in Table 5.1. In general, all Cu/CNT/µ-Ti (C2,C3,C4,C5,C6,C7,C8,C9,C10) composites exhibited higher ultimate tensile strength (UTS), but lower elongation compared to pure Cu(C1). Elongation and UTS was 9.22% and 245.84 MPa for pure Cu (C1) and 7.4% and 264.80 MPa for C2 (0.5 % CNT-1 % µ-Ti), 278.808 MPa and 6.64% for C3 (0.5CNT-1µ-Ti) respectively. This indicated that the µ-Ti particles enhanced UTS at the expense of ductility. The brittle microparticles were easily broken during the tensile test, leading to crack initiation and propagation.
It is noteworthy that the UTS and elongation of CNT/1 µ-Ti reinforced composite improved significantly to a higher value , in comparison with C1composite. Therefore, CNTs not only had a higher strengthening effect than that of µ-Ti particles but also increased the plasticity of the composite. This indicated that the synergistic effect of dual-reinforcement of CNTs and Ti microparticles contributed to greater strengthening than that of composites with single-reinforcement of either CNTs or Ti microparticles. Thus, it was obtained that C10 (1.5CNT-5 µ-Ti )composite achieved a superior combination of strength and ductility than other copper matrix composites.

**Compression Test Results**


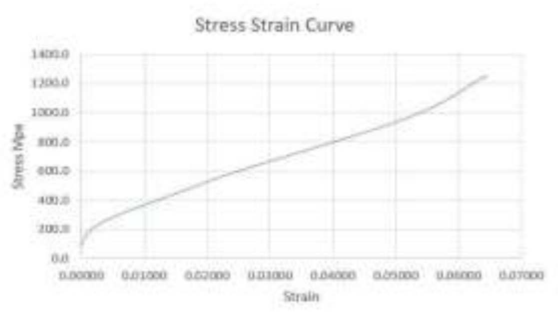


Fig 4.11. Stress-Strain curve of copper hybrid composite(C1). Fig4.12 shows Stress-strain curve obtained in compression test of pure copper C1.

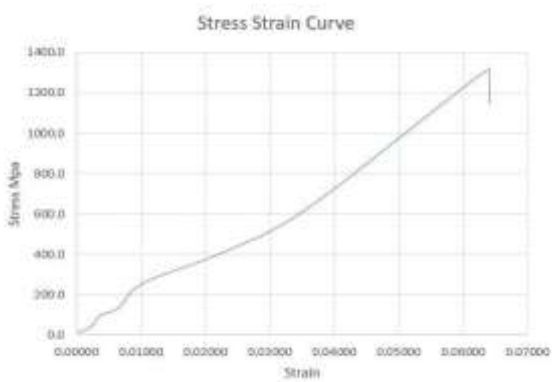


Fig4.13. Stress-Strain curve of copper hybrid composite (C2).

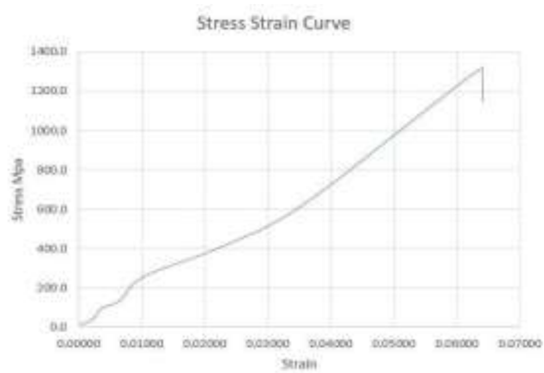


Fig 4.15. Stress-Strain curve of copper hybrid composite(C3).

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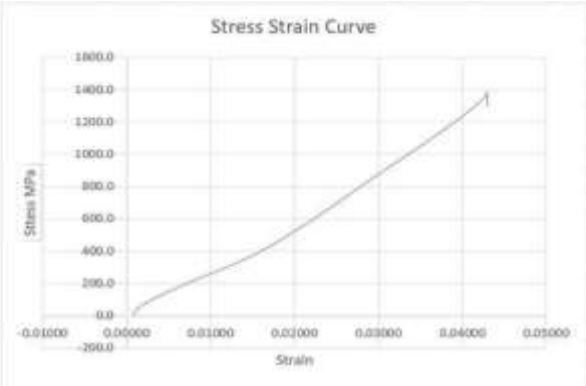



Fig 4.16. Stress-Strain curve of copper hybrid composite (C4). Fig 4.17. Stress-Strain curve of copper hybrid composite (C5)


Figure 4.18. Stress-Strain curve of copper hybrid composite (C6).

