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A Study on the Effect of Cryotreatment on Copper based Brass Alloys

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Abstract

With the enhancement of research and innovation in manufacturing industry, there comes the high demand for alloy materials that possess high physical and mechanical properties. Copper based alloys have attracted much attention when it comes to physical properties because of heavy demand for high mechanical strength, high electrical conductivity and cost effective materials from industry fields. Pure copper is a ductile material, having excellence resistance to corrosion, and a very high conductivity (%IACS). Pure Cu is so soft that it can be drawn into wires because of its large grain size. It is evident from the literature, that by adding alloying elements, the strength of copper increases but at the cost of its other properties. The current study is an attempt to investigate the properties of the alloy after addition of brass to copper in various proportions and to carry out a deep cryogenic treatment to investigate the changes in the material's property. The study reveals that Deep Cryogenic treated samples have high hardness with a slight reduction in tensile strength and % elongation as when compared to that of non-deep cryotreated samples.

Keywords; *Brass, Copper, Cryogenic treatment & Mechanical properties*

I. INTRODUCTION

One of the significantly used metals commercially in production industry and its consumption are copper and copper alloys. These exhibit high thermal and electrical conductivities. They are resistant to corrosion, good strength and easy to fabricate [1,2,3]. These properties have enabled copper to be utilized in enormous industrial applications such as in manufacturing of cables, wires, electrical contacts, electrical appliances. [1,2] They are also used in radiators of automobiles, heat exchangers, solar panels for heating, liners of bearings and bushings etc., [3,4]. The application of copper and its alloys extends to manufacturing of springs, fasteners of high strength [5], small sized gears, cams, vessels which are corrosion resistant. [5]

The copper in its purest form is very ductile in nature and difficult to be used in applications which demand material strength, stiffness, machinability, toughness etc., In order to cater to the needs of the appliances to be manufactured the copper is alloyed with differentmaterials such as lead, zinc, tin etc., [6]

The alloying elements are added to achieve necessary variations in the material properties such ad ductility, stiffness, ultimate tensile strength, and toughness. The addition of alloying elements to copper enhances the ultimate tensile strength, yield strength, where as it reduces the bending strength [6]. Literature reveals that the addition of zinc to copper improves the strength, corrosion resistance [7] and machinability [8] of the material. Hence the zinc alloyed copper, nothing but brass possesses the above said properties.

Also it is known from literature that the deep cryogenic treatment is understood as the process in

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which material is being cooled slowly from 270 C to a very low temperature of -196 0C. Then it is soaked at that temperature for a predefined period of time and then heated slowly back to its original temperature and the rate of cooling at both cooling down and reverting back is maintained at the same cooling rate. The quenching media that has been used is nitrogen in liquid form else cold nitrogen in the gaseous state with slow cooling is utilized for deep cryo-treatment. It is used in this state so as to avoid any problems related to thermal stresses and to improve the material hardness [9].

The present work is a study at a condition where brass is added in varying proportions to copper and check the properties of the alloys. Then the samples are deep-cryotreated to check the varying properties of the alloys and to make a comparison of the same.

II. METHODOLOGY

The different compositions consisting of varying proportions of brass being added to copper to get different alloys. The base material being utilized is C11000 copper of ISO Cu-ETP. The solute being CuZn30 brass consisting of 73.5% Cu with 0.5% impurities and the remaining 26% Zinc. Both copper and brass are purchased in rod form and are cut to a size of 25mm long. Weight proportion of brass that is 3%, 6% and 9% were taken separately.

Copper is taken in a crucible. It is heated in a pit furnace. It is heated to 1100 ^{0} C. During the process of melting, the brass is added. It is heated to get a homogenized mixture. Degassing agent, that is hexachloroethane is used to remove unwanted impurities and degas during the casting process. The impurities are removed and the molten metal is fed in to the die cavity and allowed to solidify. Prior heating of the die is done to get a proper melt. Three separate melts are prepared leading to the formation of 3 compositions of the alloy.

The confirmation of the composition was done using Optical Emission Spectrovac [10]. The rods were casted and cut in to different size of samples according to the respective ASTM standards. The samples were prepared for tensile testing and hardness tests.

III. INVESTIGATION

The samples were prepared for three different compositions of brass in copper as explained earlier. The samples were prepared to a repeatability of 3 samples each. The testing of various properties such as hardness, ultimate tensile strength, yield strength and percentage elongation were to be carried out and the samples were prepared for the same as per the standards. The number of samples that were prepared were 36 totally.

The test for hardness was done using Brinell's hardness tester according to ASTM E10 standard. The indentor used for the test is a steel ball and its diameter is 2.5mm, load of 62.5 kilograms, the holding time was 10 secs. The sample size utilized was of diameter 20mm and length 30mm. [1,10].

A Tensometer is used to carryout tensile test at 27 ^{0} C according to ASTM E8 standard [1,10]. The graph of tensile test readings also provided the yield strength and percentage elongation. These results obtained were tabulated and further analyzed.

