Influence of Heat Treatment on Mechanical Properties of Aluminum Bronze

Sanjay K. N, Aprameyan S., Santhosh A. N.

Abstract: ***Copper is one of the first metals ever extracted and used by humans. As a result, copper was important to early humans and continues to be a material of choice for a variety of domestic, industrial, and high technology applications today. Bronze is one of the alloys of copper. Bronzes are used mainly in highly corrosive environments due to their corrosion resistant behavior. Aluminum bronze is a type of bronze in which Aluminum is the main alloying metal added to copper. A variety of Aluminum bronzes of differing compositions have found industrial use, with most ranging from 5% to 11% Aluminum by weight, the remaining mass being copper; other alloying agents such as iron, nickel, manganese, and silicon are also sometimes added to Aluminum bronzes. Aluminum bronzes give a mix of chemo-mechanical properties superseding many other alloy series. These make them to be most preferred particularly for demanding applications. "Aluminum bronzes are most valued for their high strength and corrosion resistance in a wide range of aggressive media". In the present investigation the aluminum bronze is furnace heat treated for 500^{0}C, 600^{0}C, 700^{0}C and 800^{0}C for time period for 1hr. Different experiments were conduction and found that Tensile strength for different heat treated Aluminum Bronze metal are 500^{0}C, 600^{0}C, 700^{0}C, and 800^{0}C has high tensile strength when compared to Base metal. The heat treated aluminum bronze of 700^{0}C has more tensile strength compared to all other heat treated and base metal. The compression strength gradually decreases from base metal to the 500^{0}C, 600^{0}C, 700^{0}C, and 800^{0}C with increasing temperature. The Brinell hardness increases for heat treated bronze compared to base metal. Aluminum bronze heat treated for 500^{0}C has more hardness compared to all other conditions. Impact energy for different heat treated Aluminum Bronze are decreases as heat treating temperature increases and increases for still increase in temperature. The heat treated aluminum bronze of 700^{0}C has more impact energy.***

Index Terms: Aluminum Bronze, Compression Strength, Copper, Hardness, Heat Treatment, Impact Energy, Tensile Strength.

I. INTRODUCTION

Aluminum bronzes are most valued for their higher strength and corrosion resistance as compared to other bronze alloys. These alloys are tarnish-resistant and show low rates of corrosion in atmospheric conditions, low oxidation rates at high temperatures, and low reactivity with sulfurous compounds and other exhaust products of combustion. They are also resistant to corrosion in sea water. Aluminum bronzes' resistance to corrosion results from the Aluminum in the alloys, which reacts with atmospheric oxygen to form a thin, tough surface layer of alumina (Aluminum oxide) which acts as a barrier to corrosion of the copper-rich alloy. The addition of tin can improve corrosion resistance. Heat treatment is any one of a number of controlled heating and cooling operations used to bring about a desired change in the physical properties of a metal. Its purpose is to improve the structural and physical properties for some particular use or for future work of the metal. There are five basic heat treating processes: hardening, case hardening, annealing, normalizing, and tempering. Although each of these processes brings about different results in metal, all of them involve three basic steps: heating, soaking, and cooling.

Annealing in metallurgy and materials science is a heat treatment that alters the physical and sometimes chemical properties of a material to increase its ductility and reduce its hardness, making it more workable. It involves heating a material to above its recrystallization temperature, maintaining a suitable temperature and then cooling. In annealing atoms migrate in the crystal lattice and the number of dislocations decreases, leading to the change in ductility and hardness. In the cases of copper, steel, silver and Aluminium Bronze, this process is performed by heating the material (generally until growing) for a while and then slowly letting it cool to room. Aluminum bronzes are most commonly used in applications where their resistance to corrosion makes them preferable to other engineering materials. These applications include plain bearings and landing gear components on aircraft, Ernie Ball Aluminum Bronze guitar strings, engine components (especially for seagoing ships), underwater fastenings in naval architecture, and ship propellers.

