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Influence of Zn Addition on Microstructure & Mechanical Characteristics of Cu-Al-Ni Alloys

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ABSTRACT: *Metals and their alloys are usually subjected to heat treatment in order to improve their properties. Thus, the effect of precipitation hardening on the mechanical properties and microstructure of sand cast alloys was investigated. The comparative study of Microstructure, Austenitic transformation temperature, Impact Energy, fracture bending strengths of Cu-Al-Ni alloys with the replacement of Zn in Al have been investigated. Four alloys of Cu-Al-Zn-Ni, in the range of 9.5-14 wt% of Al, 3.5-5 wt% Zn and 3.5-4 wt% Ni, remaining wt% of Cu, were prepared on melting furnace. The microstructures of alloys have been observed by electronic microscope, the austenitic transformation temperatures have been observed by differential scanning calorimeter (DSC). Impact energies have been compared by charpy impact machine. Mechanical properties and shape memory capacity of four bend specimens (cracked) made of Cu-Zn-Al-Ni alloys have been investigated. The microstructure, austenitic transformation temperature and shape memory effect of Cu-Al-Zn-Ni alloys have been studied by optical microscopy (OM) and differential scanning calorimeter (DSC).*

Keywords: *Cu-Al-Zn-Ni, Microstructure, Electronic microscope, Optical microscopy (OM), Differential scanning calorimeter (DSC)*

I. INTRODUCTION

To analyse which composition of Cu-Al-Ni-Zn Alloy has better properties,effect of Zinc in the Alloy composition andto perform the temperature transformation of that particular Alloys.shape memory alloys with copper based and also fracture mechaincs.Shape memory alloys (SMAs) have physical and mechanical features that make them successful candidates for use in structural engineering applications. Primarily, SMAs play a key role toward the development and implementation of smart materials/devices, which can be integrated into structures to provide functions such as sensing, energy dissipation, actuation, monitoring, self-adapting, and healing of structures.The geometry of cracks in a structure are often difficult to determine accurately, leading to uncertainties in structural analysis. This paper presents a probabilistic fracture mechanics (PFM) approach to evaluate the reliability of cracked structures considering the uncertainty in crack geometry. The shape sensitivity analysis of the stress intensity factor (SIF) is performed efficiently using the scaled boundary finite element method (SBFEM). No remeshing is required as the size and orientation of a crack vary. Reliability is estimated using various probabilistic techniques.

Shape memory is a specific property some materials have to restore their original shape after a thermal load is applied.1e5 In these substances, in fact, a rise of temperature may cause the full recovery of residual strains following a mechanical loading and unloading process and this is macroscopically perceived as a cancellation of the impressed deformation. In the following, metal alloys will be discussed, despite this same phenomenology also being observed in other compounds, like ceramics or polymers.It is often also referred to as shape memory effect (SME).The microstructure, martensitic transformation behaviour and shape memory effect of Cu-Zn-Ni shape memory alloy have been studied by X-ray diffraction (XRD), optical microscopy (OM) and differential scanning calorimeter (DSC). The results show that the recrystallization occurs in the hot-rolled Cu-Zn-Ni alloy by annealing at 800˚C and alloy is primarily composed of marten site. A reverse marten site transformation temperature higher than 100˚C upon heating has been tested. The alloys exhibit good ductility and shape memory effect (SME).

II. II.EXPERIMENTAL PROCEDURE

2.1 SAND CASTING: Sand casting, also known as sand molded casting, is a metal casting process characterized by using sand as the mold material. Sand castings are produced in specialized factories called foundries. Sand casting is relatively cheap and sufficiently refractory even for steel foundry use. In addition to the sand, a suitable bonding agent (usually clay) is mixed or occurs with the sand. The mixture is moistened, typically with water, but sometimes with other substances, to develop strength and plasticity of the clay and to make the aggregate suitable for molding. The sand is typically contained in a system of frames or mold boxes known as a flask. The mold cavities and gate system are created by compacting the sand around models, or patterns, or curved directly into the sand.