After the first level of experimentation is done, the remaining samples were subjected to deep cryogenic treatment as explained above ie., cooling it to -196^{0} C and then holding it for a period of time and then heated back slowly to the room temperature. The following fig. 1. indicates the deep cryocycle. It shows the generalized cryocycle which consists of the following steps.

i) Ramp down - Here the material is cooled slowly form atmospheric temperature to -196 ^{0} C. Altogether, it takes a period of nine hours. The cooling is done slowly so that the stresses due to temperature is reduced [9].

ii) Soaking - After the first step, the material is brought down to -196 ^{0} C and is held at the same temperature for twenty-four hours [9,11].

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iii) Ramp up – After the second step, it is brought back to room temperature maintaining the same rate of heating [9,11].

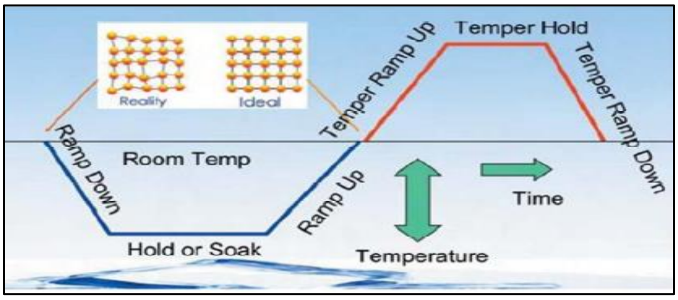

Fig.1. Generalized cycle for cryogenic treatment. [9,11]

iv) Aging – The next step that is taken up is aging as it is essential to decrease the brittleness of the deep cryotreated materials especially non-ferrous ones. This has to be done as the nucleation sites for the precipitation of II phase particles are to be provided due to cryotreatment. Literature [9,11-16] has shown that better results were obtained when the cryogenic treatment is performed directly after quenching and followed by subsequent tempering.

The above fig.1, indicates the generalized cycle for cryogenic treatment, which completely explains the deep cryogenic cycle.

The deep cryotreated samples are tested for properties essentially mechanical as per the standards chosen.

The results were tabulated and analyzed

Both the results of the samples before and after deep cryo treatment were noted and compared to draw the conclusion.

IV. RESULTS AND DISCUSSIONS

4.1 Hardness:

The following Fig. 2., illustrates the effect of the addition of brass as well as the deep cryotreatmenton copper alloys.

Brass was added to copper in increasing percentages of brass, that is 3%, 6% and 9% respectively. The results obtained after hardness test are as shown in Fig 1.,

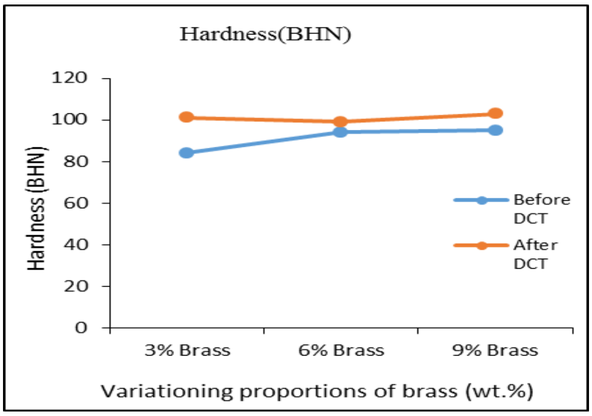

Fig 2. Hardness

which indicates that, the amount of brass content in the alloy increases, the hardness increases by 13% on a

whole, while when the same varying weight percent of brass alloys are subjected to deep cryo treatment. Upon treating, the alloys exhibit an increase in the hardness in comparison with samples being untreated but an increase with the varying compositions of brass with the treatment increases hardness by 2 %.

4.2. Ultimate Tensile Strength:

The tensile test has been carried out as per ASTM E8 standard and the results were noted.The following fig. 3. indicates the variations in the ultimate tensile strength of varying compositions of brassin copper alloys before deep-cryotreatment and after deep-cryo treatment.

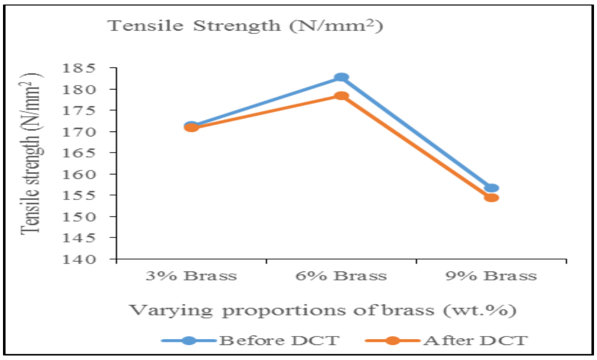

Fig.3. Ultimate tensile strength.

