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Investigation on The Effect of Addition of Magnessium on The Microstructure and Mechanical Properties of Aluminum Bronze

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ABSTRACT: *This research work covers the investigation on the effect of addition of magnesium on the microstructure and mechanical properties of Aluminum Bronze. The first approach to this research was casting a specimen with a crucible furnace. Metals were charged into the furnace according to their melting points. Magnesium was introduced into the cast in different proportions from 1-4 wt% also a cast with 0wt% of magnesium. After the alloying process, the specimens were sectioned, grinded, polished and etched before viewing under an optical metallographic microscope. Mechanical tests were carried out on the specimens such as hardness and tensile strength which shows level of hardness, yield strength and ductility of each specimen.At the end of the experiments, it was concluded that the addition of magnesium to aluminum bronze increases both hardness and yield strength of aluminum bronze and reduces its ductility.*

KEYWORDS: *Microstructure, Magnesium, Aluminum Bronze, Hardness, Yield Strength, ductility,Specimen, Microscope.*

I. INTRODUCTION

An alloy is a substance obtained by melting together two or more components. It is also possible to produce alloys by other method such as sintering, electrolysis but the most common process is that by melting together various pure elements. Alloy made predominantly of metallic properties are metallic alloys.The general procedure in making an alloy is first to melt the metal having the higher melting point then to dissolve in it the one with lower melting point and stirring the mixture so that homogenous liquid solution is formed. When this liquid solidifies the type of structure which is produced depends largely on the relative physical and chemical properties of the two metals.Pure metals are rarely used for engineering purpose except where high electrical conductivity or good corrosion resistance are required. These properties are generally of a maximum value in pure metals but such mechanical properties like tensile strength, yield strength and hardness are improved by alloying [1].

Aluminum bronze is a type of bronze in which aluminum is the main alloying metal added to copper. A variety of aluminum bronze of different composition have found industrial use, with most ranging from 5% to 11% aluminum by weight, the remaining mass copper, other alloying element such as iron nickel, manganese and silicon are also sometime added to aluminum bronze [5]. The presence of aluminum increase the mechanical properties of the alloy by the establishment of a face-centre-cubic (F.C.C) phase which could improve the casting and hot working properties of the alloy [5].Other alloying elements improve the mechanical properties and modify the microstructure. Nickel and manganese improves the corrosion resistance, whereas iron (Fe) is a grain refiner [10]. Mechanical properties of bronze alloy are depending on their chemical composition, microstructure, and production condition and can be improved significantly by heat treatment. Aluminum bronze is the most tarnish-resistant copper alloy and shows no serious deterioration in appearance and no significance loss of mechanical properties on expose to most atmospheric condition their resistance to atmospheric corrosion combined with high strength is exploited, for example in their use for bearing bushes in aircraft frames. Aluminum bronze also shows low rate of oxidation at high temperature and excellent resistance to sulphuric acid, sulphur oxide and other combustion product and are therefore used for the construction of items exposed to either both of these conditions.

Magnesium has distinction of being the height-test engineering metal with a specific gravity of 1.738. it also has one of the highest coefficient of thermal expansion, 25×10^{-6}. The melting point is 650^0C. It has a white appearance [6].More than half of magnesium produced in this country is used in powder and ingot form for alloying with aluminum. About 30% is used for chemical processes and other nonstructural applications [11].Magnesium has great effect on the mechanical properties when used as alloying element with other group of metal of the same properties. Magnesium does show an advantage over other metal system in weight reduction when section size is limited magnesium enhance high strength, but the high-strength properties cannot be put to use on long slender parts. Minimum sections are required to prevent buckling. The addition of small amount (1.0 to 5.0)% of the magnesium into aluminum bronze alloy will have effect on its mechanical properties and its wear resistance which may lead to wider horizon of application.

The development of materials that will perform optimally during service with extended service life as compared to our contemporary ones, a complete understanding of aluminum bronze micro alloyed with magnesium is still lacking and is thus the topic of a great deal of current research.

II. REVIEW OF LITERATURES

2.1 **Mechanical Properties and Microstructure of Locally Produced Aluminum –Bronze Alloy**

According to [1], the work studied the feasibility of producing a dual-phase aluminum bronze alloy and the use of selected treatments to manipulate the mechanical properties of the produced alloy using local techniques, as a potential replacement for conventional structural materials, particularly steels. Sand casting was used and was found to be effective based on its advantage of low cost, ease of use and flexibility in the production of a dual-phase aluminum bronze alloy with pre-selected composition of 11% Al content. Cold deformation of 10 and 20% degrees and selected heat treatments were used on the cast alloy to influence its mechanical properties. The selected heat treatments are solution heat treatment, normalizing, and ageing. The results showed that normalizing gave the optimum mix of tested mechanical proper- ties with ultimate tensile strength in the range of 325 MPa, elongation of around 60% and Rockwell hardness values of 46.5 - 63.7 HRc, making this alloy suitable as alternatives to steel in low/medium strength structural applications.
Summary result of the mechanical properties of the developed aluminium bronze alloy:

Treatments	**Proof stress(0.5%e, MPa)**		**UTS (MPa)**		**Hardness (HRc)**		**Elongation(%)**	
	10%	**20%**	**10%**	**20%**	**10%**	**20%**	**10%**	**20%**
C 169		**230.4**	**38.4**		**11.2**			
SHT	**125**	**185**	**267.2**	**321.8**	**49.8**	**51.3**	**53.4**	**58.7**
N 165	**175**	**327.9**	**322.4**	**63.7**	**46.5**	**60.9**	**60.7**	
AG1	**85**	**102**	**320.0**	**301.0**	**45.4**	**44.0**	**76.3**	**38.4**
AG2	**148**	**173**	**266.3**	**329.6**	**39.9**	**53.4**	**43.5**	**68.8**

Key: C = as cast Al-Bronze sample with 0% deformation and no treatment, SHT = Solution Heat Treated samples (heated to 900°C followed by quenching in chilled water), N = Samples normalised at 250°C for 20 minutes after SHT, AG1 = Samples aged at 160°C for 6 hours after SHT, AG2 = Samples aged at 180°C for 6 hours after SHT

2.2 A Study on the Annealing Process of Aluminum Bronze Alloy Based on their Microstructures Growth and their Mechanical Properties.

According to [3], this work is concerned with the investigation on the annealing process of aluminum bronze alloy based on microstructure growth and mechanical properties, This is to identify the effect of annealing process on the hardness,tensile strength and microstructure of the alloy. The annealing of samples was carried out at different temperature,such as 100,200,300,400,500,600 and 700 degree Celsius. Different heat treatments were carried out on the samples with variety of time .The time range for each of the samples was 5,10,30,90 and 120minutes respectively. Findings showed that tensile and hardness values were reducing with increase in annealing period while percentage of ductility was proportional with increase of annealing temperature.

2.3 The Crystallization of Aluminum Bronze with Additons 0f Si,Cr, Mo and W.

According to [8], additions of Cr,W,Mo and Si to aluminum bronze to create complex slides of iron about high mechanical and physical properties of the bronze. The process of formation in the microstructure of bronze with the use of the method of thermal and derivative analysis(TDA)was analyzed. The examination under the microscope and X-ray microanalysis of the surface of distribution of element were conducted.

Research result obtained from aluminum bronze after the addition of Si,Cr,Mo and W the phase κFe,κNi crystallize as the complex silicide on the iron. Element such as Fe and Si dissolve first of all in silicide in the smaller stage in the matrix of the bronze, Mn and Ni they dissolved in matrix and silicide, Cr dissolves in the larger stage in the silicide than in matrix, W and Mo dissolves in silicide however they crystallize as Nano-crystals in the metal matrix [2].

2.4 The Influence of Wall Thickness on the Microstructure of Aluminum Bronze with the Additions of Si, Cr, Mo and W.

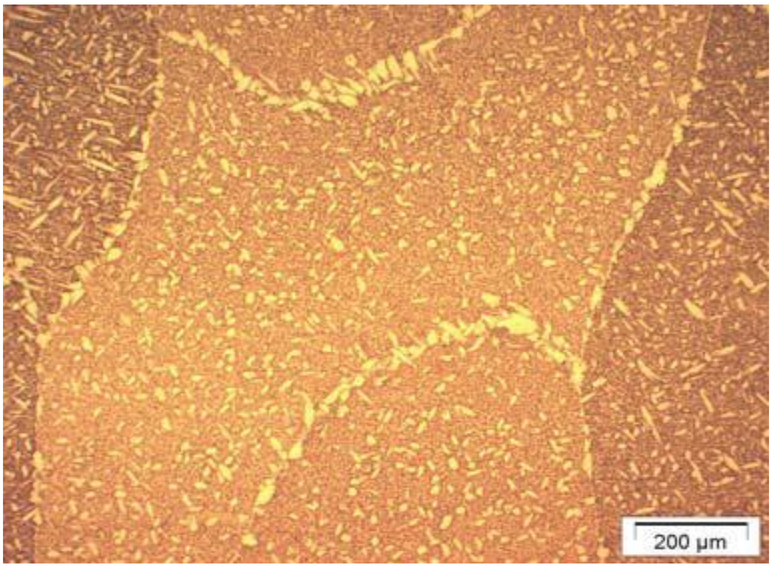
According to [9], the investigations of the influence of the wall thickness of the cast on size of crystallites of aluminum bronze were conducted: the primary β phase and intermetallic phase κ and the width separates the secondary α phase precipitate at phase boundary. The results from the investigations, that is in the aluminum bronze BA1055 after simultaneous additions of Si, Cr, Mo and in the primary β phase undergoes considerable reduction in size. The addition Mo does not influence the change of the size of the grain of the β phase significantly. The addition of singly or simultaneously of the Cr, Mo and W to the bronze CuAl10Fe5Ni5Si influences the decrease of the quantity of the α phase on the interface boundary and of width separated independently from the thickness of the wall of the cast. The simultaneous addition of the Si, Cr, Mo and W enlarges the surface of the phase κFe, κMo. The addition to the bronze CuAl10Fe5Ni5Si of the Cr, Mo or W to the quantity of crystallizing hard phase κ enlarges and the hardness HB of the bronze increases

