EFFECT OF ANNEALING ON THE HARDNESS OF COLD-WORKED CARTRIDGE BRASS

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TO

DEPARTMENT OF MECHANICAL ENGINEERING

FACULTY OF ENGINEERING

FEDERAL UNIVERSITY OYE-EKITI,EKITI STATE

SEPTEMBER, 2016

DECLARATION

I**ADEJUMO, IDRIS ABAYOMI** hereby declare that this project work carried out is the result of my personal effort under the supervision of MR O. C. OKOYE of the department of Mechanical Engineering, Federal university Oye-Ekiti, Ekiti State, as part of the requirement for the award of Bachelor Degree of Mechanical Engineering, and has not been submitted elsewhere for this purpose. All sources of information are explicitly acknowledged by means of reference.

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ADEJUMO, IDRIS ABAYOMI **Date**

(MEE/11/0401)

CERTIFICATION

This is to certify that this project title **EFFECT OF ANNEALING ON THE HARDNESS OF COLD WORKED CARTRIDGE BRASS** was carried out by ADEJUMO IDRIS ABAYOMI under the supervision of MR. O.C. OKOYE and submitted to the Department of Mechanical Engineering, Federal University Oye-Ekiti, Ekiti state in partial fulfillment of the requirement for the award of Bachelor of Engineering (B. Eng) Degree in Mechanical Engineering.

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PROF. M.S. ABOLARIN ______________________

EXTERNAL SUPERVISOR SIGNATURE AND DATE

DEDICATION

This project is dedicated to my parents, Elder T.O.S Adejumo and Mrs. Romoke Adejumo, and my brother, Mr. Ahmed Adejumo.

ACKNOWLEDGEMENT

All thanks, glory and honour belong to the Almighty God for His mercy and protection over my life from birth to this wonderful moment of my graduation.

My appreciation goes to my project supervisor in person of Mr. O. C. OKOYE for his support and advice towards making the project work a success. Also, I am profoundly grateful to all my lecturers in the Department of Mechanical Engineering for imparting knowledge in me.

Moreover, thanks and acknowledgement are extended to my brother, Mr. Ahmed Adejumo; my father, Elder T.O.S Adejumo; and especially to my mother, Mrs S.R. Adejumo for their moral and financial support to make the achievement of my first degree a reality.

Finally, I appreciate my friends, Mr. Oladipupo Michael Damilare and Mr Mohammed Usman Ayo for their understanding and friendship; and my SIWES Industrial-based supervisor, Mr. Lukman Aremu.

ABSTRACT

The problem that necessitated this research work is the need to understand the effect of the variation in annealing temperatures and times on the hardness of cold-worked cartridge brass (copper 70%, zinc 30% alloy). Twenty cartridge brass samples used were cast using sand casting method. Seventeen samples undergo homogenization annealing at 800°C for one hour using an electric resistance furnace and allowed to furnace cool for one day, leaving three samples as cast. Sixteen samples undergo 2% cold-work under a hydraulic press and vernier caliper was used to take its measurement before and after compression, leaving one sample as homogenized. Annealing was done at two different temperature: 250°C and 650°C and the samples were annealed for varying time (6, 12, 30, 60, 120minutes) on the cold worked samples. One cold-worked sample was cut into ten pieces; five pieces for each annealing temperature, and one piece for their various annealing time. The annealed samples are used to study the effect of annealing at varying annealing time and different annealing temperature on the hardness of the cartridge brass. Hardness test was also carried out on; as cast sample, homogenized sample, and cold worked sample without annealing. On each hardness test sample, hardness value is taken at three different points and the average is taken as the hardness of the sample. Also, annealing temperatures and annealing times are factors of utmost importance in the achievement of the required hardness level of the cold-worked alloy.

- Cold working changes the structure and properties of cartridge brass.
- Annealing above 30mins causes reduction in hardness.
- Annealing at 650°C causes increase in plastic properties of cartridge brass.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Copper is one of the most widely used non-ferrous metals in industry. It is extracted from ores of copper such as copper glance, copper pyrites, melachite and azurite. Pure copper is soft, malleable and ductile metal with a reddish-brown appearance. It is a good conductor of electricity. It is non-corrosive under ordinary conditions and resists weather very, effectively. Its tensile strength varies from 300 to 470 MN/m^2 and melting point is 1084°C. It is one of the best conductors of heat and it is highly resistant to corrosion. This non ferrous metal can withstand severe bending and forging without failure. It does not cast well. If copper is heated to red heat and cooled slowly it becomes brittle, but if cooled rapidly it becomes soft, malleable and ductile. It can be welded at red heat.(Singh, 2006)

Brasses are copper alloys in which the principal alloying constituent is zinc. Their properties depend primarily upon the proportion of zinc present but their properties can be modified by the introduction of additional elements to further improve specific characteristics such as strength, machinability or resistance to particular forms of corrosion. Consequently, brass are classified into; Alpha brasses, Alpha-beta brasses, Leaded brasses, Tin brasses, Nickel-silver brasses (Kaushish, 2013).

According to the Copper Development Association (CDA), the brass with Cu 70% and Zn 30% is known as Cartridge Brass with the CDA number 260. Cartridge brass studied in this work belongs to the class of alpha brasses, since alpha brasses are brasses with zinc content up to 36%.

Cartridge brass, however, is strong and ductile and it is used for drawn products like cartridge cases, tubes, sheets, radiator shells and reflectors for head lamp. They possess good cold working properties. They are used for ammunition cases, plumbing, and hardware.(CDA, 1996)

However, mechanical properties of cartridge brass can be modified by cold-working and annealing. Cold-working refers to the plastic deformation of metal at room temperature or below recrystallization temperature, while annealing is the treatment of a metal or alloy by heating to a predetermined temperature, holding for a certain time, and then cooling to room temperature to improve ductility and reduce brittleness (Kaushish, 2013). Cold working increases the mechanical properties of a metal like its hardness and strength due to strain hardening, however, a distortion of the grain structure is created. Since the material gets strain hardened, the maximum amount of deformation that can be given is limited. Any further deformation can be given after annealing. Internal stresses are set up which remain in the metal unless they are removed by proper heat-treatment.