III. DIMENSIONS FOR DESIGNING OF PATTERNS AND MOULD

3.1 Densities of Materials

Sl.No	Material	Density
1	Copper	8940 kg/ m^3
2	Aluminium	2700 kg/ m^3
3	Nickel	8910 kg/ m^3
4	Zinc	6500 kg/ m^3

3.2 Dimensions and Compositions of Workpieces

Table 3.2.1 Work piece Dimensions

Test	Size of Specimen	No. of Specimens
Impact	12*12*55mm^3	5
Bend Test	63.5*7.97*7.97mm^3	5
Transformation Temperature on DSC	5*5*2mm^3	2 (A2,A5)

Table 3.2.2 Cu-Al-Ni-Zn Alloy Compositions

ALLOYS	Cu%	Al%	Zn%	Ni%
A1	82	14	0	4
A2	82	9.5	5	3.5
A3	82	10	4.5	3.5
A4	82	10.5	4	3.5
A5	82	11	3.5	3.5

Fig 3.1 Mould Cavities and Patterns

3.3 MELTING PROCESS: The alloys with varying composition were prepared by melting exact amounts of copper, zinc, Aluminium and Nickel in a melting furnace at a temperature of 1500°C in order to attain melting state of materials. At first Copper and Nickel were melted as their melting temperatures are high. As Copper and Nickel were melted together then Aluminium and Zinc were added. Initially furnace is made to be at a temperature of 1500°C and copper and Nickel were added to it. The melting temperature of copper is 1085°C and Nickel is 1455°C so after it is melted, thenaluminum is added to it. The melting temperature of aluminum is 630°C. At last zinc is added in the furnace as the melting temperature is lower than other elements in the alloy. This alloy mixture is heated to certain eextent such that all alloying elements are melted. The furnace, crucible and the mould cavities used for the purpose of preparation of the specimens is shown in below figure.


Fig 3.2 CruciblesFig 3.3 Furnace Melting

Table 3.4 Properties of Alloys

IV. PREPARATION OF SPECIMENS FOR VARIOUS TESTS

Property	Copper value	Aluminiumvalue	Zinc value	Nickelvalue
Atomic Number	29	13	30	28
Atomic Weight (g/mol)	63.546	26.98	65.38	58.6934
Electric Valency	1	3	2	2
Crystal Structure	Cubic close-packed	Face centered cubic	Hexagonal close-packed	Facecentered cubic
Melting Point (°C)	1085	660.2	419.53	1455
Boiling Point (°C)	2562	2480	907	2730
Thermal Conductivity (0-100°C) (w/m-k)	385	0.57	116	90.9
Co-Efficient of Linear Expansion (0-100°C) (x10-6/°C)	5.1	23.5	13	13.4
Electrical Resistivity at 20°C (μΩ-cm)	17.1	2.69	59.7	69.3
Density (g/cm3)	8.96	2.6898	7.14	8.908
Modulus of Elasticity (GPa)	120	68.3	108	200
Poisson's Ratio	0.34	0.34	0.25	0.31

4.1SPECIMEN: A sample piece of block is cut from the main specimen alloy. The dimensions of this specimen are 20*22*15. This specimen is prepared by machining operations. The microstructure of the alloys are formed with different types of compositions are observed with microscope. After filing operation the specimen is polished with different grades of sand paper. This specimen is further finished on polishing machine .after applying suitable etching agent to the specimen the microstructure of the specimen can be observed clearly. The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. A disadvantage is that some results are only comparative. Today it is utilized in many industries for testing materials, for example the construction of pressure vessels and bridges to determine how storms will affect the materials used. The "Standard methods for Notched Bar Impact Testing of Metallic Materials" can be found in ASTM E23, ISO 148-1 or EN 10045-1,where all the aspects of the test and equipment used are described in detail.