2.5 Metallography of Aluminium Bronze Alloy as Cast in Permanent Iron Die.

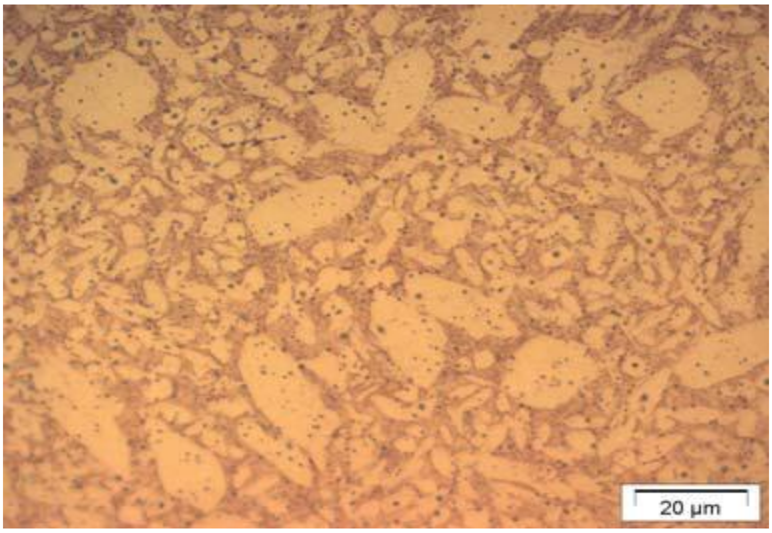
According to [5], the phases obtained in copper aluminum bronze alloy (Cu-Al10-Fe2) cast into a permanent die were investigated. The parameters examined were the pre-heating temperatures of the die and the graphite coating thickness. The phases α and γ2 were detected as well as the metastable phases β' and γ'. The intermetallic of the system Fe-Al was obtained in various stoichiometric compositions. The different cooling rates of the casting resulted in two mechanisms of transformation to α grains out of the unstable β phase, one being nucleation and growth producing needle shaped α grains, the other exhibiting a massive transformation to spherical α grains. These two mechanisms determine the changes in the size of the α grains as a result of changes in the cooling rate in its various ranges.

2.6 Summary of Results Obtained from the Experiment Carried Out:

The rates of solidification and cooling of the casting in the permanent die are influenced by the temperature of the die and the thickness of the graphite coating on the die walls. It was found that these parameters also affect the microstructure of the casting made of Cu-Al10-Fe2 in the as-cast state. In the course of the experiment the casting was allowed to cool in the die for 2 min. and is then exposed to air cooling.



Aluminum bronze, water cooled from the liquid state. Nucleation of α phase(white) at the grain boundaries; at the grain centre β-phase (x 450).



Highest cooling rate, spherical α, die pre-heated to 280ºC. Graphite coating thickness is 0.01 mm (x 360).

It was concluded that: At high or low cooling rates, the phaseα precipitates by a process of nucleation and growth to needle-like grains. At median cooling rates phase α is obtained by a process of massive transformation, the grains being spherical in shape and of large sizes. The size increases with rising cooling rates. Segregation of the γ' phase impedes the massive transformation, so that the nucleation and growth mechanism prevails in the creation of the α phase, although in the absence of the γ' phase, massive transformation would occur. Coating the die with a thick layer of graphite increases the cooling rate and leads to a needle-like structure that emphasized the grain boundaries of the β phase. In these conditions there is not massive transformation.

2.7 Mechanical Properties and Microstructure of Aluminum Alloy 2618 with Al3(Sc, Zr) Phases

According to [11], the tensile properties of a 2618 (Al–Cu–Mg–Fe–Ni) alloy containing scandium and zirconium were measured at 293, 473, 523 and 573K to study the temperature influences on the experimental alloys. The microstructure was observed by using optical microscopy, scanning electron microscopy (SEM) and transmission electron microscopy (TEM). It was found that the addition of scandium and zirconium to 2618 alloy resulted in a primary Al3(Sc, Zr) phase. Such phase could refine the alloy grains because it acted as a core of heterogeneous crystallization during solidification. The secondary Al3(Sc, Zr) particles that precipitated from the _(Al) solid solution were fully coherent with the matrix and had an obvious precipitation hardening effect. They also made the S_ phase precipitate more homogeneously. The strengths of the 2618 alloy with Al3(Sc, Zr) phases increased at both ambient and elevated temperatures, without a decrease of ductility.The tensile properties of Alloy A at 293, 473, 523 and 573K were compared with the values of Alloy B. It should be noted that the ambient and elevated temperature strengths of Alloy A were obviously greater than those of Alloy B. The yield strength and ultimate strength of Alloy A increases by about 80MPa at ambient temperature and 40MPa at 573K with almost no ductility change.