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The ultimate tensile strength increases up to 6% brass composition addition. Later at 9% it greatly reduces. This is observed before deep cryo treatment. After deep-cryo treatment, the tensile strength increases with the increase in composition up to 6% brass addition to the alloy, but stakes a deep negative exponential up to 9% brass alloy addition.

Upon comparison with untreated to treated (deep cryo) samples, the tensile strength decreases in comparison to the untreated one.

The tensile strength at 3% brass composition, remains almost same even after deep cryotreatment. Whereas at 6% brass composition, deep cryo treated samples experiences a decrease of 2% in UTS in comparison with not deep cryotreated samples. whereas at 9% brass composition, 1.5% decrease in UTS is seen after deep cryotreatment.

4.3 Yield Strength

The yield strength of the varying compositions of the alloy are as depicted in the following fig. 4.

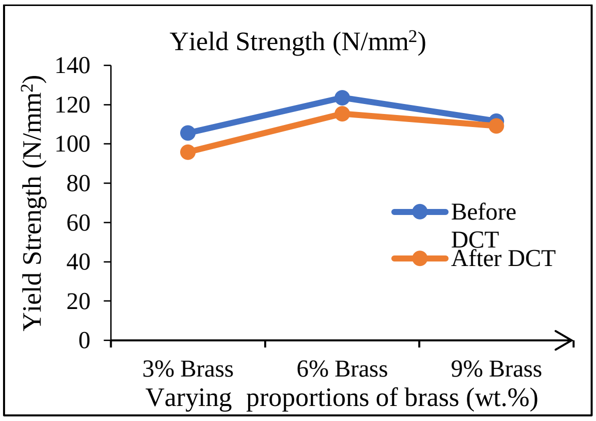

Fig.4. Yield Strength.

The yield strength of the different alloys indicates that as the percentage composition of brass increase, the yield strength also increases except at 6% brass alloy. As observed from the graph it is clear that, after deep cryogenic treatment, the yield strength decreases and this decrease is less seen at 9% brass addition. A 5.5% reduction is seen at 3% brass addition, 7.1% reduction at 6% brass and 2.29% reduction at 9% brass composition in the alloy. It clearly indicates that after deep cryogenic treatment, the alloys experience a reduction in yield strength to an average of 5% approximately between 3 to 9% brass addition to copper.

4.4 % Elongation

The % elongation of a material indicates the ductility of the material. The following fig. 5. indicates the variation of ductility of the varying compositions of the alloy.

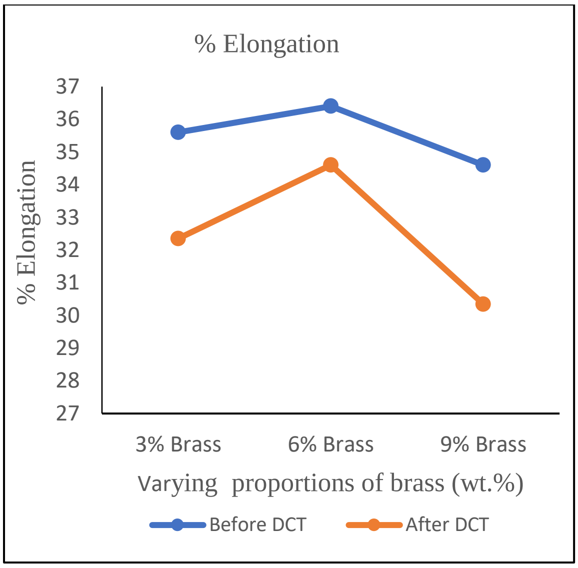

Fig. 5. % Elongation

It is observed from fig.5, that as the content of brass composition increases, at 3% brass, the alloy exhibits a drastic increase in % elongation, at 6% it reaches the highest value, then again it drops down exponentially till 9% composition addition.

At the same time, it is seen that the material loses ductility after cryotreatment, in comparison with non cryotreated samples. It experiences 8.7% reduction at 3% brass composition, 4.9% reduction at 6% brass composition and 12.28% reduction at 9% brass composition. It is evident from the result that at higher composition of brass addition, the ductility reduces significantly after being deep cryotreated.

V. CONCLUSIONS

By the analysis of the above experiments, the following conclusions were drawn.

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It is seen that the alloys of 3%, 6% an 9% brass addition into the copper base metal increases the hardness of the material and with cryotreatment a slight increase in hardness is seen at all the compositions approximately to an average of 13%

The tensile strength, decreases slightly after deep cryotreatment whereas the yield strength slightly increases compared to tensile strength, whereas upon deep cryotreatment it reduces to an average of 4.9%.

The ductility of the material reduces upon deep cryotreatment as the addition of brass increases hardness and hence brittleness induced which reduces ductility.

The deep cryotreatment on the whole has helped in enhancing hardness, whereas decreases tensile strength, yield strength and ductility of the material.

It is also seen that at 6% brass composition the trend is reversed at all the properties in comparison with the other compositions. Hence this composition has a further scope to be investigated.

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