In the present investigation the effects of furnace heat treatment on properties such as tensile strength, compression strength, hardness, and impact energy variations on the Aluminum Bronze have been studied. Different mechanical tests were conducted and the results were compared with the base alloy and the furnace heat treated alloy.

II. EXPERIMENTAL PROCEDURES

A.Production

30cm long and 2cm in diameter aluminium bronze rods of composition as given in Table 1 were produced via sand casting by dissolving a measured amount of the aluminium piece in a measured molten copper in a fired pit furnace,

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Stirred and cast. The chemical analysis of the produced aluminium bronze alloy was evaluated.

Table 1 Chemical Composition of Casted Aluminium Bronze Developed.

Copper	Aluminum	Iron	Manganese
88.5%	9%	1.5%	1%

B. Preparation of the Specimen

The casted aluminum bronze is machined for the desired size and shape according to the standards to conduct mechanical tests like tensile, compression, hardness and impact tests.

Heat Treatment

Heat treatment process is carried out **in three major stages**
Stage I: Heating the metal slowly to ensure a uniform temperature of 500^0 C, 600^0C, 700^0C and 800^0C.
Stage 2: Soaking the metal at given temperature for 1hr.
Stage 3: Quenching the metal in water to room temperature

C. Tensile, Compression, Hardness and Impact Tests

The machined and heat treated rods were subjected to tensile and compression tests which was conducted in a UTM. The dimension used for tensile test is as shown in **Fig 1**. The hardness tests were carried out on INDENTEC Hardness testing machine which was used to measure the hardness on Brinell hardness scale. The specification of the hardness tester is-Ball indenter: Tungsten Carbide ball indenter of diameter 2.5 mm, Load applied: 750 kgf, Dwell time: 10 seconds. The Impact test specimen has prepared according to IS 1757, the impact test conducted in Charpy Impact testing instrument. The dimension used is as shown in **Fig 2**.

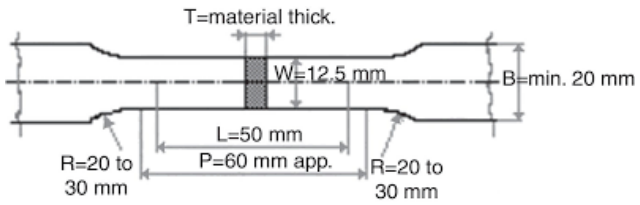

Fig 1: Sketch of Standard Tensile Specimen

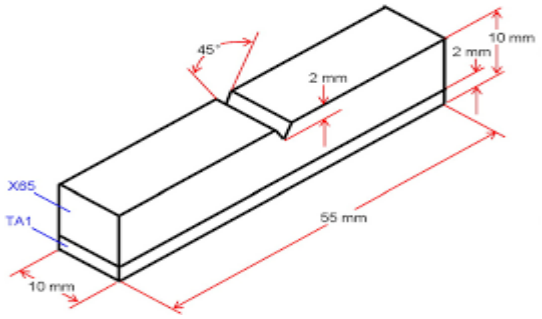

Fig 2: Sketch of Standard Impact Specimen

III. EXPERIMENTAL RESULTS

A. Effect of Heat Treatment on Tensile Strength

Fig 3 (a), (b), & (c) illustrates the response of the material heat treated at four different temperatures viz. 500^oC, 600^0C, 700^0C and 800^oC and shows the variation of peak load, % elongation and tensile strength for the speed of 1.5 mm/min.

From the fig 1 (a) it can be observed that heat treated aluminum bronze has more peak load compared to base aluminum bronze. Heat treated bronze at 800^oC had lowest peak load of about 39.66kN compared to all other heat treated aluminum bronze. It can also be observed that the peak load decreases as heating temperature increases and peak load increases for still increase in temperature. Form fig 3 (a) it can be observed that heat treated aluminum bronze for 700^0C has more peak load compared to all other heat treated and base metal. It can be seen that for heat treated aluminum bronze of 700^0C has highest peak load of 44.09KN.