Therefore, annealing is introduced to achieve the following; soften the steel, relieve internal stresses, reduce or eliminate structural in-homogeneity, refine grain size, improve machinability, increase or restore ductility and toughness (Kaushish, 2013).

This study focuses on Catridge brass (copper 70%, zinc 30% alloy). This alloy is investigated with a view to finding out how its hardness changes with variation in annealing temperatures and annealing times.

1.2 STATEMENT OF THE PROBLEM

Cartridge brass has various applications, but each of this application requires different hardness of the cartridge brass. Basis for selection of cartridge brass to meet hardness requirements for specific industrial applications have been misunderstood. Therefore, this research work aims to understand the effect of the variation in annealing temperatures and times on the hardness of cold-worked cartridge brass (CuZn30).

1.3 OBJECTIVES OF THE STUDY

The objectives of this research work are:

(i) To find out how annealing temperature varies with the hardness of cold-worked cartridge brass

(ii) To find out how annealing time affect the hardness of the cold-worked cartridge brass.

1.4 SIGNIFICANCE OF THE STUDY

The information obtained from this research work is useful for the following purposes:

(i) It provides a basis for the selection of cartridge brass to meet hardness requirements for specific industrial applications for which the alloy is intended for use

(ii) It dictates the temperature and duration of annealing that the cartridge brass must undergo in order to produce the required hardness of the alloy for use in the industry

1.5 SCOPE OF THE STUDY

This research work covers investigations on how annealing temperatures and times affect the hardness of cold-worked cartridge brass (copper 70%, zinc 30% alloy).

CHAPTER TWO

LITERATURE REVIEW

2.1 Copper and Its Alloys

Copper was undoubtedly the first metal to be used by man and it is the most useful metal. Copper is more important because of its very high electrical conductivity which is surpassed only by silver; its very high heat conductivity; its high resistance to corrosion; its ease of working i.e. forming, sheet-making, bending and fabricating properties, and; the alloys which it forms, the most important of which are brasses and bronzes (Kaushish, 2013).

It is thought that bronze was accidentally produced in Cornwall by smelting ores containing both tin- and copper-bearing minerals in the camp fires of ancient Britons. It was the best material for making knives and other cutting implements. When relative costs are considered, copper is naturally the metal used for industrial purposes demanding high electrical conductivity. The presence of impurities have effects on the electrical properties of copper. Quite small amounts of some impurities will also cause serious reductions in the mechanical properties (Haggins, 1993).

Copper is not used extensively in pure state because it is very soft and weak, but a very large part of the world's production of metallic copper is used in the unalloyed form, mainly in the electrical industries (Kaushish, 2013).

2.2 BRASS (Copper based alloy)

The copper-based alloys include the **brasses** and **bronzes**, the latter being copper-rich alloys containing tin and either aluminum, silicon or beryllium; though the tin bronzes are possibly the best known because tin is the main alloying elements in bronze. Bronzes are generally superior to brasses in terms of corrosion resistance and mechanical properties (Kaushish, 2013).

The brasses are alloys of copper and zinc containing up to 45% zinc, and constitute one of the most important groups of nonferrous engineering alloys. As shown by the equilibrium diagram Figure 2.1, copper will dissolve up to 32.5% zinc at the solidus temperature of 902° C, the proportion increasing to 39.0% at 454° C. With extremely slow rates of cooling, which allow the alloy to reach structural equilibrium, the solubility of zinc in copper will again decrease to 35.2% at 250° C. Diffusion is very sluggish, however, at temperatures below 450° C, and with ordinary industrial rates of cooling the amount of zinc which can remain in solid solution in copper at room temperature is about 39 %. The solid solution so formed is represented by the symbol **α**. Since this solid solution is of the disordered type, it is prone to the phenomenon of coring, though this is not extensive, indicated by the narrow range between liquidus and solidus. If the amount of zinc is increased beyond 39 % another phase, **β'**, will appear in the microstructure of the slowly cooled brass. This phase is hard, but quite tough at room temperature, and plastic when it modifies to **β** above 454° C. Further increases in the zinc content beyond 50 % cause the appearance of the phase γ in the structure. This is very brittle, rendering alloys which contain it unsuitable for engineering purposes (Haggins, 1993).