2.8Effect of Minor Sc and Zr on Microstructures and Mechanical Properties of Al-Zn-Mg Based Alloys.

According to [4], two kinds of Al2Zn2Mg based alloys with and without Sc ,Zr addition were prepared by ingot metallurgy. The tensile mechanical properties and microstructures of the studied alloys at different treatment conditions were studied. The results showed that addition of minor Sc and Zr can remarkably improve the strength of Al-Zn-Mg based alloys, but the alloys were melted in the crucible furnace and then poured into an iron mold for casting. After homogenization at 460 ℃for 12 hrs, the ingots were hot-rolled and then cold-rolled to 2 mm-thick plates. Tensile samples were taken along the rolling direction of the plates. After 465 ℃/ 30 min solution treatment, water quenching and 120 ℃/ 24 h aging , samples were tested on Instron28032 tensile testing machine and the tensile ratio is 2 mm/min, ductility remains on a higher level. Metallography samples for observing grain structure were examined on MET22 after electrolytic polishing and anodizing membrane with water solution of HF and H3BO3 . Metallography samples for observing crystal nucleus were etched using mixed acid. It concluded that simultaneous adding of minor Sc and Zr to Al-Zn-Mg alloys can obviously increase the strength of alloys , but the ductility can remain on a higher level. Strengthening caused by adding of minor Sc and Zr mainly comes from fine-grain strengthening, Al3 (Sc , Zr) particle precipitation strengthening and substructure strengthening caused by rest raining recrystallization**.**

III. MATERIALS AND RESEARCH METHODS

Series of experiments were carried out to investigate the effect of addition of magnesium on the microstructure and mechanical properties of aluminum bronze alloy. Universal Tensile Testing Machine and Brinell Harness Testing Machine were used for the experiments as against Tensometer Machine and Rockwell Hardness Testing Machine used by [1] in their experiments. The effect magnesium on aluminum bronze was in investigated by using sand casting method in preparation the specimen as against die casting coated with graphite used by Cenoz.

3.1 Methodology

Sand casting method was used to prepare the specimen. Wooden pattern in the shape of the specimen was produced. The mould cavity was created within the drag and cope assembly using an incorporated gating system.According to [7], dry sand mould are actually made with moulding sand in green condition and then the entire mould is dried in oven or dried naturally before the molten metal is poured into them. Aluminum bronze micro alloyed with magnesium, having aluminum composition of 10% and zinc of 2%, with addition of magnesium from 1 to 4% was melted in the furnace and cast into the mould cavity. The copper was obtained from copper windings and purchased from the market and magnesium obtained from magnesium ribbon was purchased from chemical laboratory, while aluminum and zinc were sourced from foundry department of Federal Institute Of Industrial Research, Oshodi(FIIRO) Lagos. After the preparation and selection of specimens in different ratio compositions, The crucible furnace (fig.2) was fired-up, ready for the charging of materials for melting.

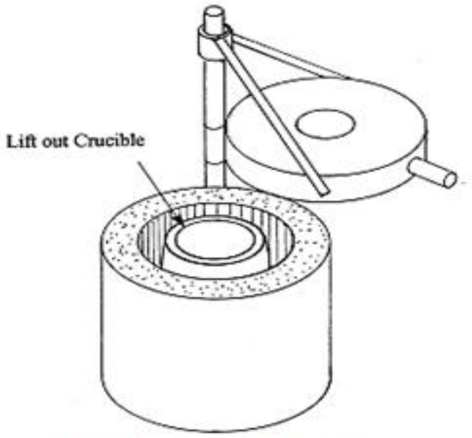


Figure 2: *Crucible Furnace*

Figure 3: *Melting Crucible*

(Federal Institute of Industrial Research, Oshodi, Lagos)

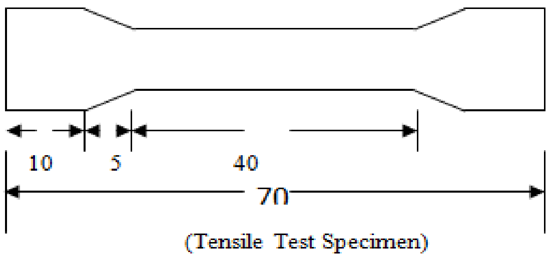
Copper has the highest melting point among the metals with a melting point of 1083^{0}C, followed by magnesium, aluminum and zinc with melting point of 670^{0}C, 659^{0}C and 419^{0}C respectively. The temperature of the molten metal was measured by the use of a Furnace thermocouple, The thermocouple was inserted through the hole in the lid of furnace and into the molten metal in the crucible to sense its temperature.