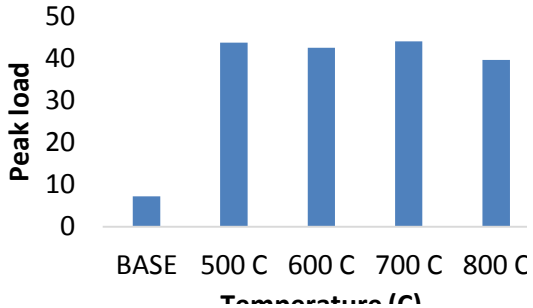

Fig 3 (a)

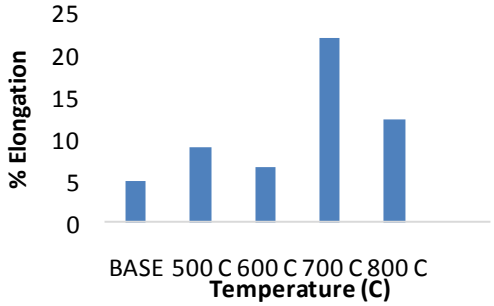

Fig 3(b)

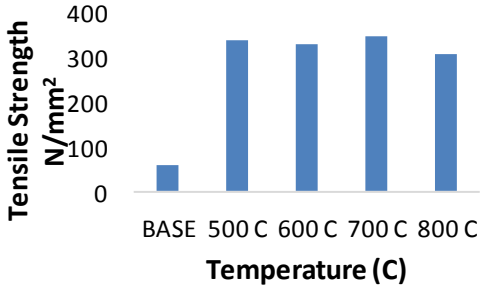

Fig 3(c)

Fig 3 (a) Variation of Peak Load for Different Heat Treated Aluminum Bronze, (b) Variation of % Elongation for Different Heat Treated Aluminum Bronze, (c) Variation of Tensile Strength for Different Heat Treated Aluminum Bronze.

The fig 3 (b) shows the variation of percentage elongation for Aluminum Bronze and heat treated Aluminum Bronze for 500^0C, 600^0C, 700^0C.and 800^0C.

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It can be observed for the alloy of heat treated for 500^0C, 600^oC, 700^0C,and 800^0C has more elongation when compared to base metal. It can be observed that heat treated of 700^0C had more elongation compared to all other heat treated and base metal. The fig 3 (c) shows the variation of tensile strength for different heat treated Aluminum Bronze and base metal. From the figure it is evident that the heat treated of 500^0C, 600^0C, 700^0C, and 800^0C Aluminum Bronze has high tensile strength when compared to Base metal. It is found that maximum tensile strength is of about 347 N/mm^2 is observed in heat treated aluminum bronze of 700^0C.

B. Effect of Heat Treatment on Compression Strength

Fig 4, illustrates the response of the material heat treated at four different temperatures viz. 500^0C, 600^0C, 700^0C and 800^0C and shows the variation of compression strength for different heat treated Aluminum Bronze and base metal for the speed of 1.5 mm/min. From the fig it is evident that the heat treated of 500^0C, 600^0C 700^0C and 800^0C Aluminum Bronze has less compression strength when compared to base metal. It is found that maximum compression strength is of 880 MPa is observed for base metal.

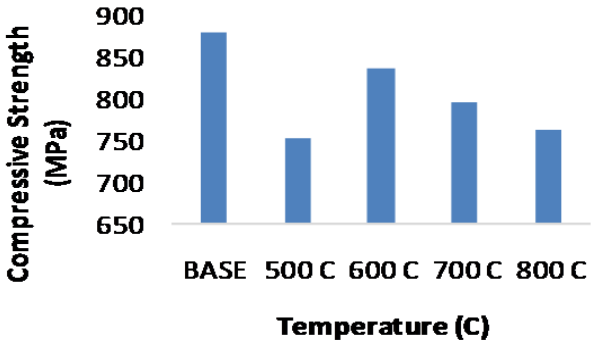

Fig 4 Variation of Compression Strength for different heat treated Aluminum Bronze.