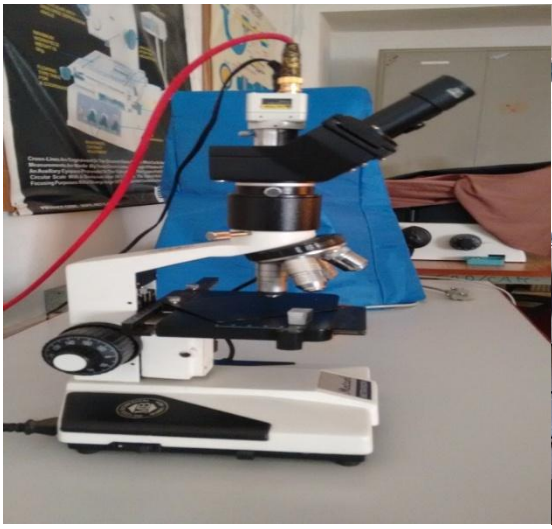



Fig 4.1 Electronic MicroscopeFig 4.2 Impact test Equipment

4.2 TEMPERATURE TRANSFORMATION USING DSC

4.2.1 Differental scanning calorimeter**:** Differential scanning calorimeter or DSC is a thermo analytical technique in which the difference in the amount of heat required to increase the temperature of a sample and reference is measured as a function of temperature. Both the sample and reference are maintained at nearly the same temperature throughout the experiment. Generally, the temperature program for a DSC analysis is designed such that the sample holder temperature increases linearly as a function of time. The reference sample should have a well-defined heat capacity over the range of temperatures to be scanned.The basic principle underlying this technique is that when the sample undergoes a physical transformation such as phase transitions, more or less heat will need to flow to it than the reference to maintain both at the same temperature. Whether less or more heat must flow to the sample depends on whether the process is exothermic or endothermic. For example, as a solid sample melts to a liquid it will require more heat flowing to the sample to increase its temperature at the same rate as the reference. This is due to the absorption of heat by the sample as it undergoes the endothermic phase transition from solid to liquid. Likewise, as the sample undergoes exothermic processes (such as crystallization) less heat is required to raise the sample temperature. By observing the difference in heat flow between the sample and reference, differential scanning calorimeters are able to measure the amount of heat absorbed or released during such transitions. DSC may also be used to observe more subtle physical changes, such as glass transitions. It is widely used in industrial settings as a quality control instrument due to its applicability in evaluating sample purity and for studying polymer curing.

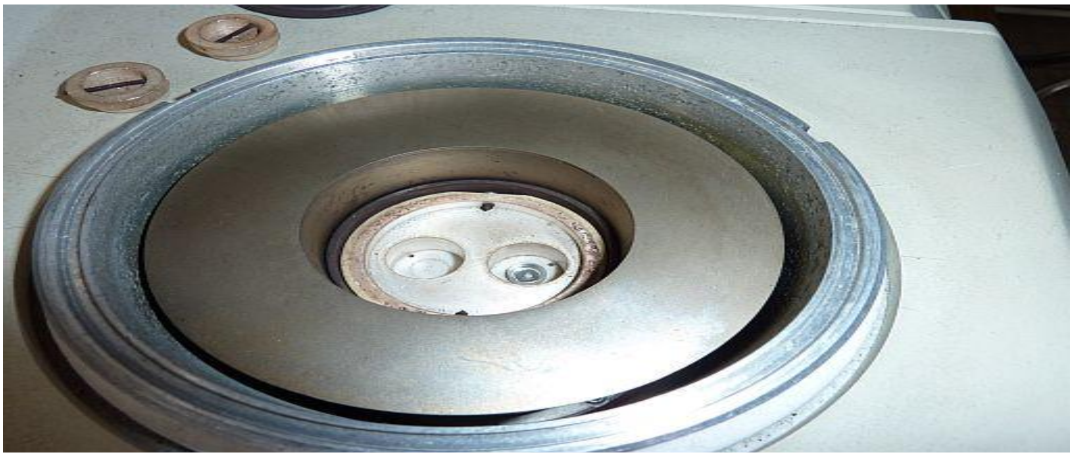


Fig 4.3 Differential Scanning Calorimeter

4.3 THREE POINT BENDING TEST: The three point bending flexural test provides values for the modulus of elasticity in bending, flexural stress response of the material. The main advantage of a three point flexural test is the ease of the specimen preparation and testing. However, this method has also some disadvantages: the results of the testing method are sensitive to specimen and loading geometry and strain rate.