Figure 4: Furnace Thermocouple (FIIRO,Oshodi).

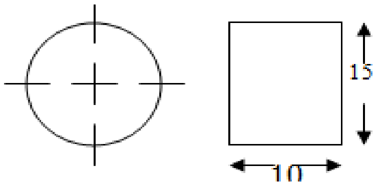
Copper was first charged into the melting furnace, after it had reached a fluidity level the rest of the materials were introduced with respect to their melting points. The table below shows the percentage weight composition of each specimen. Total weight composition of each specimen is 500g.

3.2 TEST SPECIMEN

Aluminum bronze alloy without magnesium as samples was selected aside, while others with various percentage of magnesium selected and machined into standard specimen. Dimension of sketch specimen in (mm).



(Tensile Test Specimen)



(Hardness Test Specimen)

3.3 Metallography

Preparation of material samples was done by polishing and etching, so that the structure can be examined using optical metallurgical microscope. The artistry lies in the technique used in preparing specimen sectioning, mounting, grinding, polishing and etching and to photograph a specimen. The specimen was grinded by the use of series of emery papers and polished using fine polishing cloth. A chemical solution composed of 10cm^3 of ferric chloride ($FeCl3$), 25cm^3 of hydrogen chloride (HCl) and 75 cm^3 of ethanol ($CH3\text{-}CH2\text{-}OH$) was used as etching agent before mounting on the microscope (fig. 1) for microstructural examination of the specimen.

Figure 1: Optical Metallurgical Microscope used for the experiments
(Federal University of Technology, Akure)

3.4 Mechanical Test

The mechanical properties of aluminum bronze micro alloyed without magnesium was firstly determined to serve as reference, while the mechanical properties of alloying with magnesium was determined after. The tensile property was determined by the Universal Tensile Testing Machine, while the Hardness Property was determined by Brinell Hardness Testing Machine.

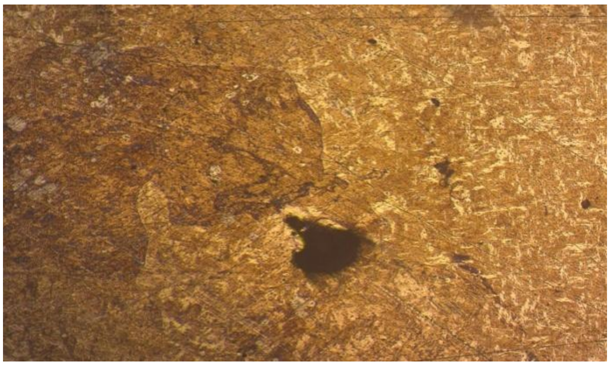
3.5 Table 1: Weight and percentage composition ratio of specimen

SPECIMEN	COPPER	MAGNESIUM	ALUMINUM	ZINC
1	88% (440g)	0% (0g)	10% (50g)	2% (10g)
2	87% (435g)	1% (5g)	10% (50g)	2% (10g)
3	86% (430g)	2% (10g)	10% (50g)	2% (10g)
4	85% (425g)	3% (15g)	10% (50g)	2% (10g)
5	84% (420g)	4% (20g)	10% (50g)	2% (10g)

To avoid evaporation of material, the temperature of the furnace was adjusted to allow materials with lesser melting point to melt without evaporating. Materials such as: Magnesium, Aluminum and Zinc were introduced in lumps and stirred with a rod before being poured into the prepared mould. These procedures were repeated for all cast specimens, after solidification, the specimen was prepared for viewing under microscope and testing of mechanical properties.

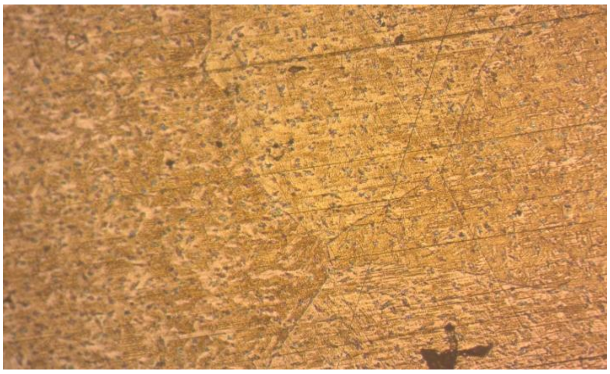
IV. RESULT AND DISCUSSION

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 these parameters also affected the microstructure of the cast made of Cu, Al, Zn, mg. In the experiment some cast were allowed to cool in the mould while some, subjected to quenching and expose to air. From cu-Al alloy phase equilibrium with 10wt% of Al, a solid phase was formed first and at about 930^0C the α-phase begins to precipitate from solid β-phase. The growth of the α-phase depends on the rate of the heat extraction in the solid state (Fig 5). Inability of grain growth was attributed to the low temperature of the mould at room temperature (Fig 6). The grains of aluminum, magnesium and zinc have fully developed into α-phase (Fig 7).