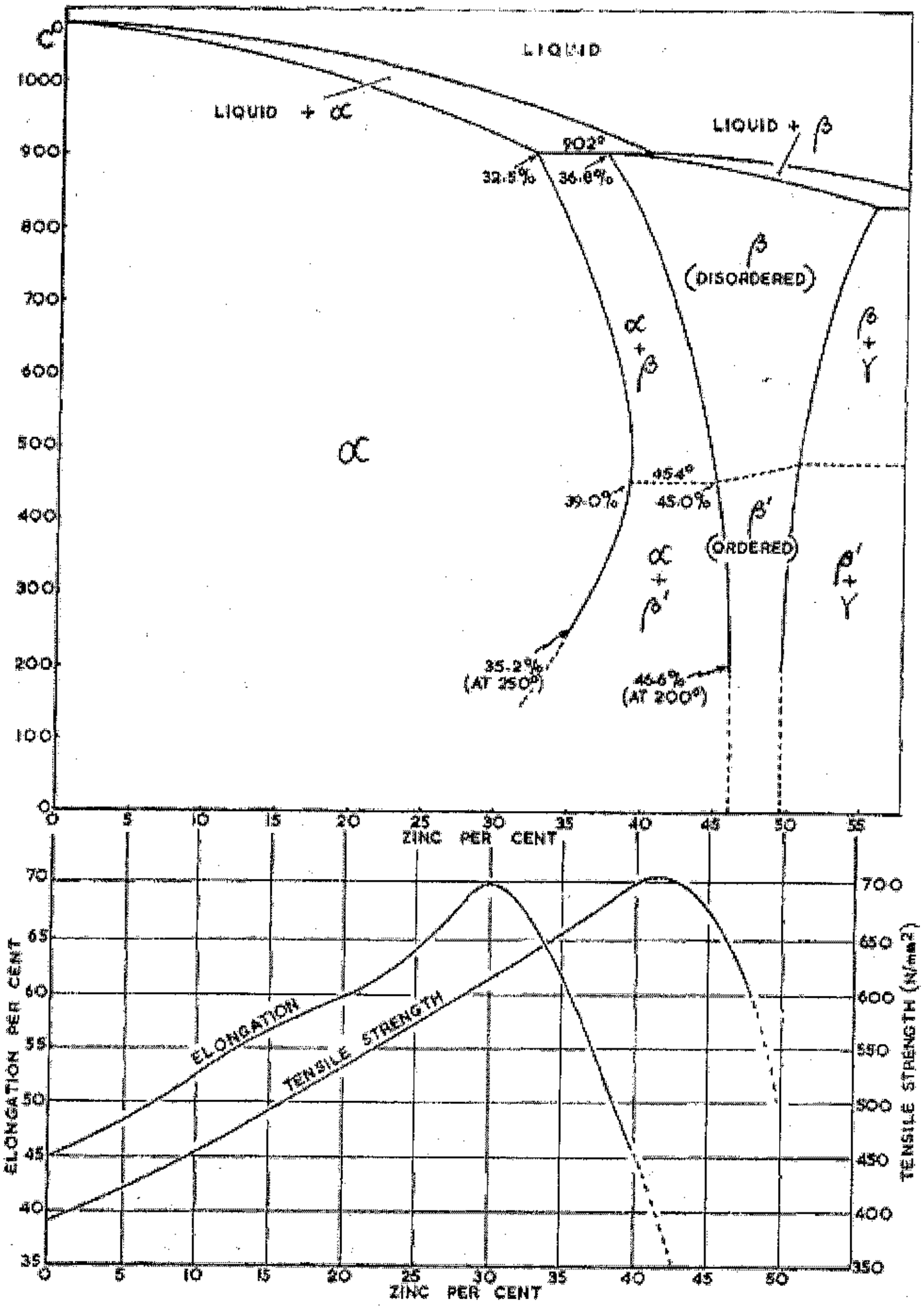

Figure 2.1. The Copper-Zinc Constitutional (Thermal-equilibrium) Diagram (Haggins, 1993).

Brass is formed by alloying copper with zinc in varying proportions and the brass is stronger than either of the materials from which it was made. Brasses contain up to 70%copper, 5 to 45%zinc, besides small amount of aluminium, tin, manganese, lead, etc. to give special properties to the brass. Precipitation hardening brass also has copper 70%, zinc 30% (approx.) and small amount of nickel and aluminium and is used for gears, and formed parts and has the ability to harden after working (Kaushish, 2013)

Some of common phases of brass are discussed below (Singh, 2006):

- **Alpha Phase**

If the copper crystal structure is face centered cubic (FCC), there will be up to 36% of zinc. This solid solution is known as alpha brass. It has good mechanical properties, good corrosion resistance but it possesses lower electrical conductivity than copper.

- **Beta Phase**

If the amount of zinc increases beyond 36%, beta brass will appear in the microstructure of the slowly cooled brass. This has body centered cubic structure (BCC). This phase is hard but quite tough at room temperature.

- **Gamma Phase**

When zinc content is increased in brass beyond 50%, then gamma phase appears in its structure. This structure is extremely brittle, rendering the alloy unsuitable for general engineering purposes.

2.2.1 Types of brasses.

Brasses are of different types and applications, some of which are mentioned in Table 2.1:

TABLE 2.1: Properties and Applications of different brasses (Singh, 2006)

TYPE OF BRASS/(CLASS)	CONTENT	PROPERTIES	APPLICATIONS
Red brass	Cu 85%, Zn 15%.	Corrosion resistance and workability. Tensile strength (27-31 kg/mm). Percentage elongation (42-48).	Heat exchanger tubes, condenser, radiator cores, plumbing pipes, sockets, hardware, etc.
Yellow Brass or Muntz Metal	Cu 60%, Zn 40%.	High strength and high hot workability. It has tensile strength of 38 kg/mm^2 (approximately). The percentage elongation of this brass is 45%.	In making bolts, rods, tubes, valves and fuses. pump parts, valves, taps, condenser tubes, sheet form for ship sheathing
Cartridge Brass	Cu70% and Zn30%	Strength and ductility. It has tensile strength between 31-37 kg/mm^2. Percentage elongation of this brass is 55-66%.	For making tubes, automotive radiator cores, hardware fasteners, rivets, springs, plumber accessories.
Admiralty Brass	Cu 71%, Zn 29%, Sn 1%	Highly resistant to corrosion and impingement attack of sea water. Tensile strength 30 kg/mm^2 (approx.).Can be cold worked. percentage elongation is 65%.	For making condenser tubes in marine and other installations, plates used for ship building, bolts, nuts, washers, condenser and ship fittings parts, etc.

Table 2.1: Properties and Applications of different brasses (Cont'd)

TYPE OF BRASS/(CLASS)	**CONTENT**	**PROPERTIES**	**APPLICATIONS**
Naval brass	Cu 59%, Zn 40%, Sn 1%	Corrosion resistance to sea water is significantly improved. Percentage elongation is 47%. Tensile strength is 38 kg/mm^2 (approx.).	For making marine hardware casting, piston rods, propeller shafts, welding rods etc.
Manganese brass	Cu 60%, Zn 38%,Mn0.5%, Fe1.0%,Sn0.5%	Sufficient toughness and good corrosion resistance. It is very active in reducing the oxides of other metals.	For making hydraulic rams, valves and cylinders, tubes, pump rods, propellers, bolts, nuts etc.
Iron brass or delta brass	Cu 60%, Zn 37%, Fe 3%	Hard, strong, tough, and having good corrosion resistance. It can be cast easily.	For resisting corrosion in mild steel.
Gilding brass	Cu 85%, Zn 15%		Commonly used for jewellery, decorative and ornamental work.
Free cutting brass	Cu 57.5%, Zn 40%, Pb 2.5%.	Highly machinable and it does not allow bending.	For making cast, forged or stamped blanks to be used for further machining such as high speed turning and screwing.
Lead brass or cloak brass	65%, Zn 34%, Pb 1%		In making small gears and pinions for clock work.