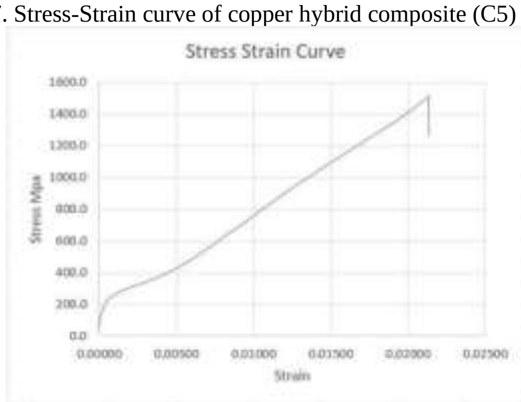


Fig 4.19. Stress-Strain curve of copper hybrid composite(C7)

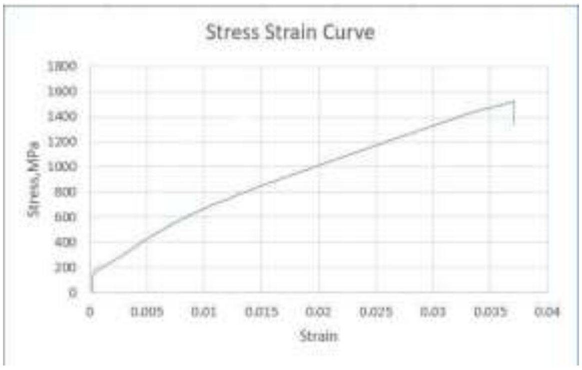


Fig 4.20. Stress-Strain curve of copper hybrid composite(C8)

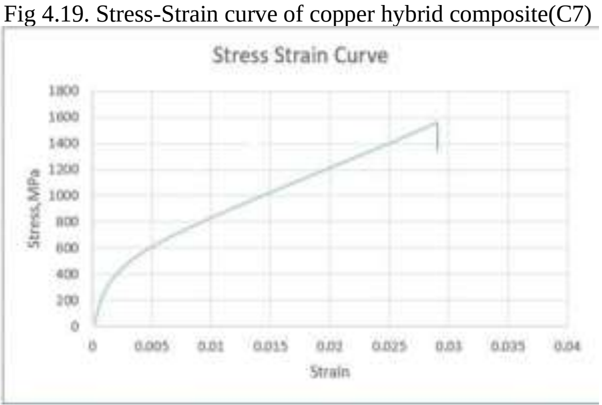


Fig4.21. Stress-Strain curve of copper hybrid composite(C9)

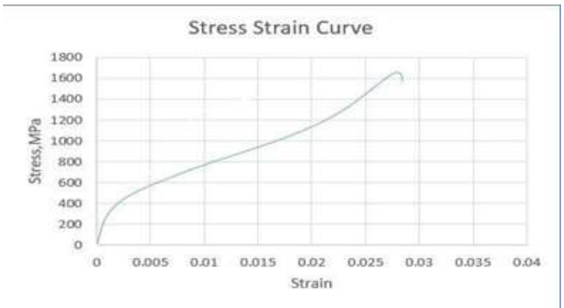


Fig 4.22. Stress-Strain curve of copper hybrid composite(C10)

Table 4.2. Compressive Strength of µ-Ti and CNT reinforced Copper matrix MMC.

| Specimen Designation | % CNT | % µ-Ti | Compression Strength MPa | % Reduction |
|---|---|---|---|---|
| C1 | 0 | 0 | 1275 | 6.56 |
| C2 | 0.5 | 1 | 1332.7 | 6.26 |

  

| | | | | |
|---|---|---|---|---|
| C3 | 0.5 | 3 | 1355.6 | 5.75 |
| C4 | 0.5 | 5 | 1367 | 5.34 |
| C5 | 1 | 1 | 1424.8 | 5.12 |
| C6 | 1 | 3 | 1457.6 | 4.71 |
| C7 | 1 | 5 | 1521.1 | 4.56 |
| C8 | 1.5 | 1 | 1548.23 | 3.56 |
| C9 | 1.5 | 3 | 1579 | 2.74 |
| C10 | 1.5 | 5 | 1594.34 | 2.34 |

## V. CONCLUSION

The research on composite materials where composites have a vital role in industrial application, bring into the limelight various tailored properties that compete with monolithic materials. The Copper reinforced with CNT and Micro-Titanium is manufactured and their inherent properties are found out via different tests. The major contribution of the research work is concluded below.

- It notices that the UTS of CNT/µ-Ti reinforced copper metal matrix composites C2, C3, C4, C5, C6 C7. C8, C9 and C10 enhanced by13.4%,21.59,31.2%,40%,22.73%,29%,37% and 46% than pure copper C1. The UTS of pure copper is 245.84 MPa. The copper metal matrix composites C2 and C10 shows the least and greatest tensile strength of 278.80 and 358.5MPa.
- It is noteworthy that the UTS of copper composites are improved, in comparison with C1composite. Therefore, CNTs not only had a higher strengthening effect than that of µ-Ti particles but also increased the plasticity of the composite.
- The compressive strength of pure copper is 1274.2 MPa. The copper metal matrix composites C2 and C10shows the least and greatest compressive strength of 1330.86 MPa and 1594 MPa.
- It is observed that the compressive strength of the composites monotonically increases as the particulate content is increased up to 1.5 wt.% of CNT and 5 wt.% of µ-Ti.
- The increase in strength can also be attributed to the addition of Micro-Titanium which impart strength to the matrix alloy them by enhanced resistance. There is a reduction in the inter-special distance between particulates, which cause an increase in the dislocation pile-up as the particulate content increased.

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