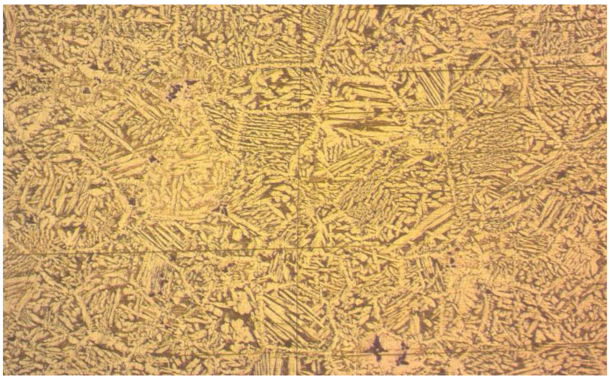
0% of mg, as cast

Figure 5: *Needle-shaped (white) α grains growth as a result of temperature drop in the mould.(x100)*



1% of mg, as cast

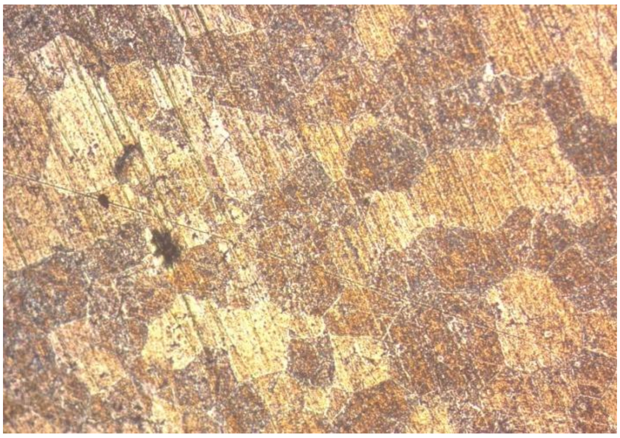
Figure 6: *Inability of grain growth as a result of cooling from the mould.(x100)*



2% of mg,quenched@550^oC

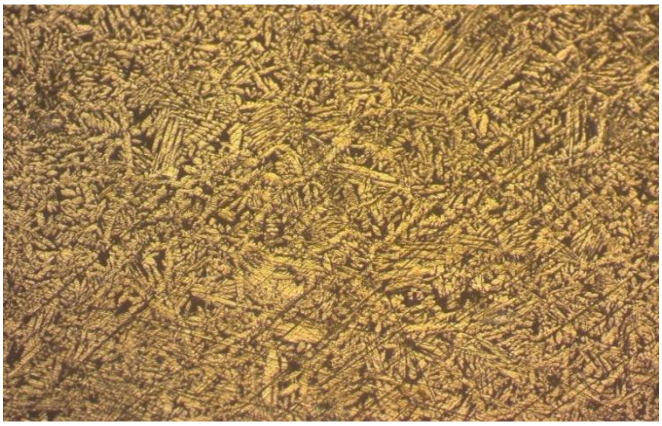
Figure 7: *The development of needle-shape grains (α-phase) and the β-phase at the Centre due to rapid solidification (x50).*

Emphasized grain arrangement and β-phase demonstrated due to rapid cooling (Fig 8). The grain of both Cu, Al, Mg and Zn as being fully developed to α - phase as a result of slow solidification (Fig 9).



3% of mg,quenched@450^0C

Figure 8: *Development of hexagonal shape grains from needle-like shapes in fig 8. as a result of quenching (x100)*