2.3 Previous studies on Cartridge brass (Cu 70%, Zn 30%)

According to Haque and Khan (2007), in their investigation on the structure and properties of brass casting, aimed at observing the effects of cooling rate on α brass casting with a main objective to investigate the properties as well as microstructural changes of the brass due to casting in sand and chill moulds. Their results shows that the dendritic grains of sand cast specimen are bigger compared to those of the chill cast specimen. Actually, the rate at which a casting cools affects its microstructure, quality, and properties. The products of sand casting process, often large with thick walls, generally cool slowly. This increases the metal's grain size, creating a coarse microstructure. Thus, the cooling rate at which the alloy is solidified, controls the microstructures of the cast products. This in turn affects the physical and mechanical properties of the alloy. In their study, the ductility (both elongation and reduction in area) in sand casting has higher values. There may be one reason: the slow cooling rate in sand castings has kept the metal liquid (molten state) longer, which allows more gases and waste metal to escape, reducing the voids and inclusions. Thus, the sand cast sample has taken longer time to be separated during tensile testing, giving more elongation and reduction in area. It was also reported that in annealed cartridge brass, when grain size is increased, both the strength and hardness are decreased, while the elongation is increased. Finally, they concluded that the grain size of α brass in green sand mould is bigger than that of the metallic chill mould. As the grain size decreases, the strength of the chill cast brass increases and the tendency for the casting to crack also decreases, producing denser, harder and stronger products. The experimental results show that the UTS and hardness values in the chill cast products are 1.32 times and 1.30 times higher than those of the sand cast products, respectively, but the chill cast products possess lower ductility.

According to Ozgowicz, Kalinowska-Ozgowicz and Grzegorczyk (2010), in their study of CuZn30, aimed at determining the influence of the recrystallization temperature on the microstructure and mechanical properties of the brass CuZn30 subjected to cold deformation in the process of rolling at various degrees of strain. In their approach, the brass CuZn30 was recrystallization annealed within the temperature range of 300-650°C after cold rolling with the strain of 15.8-70.2%.

They concluded that an increase of the recrystallization temperature within the range of 400-650°C results in a deterioration of the mechanical properties of the brass CuZn30 and an increase of its plastic properties.

2.4 COLD WORKING

Cold-working is the plastic deformation of metal or alloy at room temperature or below recrystallization temperature of the metal or alloy. Ductility of a metal determines the extent to which it can be cold-worked. Greater loads are required to deform a metal in cold-working as it does not get permanently deformed until the stress exceeds the elastic limit. No recovery from grain distortion or fragmentation occur in cold working, since there is no recrystallization of grain during cold-working range (Kaushish, 2013).

During cold working, the number of dislocations increases, causing the metal to be strengthened as its shape is changed. Although normal room temperatures are ordinarily used for cold working, temperatures ranging between room temperature and recrystallization temperature are sometimes used to provide increased ductility and reduced strength.(Total materia, 2010)

2.4.1 PURPOSE OF COLD WORKING

The common purposes of cold working are given below (Singh, 2006):

- Cold working provides better surface finish on parts.
- It is applied to obtain increased mechanical properties of the material being cold-worked.
- It is widely applied as a forming process of making steel products using pressing and spinning.
- It is used to obtain thinner material from a thick material.

In general, the main characteristics of cold working are given below (Singh, 2006):

- Cold working involves plastic deformation of a metal, which results in strain hardening.
- The larger the amount of deformation, the larger the stress required for deformation
- The material can only undergo limited amount of deformation without introducing other treatment.
- There exist a general distortion in grain structure.
- Good surface finish is obtained.
- The maximum temperature at which strain hardening is retained is equivalent to the upper temperature limit for cold working.
- The loss of ductility during cold working has a useful advantage in machining. Since the chips break more readily and facilitate the cutting operation with less ductility.
- Heating is sometimes required.
- Cold working is often more economical than hot working, for relatively ductile metals,
- In cold working, directional properties is easily imparted.
- Spring back is a common phenomenon present in cold-working processes.

There is some increase and some decrease in properties of the cold worked part, which are presented in Table 2.2.

Table 2.2: Effect of cold working on metals (Singh, 2006)

Cold working process increases:	Cold working processes decreases:
• Ultimate tensile strength	• Percentage elongation
• Yield strength	• Reduction of area
• Hardness	• Ductility
• Fatigue strength	•Impact strength
• Residual stresses	• Resistance to corrosion

2.4.2 LIMITATIONS OF COLD WORKING

The following are the limitations of cold working (Singh, 2006):

- ➢ The cold worked process possesses less ductility.
- ➢ During cold working process, strain hardening occurs.
- ➢ Imparted directional properties may be detrimental
- ➢ The surfaces of the metal must be clean and scale free before cold working can be done.
- ➢ It requires large amount of stress for deformation than those in hot working.
- ➢ It requires more powerful and heavier equipment.

The major cold working processes can be divided into four, which are: shearing, drawing squeezing and bending. The sub-division of the major cold working processes are presented in Table 2.3.

Table 2.3: The sub-division of the major cold working processes (Kaushish, 2013)

Shearing	**Drawing**	**Squeezing**	**Bending**
Blanking	Wire drawing	Cold rolling	Bending of bars
Punching	Tube drawing	Coining	Angle bending
Perforating	Embossing	Riveting	Roll forming
Trimming	Stretch forming	Stamping	Seaming
Slitting		Cold forging	
		Thread rolling	
		Knurling	

Cold rolling accounts for by far the greatest tonnage of cold-worked products. Sheets, strip, bars and rods are cold rolled to obtain products that have smooth surfaces and accurate dimensions (Kaushish, 2013).

Extremely large quantities of products are made by cold forging, in which the metal is squeezed into a die cavity that imparts the desired shape. Cold heading is used for making enlarged sections on the ends of rod or wire, such as the heads on bolts, nails, rivets and other fasteners (Kaushish, 2013).

Drawing involves the pulling of a metal rod through a die to produce a wire. Product of uniform cross-section are formed by the drawing process. Products of drawing include tubes, rods, aluminium trim for windows and doors, Utensils of stainless steel are generally made by this process (Kaushish, 2013).