Calculation of the flexural strain ϵ_f	In these formulas the following parameters are used
$$\epsilon_f = \frac{6Dd}{L^2}$$ Calculation of flexural modulus E_f $$E_f = \frac{L^3 m}{4bd^3}$$	• ϵ_f = Strain in the outer surface, (mm/mm) • E_f = flexural Modulus of elasticity,(MPa) • L = Support span, (mm) • b = Width of test beam, (mm) • d = Depth of tested beam, (mm) • D = maximum deflection of the center of the beam, (mm) • m = The gradient (i.e., slope) of the initial straight-line portion of the load deflection curve,(P/D), (N/mm)

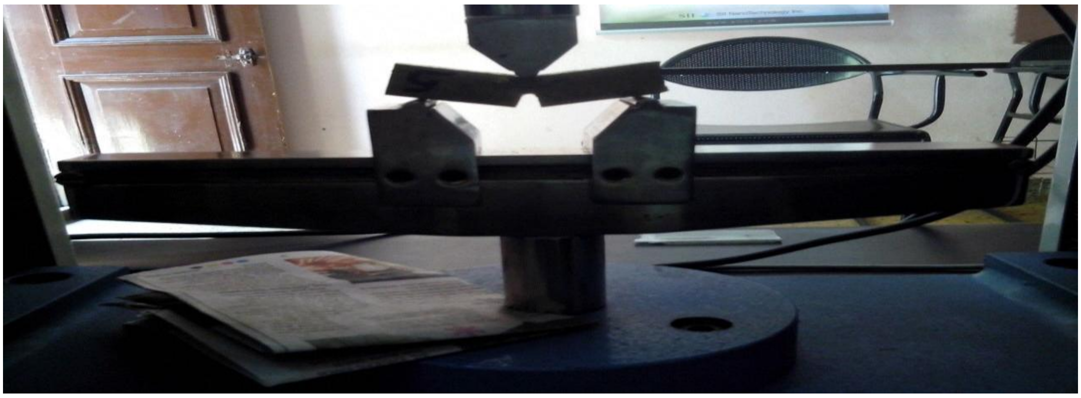


Fig 4.4 Point Bend Test Equipment

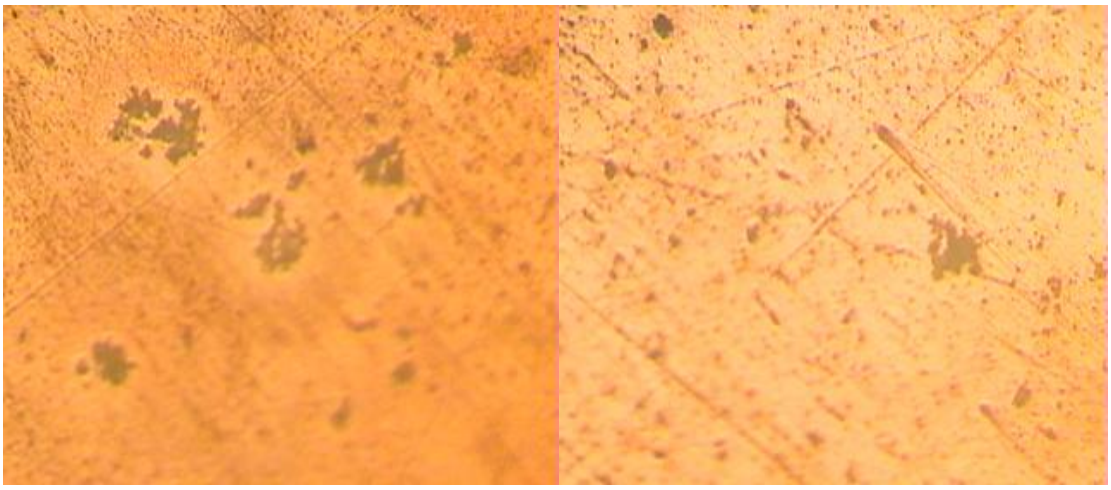
V. RESULTS AND DISCUSSION

5.1 FAILURE OF ALLOY 3

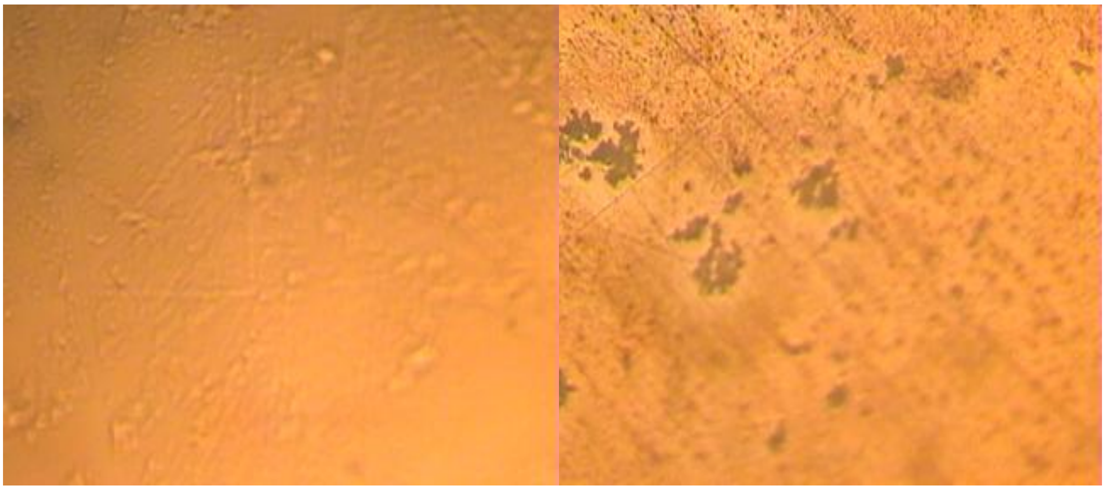
Alloy 3 with composition of Cu-82%, Zn-4.5%, Al-10% and Ni-3.5% has failed because of high brittleness. Because of its high brittleness we could not make tests on it to determine its impact strength, fatigue strength and microstructure analysis.

5.2 MICROSTRUCTURES