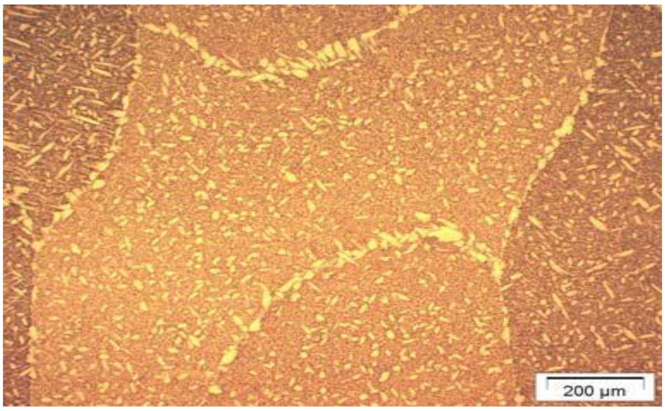


4% of mg

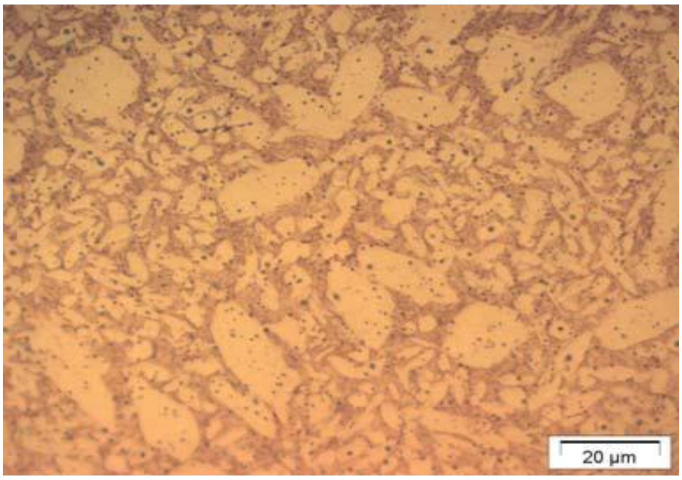
Figure 9: *There was grain growth into needle-shape grains (α-phase) from hexagonal shape in fig. 8 as a result of slow solidification.Cooled in air at 300^oC(x100).*

4.1 Comparison between Micrograph of Test Specimens and that of Cenoz

Comparing results with micrographs obtained by [4], the grain size and orientation obtained from an aluminum bronze, water cooled from a liquid state in a die coated with graphite is smaller in size compared to micrograph of cast in a sand mould. This shows that there was harder aluminum bronze obtained in fig.7 in a die pre-heated to 280^0c coated with graphite of 0.01mm thickness.Spherical grains were obtained compared to fig.8 where hexagonal shape grains were obtained.



Aluminium bronze, water cooled from the liquid state. Nucleation of α phase(white) at the grain boundaries; at the grain centre β-phase (x 450).compared with fig.7



Highest cooling rate, spherical grain, dies pre-heated to 280ºC. Graphite coating thickness 0.01 mm (x 360). Compared with fig.8

4.2 Table2: Hardness Variation of Aluminum Bronze with Different Percentages of Magnesium.

S/N	Wt% of Mg inclusion in specimen	Diameter of Indentation (mm)	Hardness Brinell Number (HBW)
1	0	2.5	9.98
2	1	3.0	14.47
3	2	3.8	23.56
4	3	4.0	26.23
5	4	4.2	34.40

The brinell hardness test method consists of indenting the test specimen with a 10mm diameter carbide ball (Tungsten (W)) subjected to a load of 500kg force, considering aluminum bronze as a soft material. Materials like: steel can be subjected to 3000kg force.

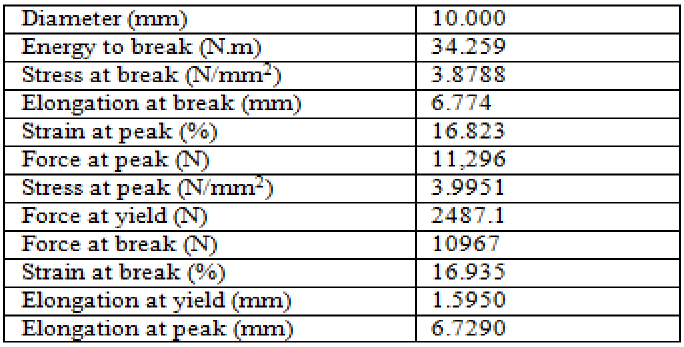
The load time (10 – 15 sec) period is required to ensure that plastic flow of metal has ceased, after removal of the load, the resultant recovered round impression was measured across the diagonal at right angles and was recorded in mm using a low power microscope or an accurate measuring device (http://en.m.wikipedia.org/wiki/brinell-scale).

4.3 Tensile Test of Aluminum Bronze with Different Percentages of Magnesium

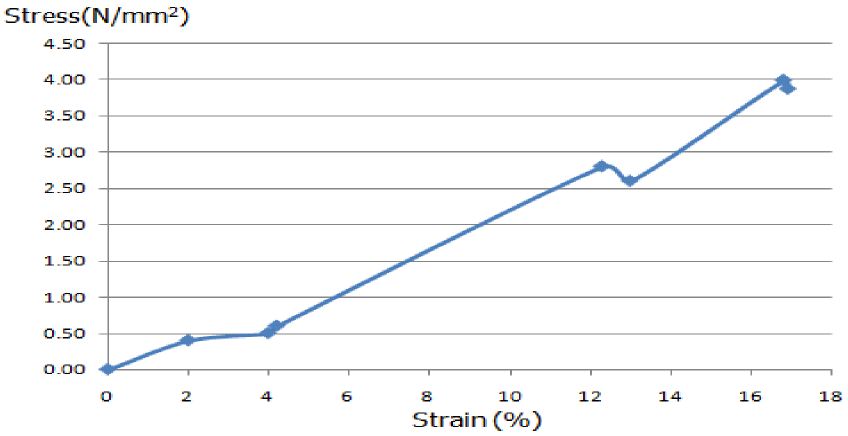
The specimens were machined to the required shape so as to enable firm grip of the specimen by the lower and the upper jaw of the tensile testing machine. The machine was incorporated with a computer system which shows different properties of the specimen such as: Elongation percentage, Stress, Strain, 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.