According to Singh (2006), Wire drawing, as a cold-working process, improves the mechanical properties. The material loses its ductility during the wire drawing process and when it is to be repeatedly drawn to bring it to the final size, intermediate annealing is required to restore the ductility. Schematic for wire drawing is shown in Figure 2.2

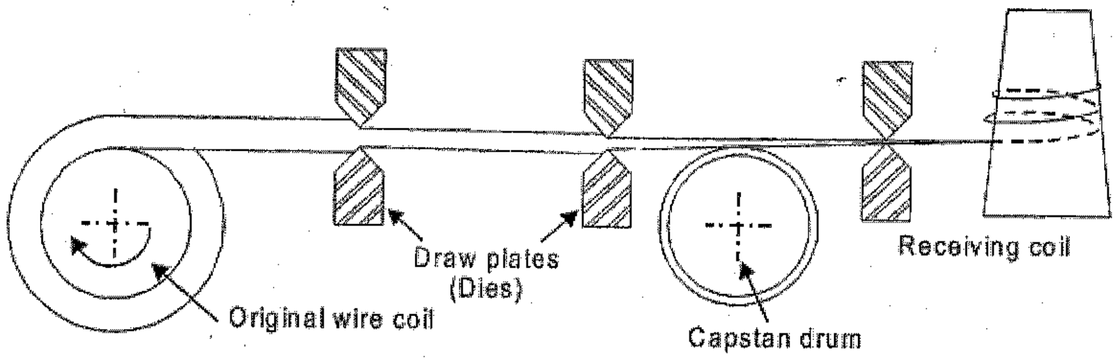

Figure 2.2: Schematics for wire drawing (Singh, 2006)

2.5 ANNEALING

Changes occur in both the physical and mechanical properties of a metal when it is cold-worked, by any of the many industrial shaping operations. While the increased hardness and strength which is a result of the cold working treatment may be of importance in certain applications, it is frequently necessary to return the metal to its original condition to allow further forming operations (e.g. deep drawing) to be carried out of for applications where optimum physical properties, such as electrical conductivity, are essential. Therefore, the treatment given to the metal to bring about a decrease of the hardness and an increase in the ductility is known as annealing. (Smallman & Bishop, 1999)

2.5.1 OBJECTIVES OF ANNEALING

The purpose of annealing is to achieve the following (Singh, 2006):

- To soften the metal.
- To refine grain size of the metal.
- To relieve internal stresses in the metal due to cold working.
- To reduce or eliminate structural in-homogeneity of the metal.
- To increase or restore ductility and toughness of the metal.
- To improve machinability of the metal.

Annealing proceeds in three stages: recovery, recrystallization, and grain growth. The stages of annealing are discussed as follows:

Recovery: During recovery, as a result of enhanced atomic diffusion at the elevated temperature, some of the stored internal strain energy is relieved by virtue of dislocation motion (in the absence of an externally applied stress). There is some reduction in the number of dislocations, and dislocation configurations are produced having low strain energies. In addition, physical properties such as electrical and thermal conductivities and the like are recovered to their precold-worked states.(Callister, 2007)

Recrystallization: According to Smallman and Bishop (1999), the most significant changes in the structure-sensitive properties occur during the primary recrystallization stage. In this stage the deformed lattice is completely replaced by a new unstrained one by means of a nucleation and growth process, in which practically stress free grains grow from nuclei formed in the deformed matrix.

Recrystallization is a process, the extent of which depends on both time and temperature. The driving force to produce this new grain structure is the difference in internal energy between the strained and unstrained material. Also, during recrystallization, the mechanical properties that were changed as a result of cold working are restored to their precold-worked values; that is, the metal becomes softer, weaker, yet more ductile. (Callister, 2007)

Grain Growth: When primary recrystallization is complete (i.e. when the growing crystals have consumed all the strained material) the material can lower its energy further by reducing its total area of grain surface. With extensive annealing it is often found that grain boundaries straighten, small grains shrink and larger ones grow. The general phenomenon is known as grain growth, and the most important factor governing the process is the surface tension of the grain boundaries.(Callister, 2007)

2.5.2 TYPES OF ANNEALING

Annealing is of various types, some of which are (Callister, 2007):

(*a*) Process annealing

(*b*) Stress relief annealing.

(c) Full annealing

In process annealing, ductility is increased, metal is softened, and the grain structure is refined. In stress relief annealing the main purpose is to eliminate internal residuals as a result of non-uniform cooling of a piece that was processed or fabricated at an elevated temperature, such as a weld or a casting, while full annealing is often utilized for low and medium carbon steel that will experience extensive deformation during a forming operation. It results in smaller grains and a uniform grain structure (Callister, 2007).

CHAPTER THREE

MATERIALS AND METHODS

3.1 PREPARATION OF THE TEST SAMPLES.

For this work, twenty samples of cast cartridge brass(Cu70%, Zn30%) each having a diameter of 15 mm and a height of 250 mm are required. The samples were prepared at JAMAH TECHNICAL WORKS, Idi-Ape, Ibadan, Oyo state, Nigeria

3.1.1 MOULD PREPARATION

The following are the apparatus used for mould preparation:

- Moulding box
- 10 pattern(steel cylindrical rod)
- Spade
- Trowel
- Ram
- Moulding sand
- Venting wire
- Brush

The method of casting employed for this work is sand casting. The pattern used to make the mould shape is a steel cylindrical rod measuring 15 mm in diameter and having a length of 250 mm. The stages involved in the making of the sand mould are described below:

The sand to be used for mould preparation was poured on the foundry floor. A little quantity of water was added to it to breakdown the big sand particles. Then the trowel is used to mix the sand and water together. More water was added until the sand became sticky and possess moldable texture. The patterns were then placed in the moulding box in a vertical position at a small distance from each other. The sand was poured into the moulding box, then trowel was used to level the sand while the ram was used to compact the sand so that it sticks together and form a solid mould. Pouring of sand, levelling and ramming was continuously done until the mould box was completely filled and the sand was sticky and tight enough to form the shape of the pattern. The venting wire was used to create air passage for the escape of mould gases. The patterns were then removed from the mould carefully. The mould cavity then had the shape of the patterns. Thereafter, the mold was baked with fire to dry up the mould. Thus, the mould was ready for casting operation. The mould preparation is shown in Figure 3.1