The rates of solidification and cooling of the cast in mould was influenced by the temperature of the moulding sand and amount of moist in the sand as binding strength to the moulding sand. It was found that the parameters also affected the microstructure of the cast made of Cu, Al, Zn&Ni. In the experiment some cast were allowed to cool in the mould while some, subjected to quenching and expose to air.



Alloy 1 Alloy 2



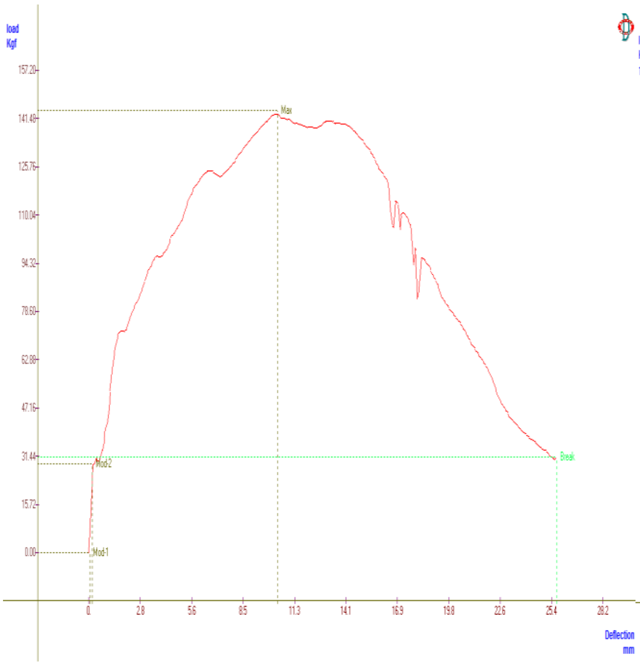
Alloy 4 Alloy 5

Fig 5.1 Microstructures of Alloys

5.3 THREE POINT BEND TEST RESULTS

The specimens were machined to the required shape so as to enable firm grip of the specimen by the lower and the upper jaw of the tensile testing machine. The machine was incorporated with a computer system which shows different properties of the specimen such as: Elongation percentage, stress, strain, yield point and stress/strain graph when subjected to tensile pull. The specimen was fixed between the lower and the upper jaw of the machine after this was completed, the machine was controlled to pull the specimen apart, putting the specimen under tension which caused the specimen to break at a breaking force. During the pull of the specimen, the tensile properties were also recorded by the computer simultaneously.

