Effect of soft annealing on copper, brass and gunmetal

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Abstract - *Copper and its alloys have proved to be highly important in wide area of applications. Its applications include high quality architectural components, defense and military applications and other high strength uses. Therefore, analyzing the mechanical behavior pre- and post- heat treatment of such materials is crucial. This paper attempts at carrying out preliminary investigations on the hardness, micro-structure and wear on copper, brass and gunmetal samples before and after annealing. The samples were annealed at 850˚C. Rockwell hardness was calculated before and after the annealing process at three different positions for each sample viz. centre, edge and between centre and edge. Brass was found to be the hardest before annealing and copper after annealing. The micro-structures of the samples were observed and studied both pre- and post- heat treatment. The annealed samples were tested for their wear resistance using a rotary tribometer. The results of wear test were plotted as a graph of time vs. wear. Copper sample was found to be the most resistant to wear.*

***Key Words*: Copper, brass, gunmetal, soft annealing, mechanical properties, micro-structure**

1. INTRODUCTION

Today copper and copper alloys have found a deep seated application in almost all the aspects of worldwide consumption and this demand is undoubtedly increasing at a steady rate. Their excellent electrical and thermal conductivities, high strength and good formability, excellent resistance to corrosion and fatigue deformations and non-magnetic character makes them the iconic metals globally utilized and employed in plethora of industrial and manufacturing industries [1,2].

Deep drawn and extensively worked copper alloy articles should be heat treated for stress relief to avoid any chances of stress corrosion cracking in its service period [3]. It is very difficult to work with metals which have been cold worked many a times without causing it to crack upon working. Annealing is done to soften the cold worked metal that follows the re-crystallization of the crystal lattice to improve the workability and formability of the metals by regaining its original properties [4]. The two types of annealing processes are the light anneal and the soft anneal. While the prior method involves heating the metal at a temperature slightly above the re-crystallization temperature, the latter involves heating it to several hundred degrees higher at the temperature where rapid grain growth begins. Therefore, annealing becomes important for grain refinement impacting the surface to restructure thereby affecting the properties such as corrosion, fatigue deformations and hardness [4].

Wear test results plotted in the form of a graph between time (in seconds) and wear (in microns) reveal the amount of wear a sample undergoes with a certain load and hence gives an insight about its wear resistance.

In this context, this paper aims to study the effect of heat treating copper, brass and gunmetal which can further give us important information of their applications.

2. MATERIALS AND METHODS

Commercially oxygen free pure copper (UNS C10100), low brass (UNS C24000) and gunmetal (UNS C83600) were procured as samples.

2.1 Specimen preparation for micro-structure analysis

The surfaces of the samples were first belt grinded to remove any unwanted protuberances on the surface. The samples were then polished on four different grits emery papers starting from coarse grit to ultra fine grit viz. 100W, 320W, 480W and 1000W. Final polishing of the samples was done by velvet polishing. The final surface obtained was seamlessly polished like a mirror surface.

The samples were then etched with Ferric chloride solution, containing 2 parts of ferric chloride and 2 parts of distilled water, for a time duration of 4-5 seconds. The samples were then observed under an optical microscope (supplied by Chennai Metco Pvt. Ltd. & model – METJI-I) with a magnification of 200 X.

2.2 Rockwell hardness measurement

The Rockwell hardness was measured using Rockwell Hardness Tester (supplied by Casteel Industries & model – ALZ-B-250) for the three metals at three positions viz. centre, between edge and center and at the edge using a diamond indenter. Minor load was kept to be at 10 kgf while the major load of 100 kgf and 60 kgf with scale B and scale F respectively for pre- and post-heat treatment measurements.

2.3 Annealing

Annealing involves heating the metal to a predetermined temperature in a box type muffle furnace (supplied by Indfurr & Sl. no. R.20), holding at that temperature for some time and then cooling at a very slow rate at room temperature. Annealing results in the migration of atoms in the crystal lattice leading to the reduction in number of dislocations and therefore affecting the ductility and hardness of the metals. Generally, ductility is increased at the cost of the hardness thereby making the metals more workable. Here, the samples were heated to 850˚C and then left to cool inside the furnace.

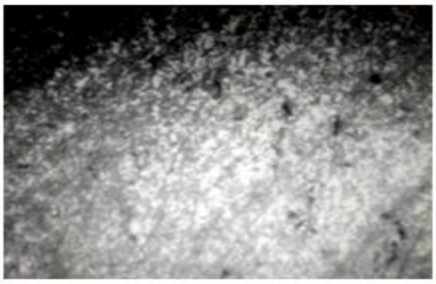
2.4 Wear test

The three metal samples were tested for their wear resistance using a rotary tribometer (supplied by Ducom Instruments & Sl.no. 867). A stationary upper specimen either cylindrical pin/ball is pressed on a hardened rotating disc (using an application of external load) and the friction and wear generated are compared to evaluate the characteristic properties of the material. The result of the wear test is a graph plotted between time and wear (in microns). The diameter of the samples was 10 mm and they were tested for 60 seconds. Copper with 10 N load rotated at 300 rpm, brass with 15 N load rotated at 400 rpm and gunmetal with 5 N load rotated at 200 rpm.