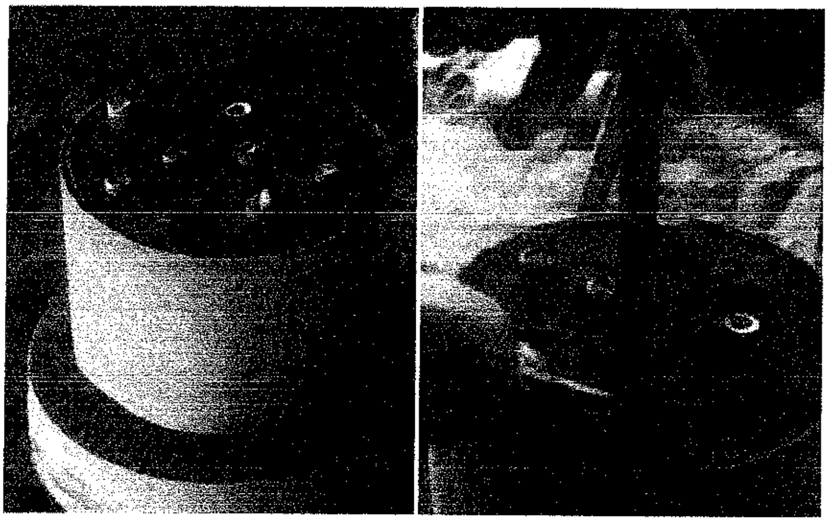

Fig 3.1: Final stage of mould preparation

3.2 CHARGE PREPARATION

The charges used for this experiment are copper and zinc. The copper was obtained from copper wire while the zinc was obtained from a zinc scrap.

3.2.1 CHARGE CALCULATION

The calculation used to define the various masses of the alloying elements that will give CUZN30 is given below:

Diameter of pattern, $D = 15$ mm $= 1.5$ cm

Length of pattern, $h = 500$ mm $= 50$ cm

Since the pattern is a cylindrical pattern

Volume of pattern, $V_P = (\pi/4)D^2h = (3.142/4)\ 1.5^2 \text{ X } 50 = 88.369 \text{ cm}^3$

Density of copper, $\rho_{Cu} = 8.96 \text{ g/cm}^3$

Density of zinc, $\rho_{Zn} = 7.13 \text{ g/cm}^3$

The percentage by mass calculation of each element is:

Copper, Cu = 70%

Zinc, Zn = 30%

Consider 100g of alloy

Mass of Cu in 100g of alloy = (70/100) x 100 = 70 g

Mass of Zn in 100g of alloy = (30/100) x 100 = 30 g

Volume of Cu in the alloy $= \frac{\text{mass of Cu}}{\text{Density of Cu}} = \frac{70}{8.96} = 7.8125 \text{ cm}^3$

Volume of Zn in the alloy $= \frac{\text{mass of Zn}}{\text{Density of Zn}} = \frac{30}{7.13} = 4.2076 \text{ cm}^3$

Total volume of the alloy$= 7.8125 \text{ cm}^3 + 4.2076 \text{ cm}^3$

$= 12.0201 \text{ cm}^3$

Density of alloy, $\rho = \frac{\text{mass of the alloy}}{\text{Volume of the alloy}} = \frac{100}{12.0201} = 8.3194 \text{ g/cm}^3$

The mass of alloy required to fill the mould cavity, m, is given by:

$m = V_P \times \rho = 88.369 \times 8.3194 = 735.175$ g

The mass of copper required = 735.175 x 0.7 = 514.6225 g

The mass of zinc required = 735.175 x 0.3 = 220.5525 g

To ensure the alloy prepared is sufficient, the required masses of copper and zinc are multiplied by 11

Mass of copper = 514.6225 x 11 = 5660.8475 g

Mass of zinc = 220.5525 x 11 = 2426.0775 g

Assuming 20% loss in the mass of zinc due to evaporation and slag, the mass that will be lost is:

$\frac{20}{100}$x 2426.0775 g = 485.2155 g

Mass of copper used = 5660.8475 g = 5.7 kg

Mass of zinc used = 2426.0775 g + 485.2155 g = 2911.293 g = 2.9 kg

3.3 CASTING OF THE ALLOY

3.3.1 MATERIALS REQUIRED

The materials used during the casting operation are:

- Charcoal fired furnace
- A pot with higher melting point than copper.
- Weighing scale
- Stirrer

- Tongs
- Iron brush

3.3.2 CASTING PROCEDURE

5.7 kg of copper wire and 2.9 kg of zinc scrap was measured out using the weighing scale as shown in figure 3.2.

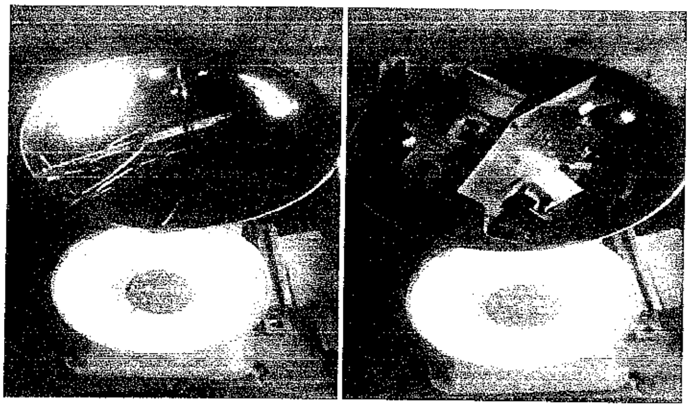

Fig. 3.2: Weighing copper and zinc

The furnace was lit and the pot was placed on it. The copper measured out was put in the pot and allowed to heat up. The copper was heated to its melting point. The process of melting is shown in Figure 3.3.

Fig 3.3: Melting process

During the process of melting the copper, the furnace is refilled with charcoal because of the high melting temperature of copper and the furnace was covered to reduce heat loss as shown in Figure 3.4.