C. Effect of Heat Treatment on Hardness

Fig 5 illustrates the response of the material heat treated at two different temperatures viz. 500^0C, 600^0C, 700^oC and 800^0C and shows the variation of Brinell hardness for different heat treated aluminum bronze. From fig it is observed that there is increase in hardness of heat treated aluminum bronze compared to base metal. It can be observed that the hardness increased as the temperature increases and then decreases for still increase in temperature. It can be observed that maximum hardness is recorded for heat treated aluminum bronze of 500^0C. The maximum hardness recorded was 138BHN.

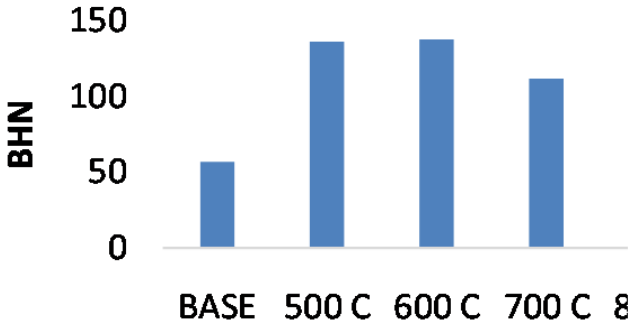

Fig 5 Variation of Compression Strength for Different heat treated Aluminum Bronze.

D. Effect of Heat Treatment on Charpy Impact Energy

Fig 6 illustrates the response of the material heat treated at four different temperatures viz. 500^0C, 600^0C, 700^0C and 800^0C and shows the variation of impact energy for different heat treated aluminum bronze. From fig it can be observed that there is a decrease in impact energy for heat treated aluminum bronze of 500^0C and 600^0C and increase in impact energy for 700^0C and 800^0C compared to base metal. It can be observed that maximum impact energy is for heat treated aluminum bronze of 700^0C and is recorded of about 158J.

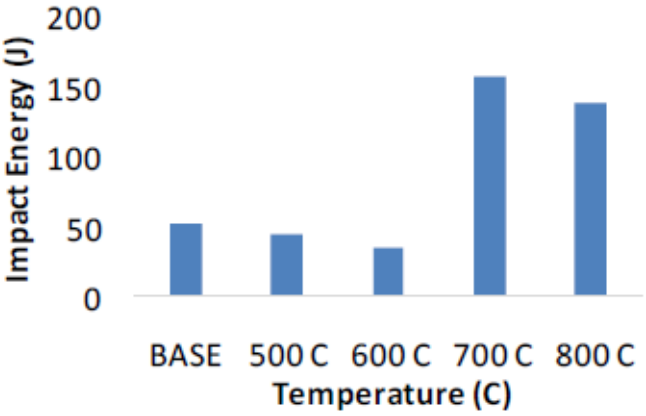

Fig 6 Variation of Charpy Impact Energy for different heat treated Aluminum Bronze.

IV. CONCLUSION

Based on the results obtained by carrying out heat treatment on casted Aluminum bronze and systematic experimentation and observations the following conclusions are drawn in the present study

1. Tensile strength for different heat treated Aluminum Bronze metal are 500^0C, 600^0C, 700^0C, and 800^0C has high tensile strength when compared to Base metal.
2. The heat treated aluminum bronze of 700^0C has more tensile strength compared to all other heat treated and base metal.
3. The compression strength gradually decreases from base metal to the 500^0C, 600^0C, 700^0C, and 800^0C with increasing temperature.
4. The Brinell hardness increases for heat treated bronze compared to base metal. Aluminum bronze heat treated for 500^0C has more hardness compared to all other conditions.
5. Impact energy for different heat treated Aluminum Bronze are decreases as heat treating temperature increases and increases for still increase in temperature. The heat treated aluminum bronze of 700^0C has more impact energy.

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