5.3.1 Results for ALLOY1 and ALLOY2



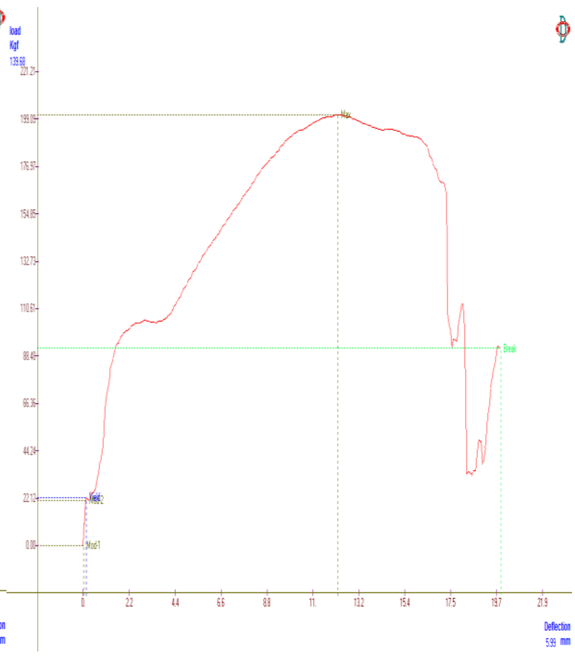


Fig 5.2 Load vs Deflection Graph for ALLOY 1 Fig 5.3 Load vs Deflection Graph for ALLOY 2

5.3.2 Results for ALLOY 4 and ALLOY 5

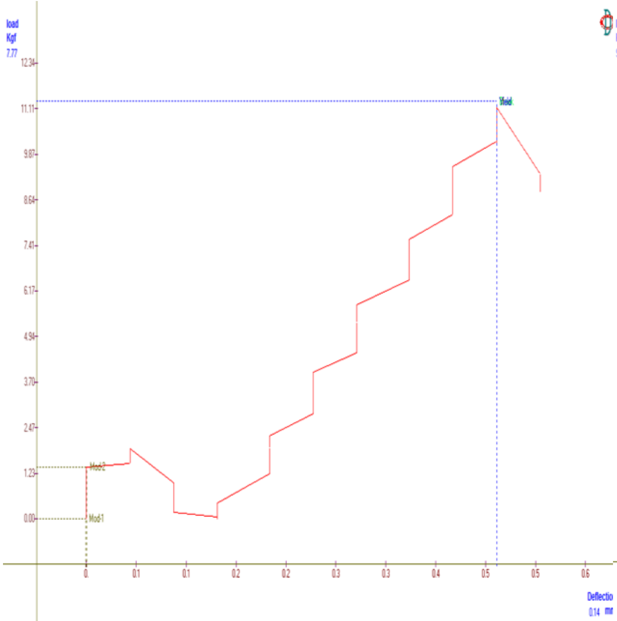
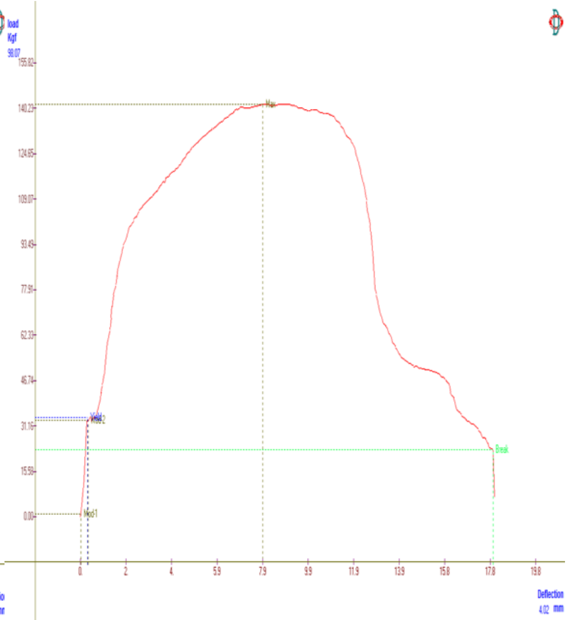
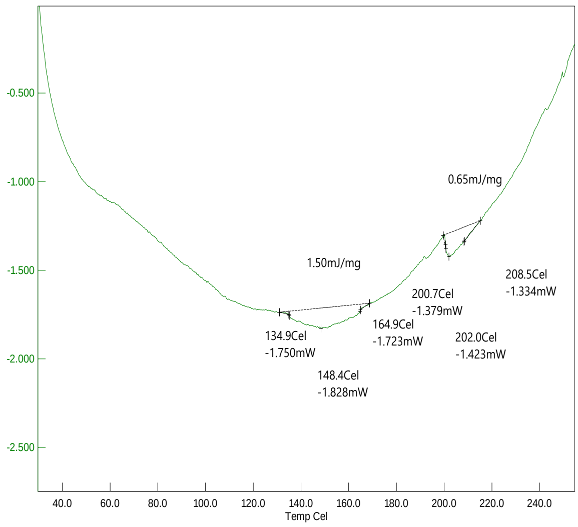