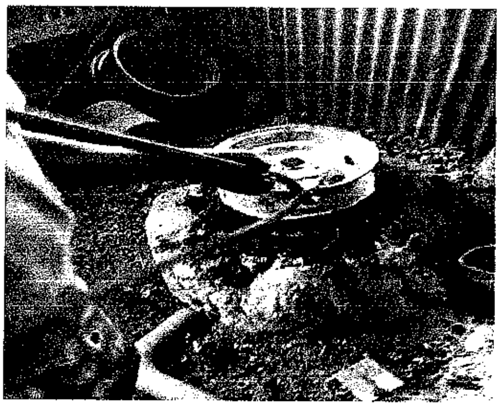

Fig 3.4: Refilling the furnace with charcoal

The measured zinc was put into the copper and stirred thoroughly. The zinc melted almost immediately it was put inside the molten copper because it has a melting point that is lower than that of copper. After the zinc scrap had melted in the molten copper, the floating slag was then taken. Slag removal from the melted alloy is shown in figure 3.5.

Fig. 3.5: Removing the slag

The tong was then used to carry the pot containing the molten copper-zinc alloy out of the furnace. Then the molten copper-zinc alloy was poured into the moulds and allowed to solidify. The mould was then broken up and the cast cartridge brass rod were removed and allowed to cool in dry air. Thereafter, the cast rods were cleaned using the wire brush. Each brass cast are then cut into two equal part of 15mm diameter and 250mm length.

3.4 HOMOGENIZING THE ALLOY (800°C)

After casting the sample, homogenization was performed to maintain a uniform microstructure all over the length of each sample. 17 samples of the cast cartridge brass were loaded in an electric resistance furnace and homogenized at a constant temperature of 800°C for an hour and then allowed to cool in the furnace. One sample was not put in the furnace. This is the sample from which the hardness of the alloy 'as cast' will be obtained. Homogenizing was done in the Heat treatment laboratory, Material and Metallurgy Engineering Department, Federal University of Technology Akure (FUTA), Ondo state.

3.5 COLD WORKING THE SAMPLES

In this stage, twenty samples are cold worked and hydraulic press was used to compress the samples. The compression was carried out in Machining workshop, Mechanical Engineering Department, Federal Polytechnic Ado-Ekiti, Ekiti state. 10 samples of 250 mm length were first cut into two equal length of 125mm to reduce buckling (due to the small diameter and long length) to get 20 samples to undergo a 2% plastic deformation. The samples to be cold-worked were carefully aligned in between the pressure blocks of the hydraulic press. A compressive load was then applied for the sample to be cold-worked by 2%, as the compressive load was applied, the alloy shrinked in length until it has attain a 2% plastic deformation. A vernier caliper was used to verify the deformation by taking the initial and final measurement of the length.

3.6 ANNEALING THE SAMPLES

Ten cold worked samples are annealed in an electric resistance furnace at two different temperatures; five samples at 250°C and Five samples at 650°C. For each temperature, annealing time for each of the sample was (6, 12, 30, 60, 120) minutes. In other words, at 250°C and at each annealing time, one sample is taken out of the furnace and the samples were cooled in the air. The same procedure was repeated at 650°C.

3.7 HARDNESS TEST

Test was carried out on the samples annealed at two temperatures (250°C and 650°C) and at the varied time. The samples annealed at varied time at 250°C and 650°C is used to study the effect of annealing at varying time and lower and higher annealing temperature on the hardness of the cartridge brass. This test was also conducted for; as cast, as homogenized, and as cold worked without annealing.

On each hardness test sample, hardness value is taken on three different point and the average is taken as the hardness of the sample. The hardness test was done on the following samples;

- As cast
- As homogenized
- As cold worked without annealing
- Annealed 6 minutes at 250°C
- Annealed 12 minutes at 250°C

- Annealed 30 minutes at 250°C
- Annealed 60 minutes at 250°C
- Annealed 120 minutes at 250°C
- Annealed 6 minutes at 650°C
- Annealed 12 minutes at 650°C
- Annealed 30 minutes at 650°C
- Annealed 60 minutes at 650°C
- Annealed 120 minutes at 650°C

The hardness test was conducted using a digital brinnell hardness testing machine at the Heat treatment laboratory, Material and Metallurgy Engineering Department, Federal University of Technology Akure (FUTA), Ondo state

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 HARDNESS TEST

The result of the hardness tests conducted for each samples are presented in Tables 4.1, 4.2 and 4.3;

From Table 4.1, it can be seen that the hardness of the homogenized sample is higher than as the cast sample. This is due to the fact that coring has been eliminated and the homogenized sample has an unsegregated microstructure according to Omotoyinbo and Aribo, (2009). Also, the hardness of the 2% cold-worked sample that was not annealed is higher compared to homogenized sample, this is due to the fact that cold working causes increase in hardness of the brass but leaves internal stresses (Singh, 2006).

Table 4.1: Hardness result for; as cast, homogenized, and 2% cold worked sample without annealing

HARDNESS	1ST READING (HB)	2ND READING (HB)	3RD READING (HB)	AVERAGE VALUE (HB)
AS CAST	73.80	76.30	74.50	71.30
HOMOGENIZED	73.50	72.30	70.40	72.07
2% COLD-WORKED WITHOUT ANNEALING	74.50	68.70	74.20	72.47

Figure 4.1 shows the graphical representation of Table 4.2 hardness value against annealing time at 250°C, it is noted that the hardness of the samples increases up to 30mins annealing time, and then drastically reduce at higher annealing time.

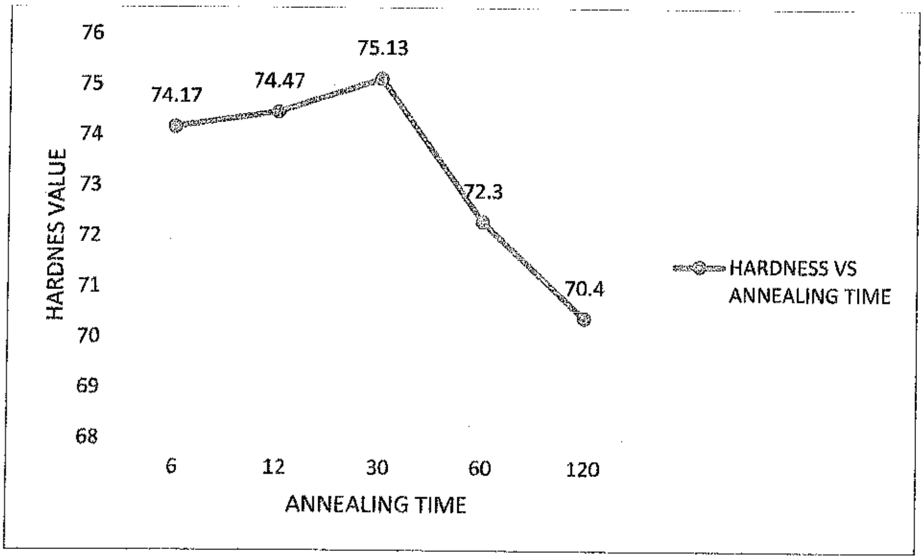

Figure 4.1: Hardness value VS Annealing time @ 250°C

Table 4.2: Hardness value at 250°C.