3. RESULTS AND DISCUSSION

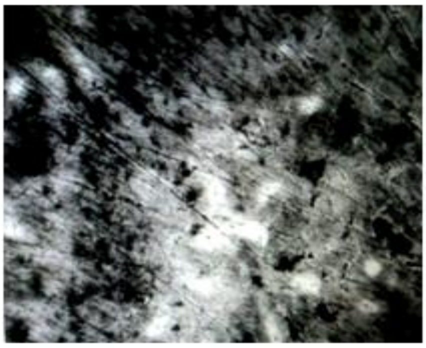
Figure 1 shows the microstructure image obtained from copper, brass and gunmetal sample before annealing. From the micro-structure, we can infer that brass crystallizes in single phase with solid solution of zinc and alpha copper. The micro-structure obtained for brass is often termed as basket weave structure that is generally obtained after room temperature air cooling of annealed samples. The beta-phase zinc occurs as a peritectic phase. Similarly, gunmetal also crystallizes according to the peritectic equation in which tin and zinc from solid solution (beta phase).

Figure 2 shows micro-structure of the samples after annealing. We observe grain refinement in the copper sample but no visible changes in brass sample. In the case of gunmetal, it can be easily seen in the image the presence of cracks and pores which have occurred (also seen in the annealed sample) thereby making it vulnerable for its application in engineering purpose.



(a)

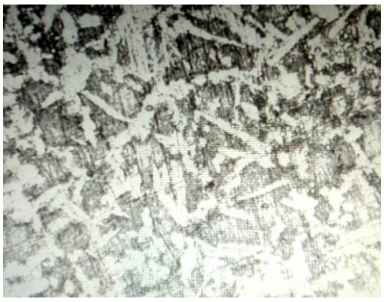
(b)



(c)

Fig – 1: Micro-structure of (a) Copper, (b) Brass and (c) Gunmetal before annealing

(a)



(b)

(c)

Fig – 2: Micro-structure of (a) Copper, (b) Brass and (c) Gunmetal after annealing

Table 1 refers to the hardness values for copper, brass and gunmetal at three positions i.e. edge, centre and between edge and centre obtained before and after annealing.

Table – 1: Rockwell hardness values before and after annealing

Position		Edge	Centre	Between edge and centre
Metal Sample				
Copper	Before	50.5	52	51
	After	39	45.5	41
Brass	Before	58	59	56
	After	23	29	28.5
Gunmetal	Before	55.5	58.5	55
	After	37	38	37.5

The hardness decreases in the order brass, gunmetal and copper. The hardest sample among them is observed to be brass before annealing and copper after annealing. The common trend noticed is that the hardness is the maximum at the centre of the sample compared to the other two positions.

The hardness values for copper after annealing can be attributed to the grain refinement post heat treatment as observed from the micro-structure. Grain refinement improves the workability without affecting hardness to a great extent.

The hardness values for gunmetal after annealing can be attributed to the cracks and pores occurred after the heat treatment that has greatly affected its hardness.

The hardness of cold worked brass decreases by almost half of the original hardness with annealing at elevated temperature.

Annealed copper has the highest hardness. One trend observed is that the hardness decreases with the decrease in copper content in the order copper, gunmetal and brass in the annealed samples contrary to the reverse order obtained before annealing.

Moreover the hardness values were more consistent at the three positions in the annealed samples compared to the original samples due to the redistribution of the grains in the annealed sample.

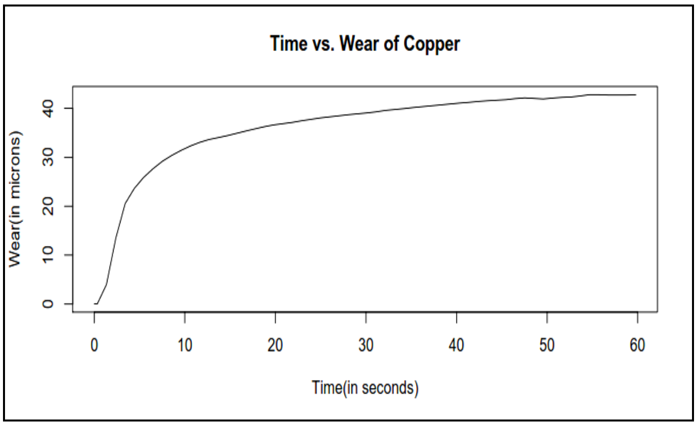


Fig 3 – Time vs. wear graph of copper

Figure 3 shows the graph obtained after the wear test of copper. For copper, wear is the least among the three samples with average wear of 97.93 microns for one minute time period. Its wear resistance can be attributed to its comparable hardness post annealing.