Fig 5.4 Load vs Deflection graph for ALLOY 4Fig5.5 Load vs Deflection Graph for ALLOY 5

From the above 3 point Bend Test we can observe that as the percentage of Zinc increases the flexural modulus decreases.

5.4 TEMPERATURE TRANSFORMATION

5.4.1 Phase Transformation for Alloy 2 and Alloy 5



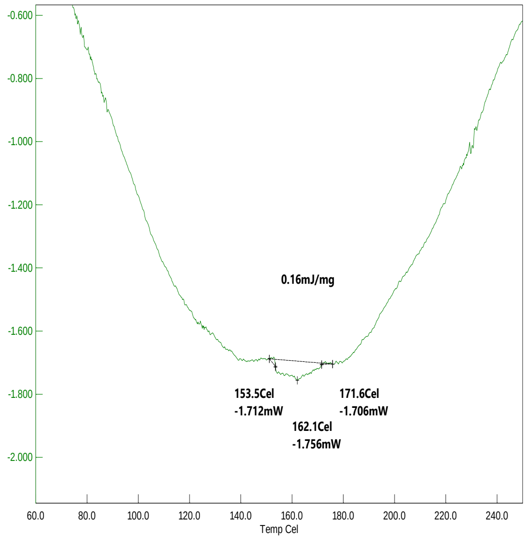


Fig 5.6 Temperature transformation for Alloy 2Fig 5.7 Temperature transformation for Alloy

The transformation of temperature of Alloy 2 with composition of Cu-82%, Al-9.5%, Zn-5%, Ni-3.5% is from 134.9 Cel to 164.9 Cel.This implies that as the composition of Zinc decreases the austenitic phase transformation temperature increases. The remaining alloys with Zinc composition can be in between these phase transformation temperature,The transformation temperature of Alloy 5 with composition of Cu-82%, Al-11%, Zn-3.5%, Ni-3.5% is from 153.5 Cel to 171.6 Cel.

VI. CONCLUSION

The composition of Cu-Al-Ni-Zn Alloys can have better properties like impact energy, flexural modulus. The microstructures of Alloys with clear visibility of grains is observed. From Impact Test, it have been seen that as the composition of Zinc decreases, the energy of Alloy increases. From Bend Test, it is seen that as Zinc decreases, flexural modulus increases. The phase transformation also states that as Zinc decreases, austenitic transformation temperature increases. From all these tests it is clear that Alloy composition with 3.5% of zinc composition have better impact energy, flexural modulus and austenitic phase transformation.

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Mr.Tamirat Tariku has completed his B.SC Mechanical Engineering from Jimma University Ethiopia. Presently working as Head of the Department, Department of Mechanical Engineering, Bulehora University and he has 3 years' experience.

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