HARDNESS	1ST READING (HB)	2ND READING (HB)	3RD READING (HB)	AVERAGE VALUE (HB)
6mins	75.00	73.30	74.20	74.17
12mins	73.40	75.40	74.60	74.47
30mins	76.30	74.80	74.30	75.13
60mins	73.40	73.00	70.50	72.30
120mins	71.60	71.00	68.60	70.40

Figure 4.2 shows the graphical representation of Table 4.3 hardness value against annealing time at 650°C, it is also noted that hardness of the samples increases up to 30mins annealing time, and then little reduction at higher annealing time. This practical implication of this is that, hardness of CuZn30 starts decreasing after 30mins annealing time.

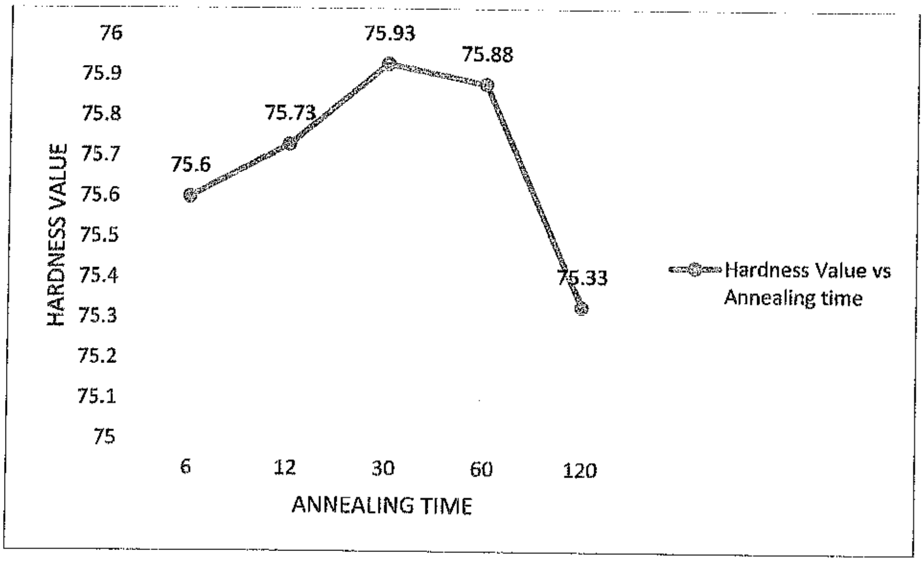

Fig. 4.2: Hardness value VS Annealing temperature @ 650°C

Table 4.3: Hardness value for 650°C and corresponding annealing time.

HARDNESS	1ST READING (HB)	2ND READING (HB)	3RD READING (HB)	AVERAGE VALUE (HB)
6mins	75.50	76.00	75.30	75.60
12mins	75.80	75.90	75.50	75.73
30mins	75.80	75.90	76.10	75.93
60mins	75.80	76.50	75.10	75.88
120mins	73.70	76.00	76.30	75.33

Comparing the hardness value of 250°C and 1 and 2 hours from Table 4.2 with hardness values of in Table 4.1, it is noted that the hardness value due to cold working is reduced significantly by annealing and it takes less time for hardness to reduce.

Comparing Table 4.2 and Table 4.3, it can be seen that at 250°C within the range of 6mins and 120mins, hardness value decreases by 3.77, while at 650°C, within the same annealing time range, hardness value decreased by 0.27. The hardness value of the samples annealed at 650°C does not show a significant reduction over 120 minutes annealing time.

Therefore, the suitable hardness value for the various application of cartridge brass can be modified by the annealing temperature and annealing time.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The annealing temperature and annealing time is also considered to be utmost factor that determines the application of the cartridge brass.

From this investigation, we can conclude that;

- Cold working changes the structure and properties of cartridge brass.
- Hardness of CuZn30 starts reducing after 30mins annealing time.

5.2 LIMITATIONS AND RECOMMENDATIONS

5.2.1 LIMITATIONS

The University foundry section is non-functional. The casting was done in Jamah Technical Works, foundry section, Idi-Ape, Ibadan, which resulted in higher cost of casting workmanship and transportation. Also, the University does not have a heat treatment laboratory. The heat treatment was performed in Heat Treatment Laboratory, Materials and Metallurgy department, Federal University of Technology, Akure (FUTA), which resulted in higher cost of heat treating and transportation. Likewise, the University Machine workshop is non-functional due to lack of tools and consumables, also the Universal Testing Machine (UTM) is not available when it was needed. I was told it has broken down. The cold-working was done in Machining workshop, Mechanical Engineering Department, Federal Polytechnic Ado Ekiti, which also resulted in higher cost of cold working due to the fact that I am an external student.

5.2.2 RECOMMENDATIONS

- The University foundry section is a means of generating internal revenue for the institution. It should start functioning and it should be properly maintained so that students and researchers can utilize this facility for conducting researches effectively and efficiently.
- The University should provide a heat treatment laboratory equipped with sufficient furnaces so that the researchers can make use of the equipment. By doing this, internal revenue will be generated for the institution.
- The machining workshop should be provided with tools and consumables in order for the machines to be functional. These machines helps to train students, as most students only know the theoretical operation of these machines. The Universal testing Machine together with other machines and equipment should be properly maintained. It also provide ease of carrying out research or investigation to students. It is a means of generating internal revenue.

5.2.3 RECOMMENDATION FOR FURTHER WORK

As an extension of this work, further study should focus on;

- Studying the effect of cold-work by varying the degree of cold-work by using flat rectangular bars.
- Other test like; Tensile test, Impact test.
- Examination of the microstructure of the alloy.

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