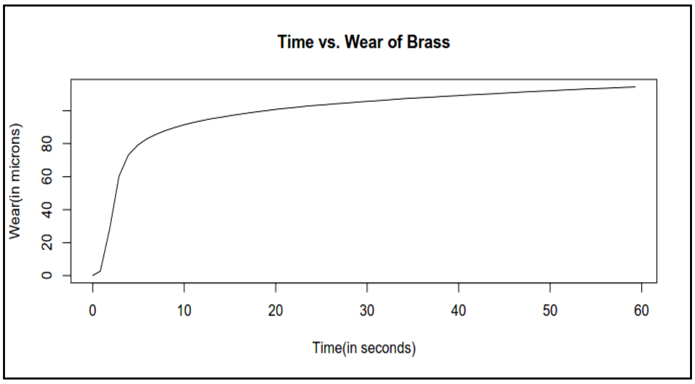


Fig 4 – Time vs. wear graph of brass

Figure 4 shows the graph obtained after the wear test of brass. For brass, the average wear is 98.15 microns for one minute time period. The wear resistance of brass is comparable to the copper sample and can be because of its well distributed grains that are not affected even after heat treatment.

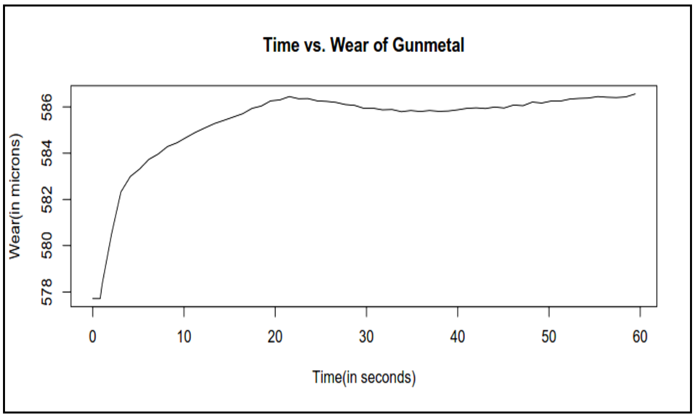


Fig 5 – Time vs. wear graph of gunmetal

Figure 5 shows the graph obtained after the wear test of gunmetal. It has the highest value of wear even for the lowest load. The average wear is 585.22 microns. It is directly proportional to the condition of the sample post annealing i.e. due to cracks and pores developed on its surface indicating loss in strength.

The wear tests for the annealed samples reveal that gunmetal is most vulnerable to wear while copper and brass have nearly equal wear and much less than gunmetal thus sufficiently wear resistant.

4. CONCLUSIONS

The hardness values decreases after annealing because of the migration of atoms in the crystal lattice upon heating and reduction in the number of dislocations in the metal lattice thereby increasing the ductility at the cost of hardness.

For copper, as the temperature goes down it tends to become more ductile and therefore more workable among the three metals while for brass it is more ductile and workable compared to other two metals after annealing.

Due to the rapid grain growth at elevated temperatures involved when soft annealing the metals, coarse grains are formed as a result which reduces the hardness of the metals by manifold thus increasing their ductility and hence, workability and formability.

Hence, we deduce that annealing heat treatment can possibly increase the workability of the cold worked metals.

Among the three samples, copper has the least wear with the highest load followed by brass and gunmetal. We also observe that the wear resistance increases with the increase in hardness values of the annealed samples.

ACKNOWLEDGEMENT

The authors thank the Material Characterization lab, Manufacturing lab and Advanced Manufacturing Technology lab, School of Mechanical and Building Sciences (SMBS), VIT University, Chennai Campus where the various tests as quoted in this paper were conducted. The authors would also like to extend their gratitude to lab in-charges, for their technical support throughout the duration of the research.

REFERENCES

[1] The Copper Advantage, Copper Development Association, 260 Madison Avenue New York, NY 10016-2401

[2] Tyler D.E., Black W.T.: Introduction to Copper and Copper Alloys, in: ASM Handbook Volume 2, Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, ASM International, Metals Park, (1990), 216-240.

[3] The brasses – properties and applications, Copper Development Association, publication 117

[4] A.K. Bhargava, M.K. Banerjee, Heat-Treating Copper and Nickel Alloys, Reference Module in Materials Science and Materials Engineering, from Comprehensive Materials Finishing, Volume 2, 2017, Pages 398-420, Current as of 21 September 2016