4.4 Table and graph of each specimen are detailed below:

Specimen 1 = 0% of mg

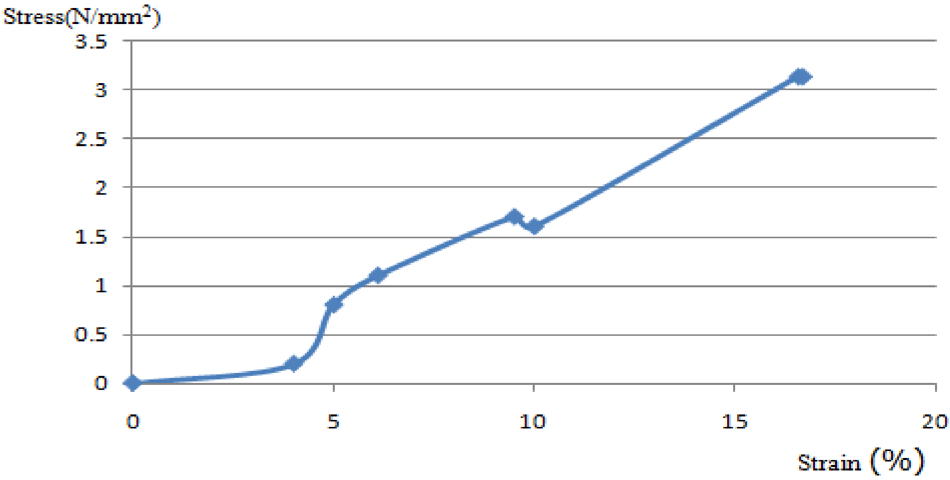


Diameter (mm)	10.000
Energy to break (N.m)	34.259
Stress at break (N/mm^2)	3.8788
Elongation at break (mm)	6.774
Strain at peak (%)	16.823
Force at peak (N)	11,296
Stress at peak (N/mm^2)	3.9951
Force at yield (N)	2487.1
Force at break (N)	10967
Strain at break (%)	16.935
Elongation at yield (mm)	1.5950
Elongation at peak (mm)	6.7290



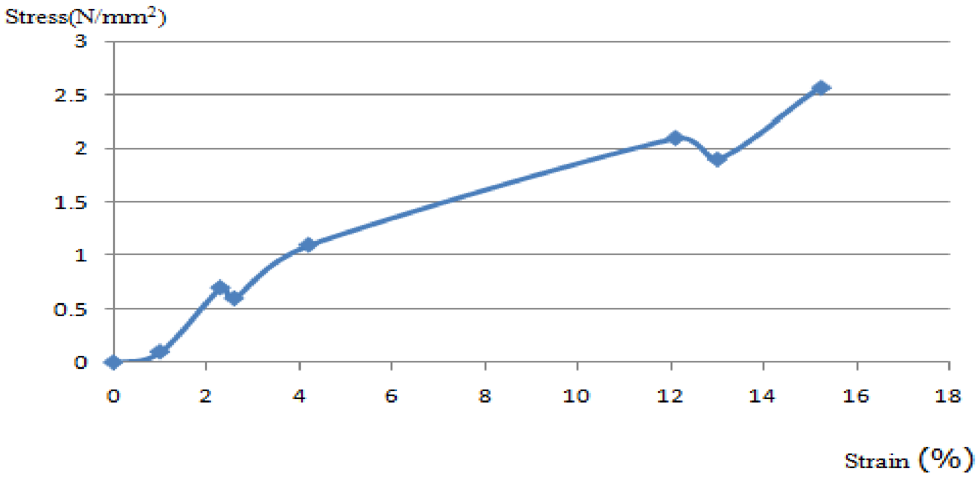
Specimen 2 = 1% of mg

Diameter (mm)	10.000
Energy to break (N.m)	26.633
Stress at break (N/mm^2)	3.1375
Elongation at break (mm)	6.6740
Strain at peak (%)	16.570
Force at peak (N)	8877.0
Stress at peak (N/mm^2)	3.1396
Force at yield (N)	2981.0
Force at break (N)	8871.0
Strain at break (%)	16.685
Elongation at yield (mm)	2.4860
Elongation at peak (mm)	6.6280



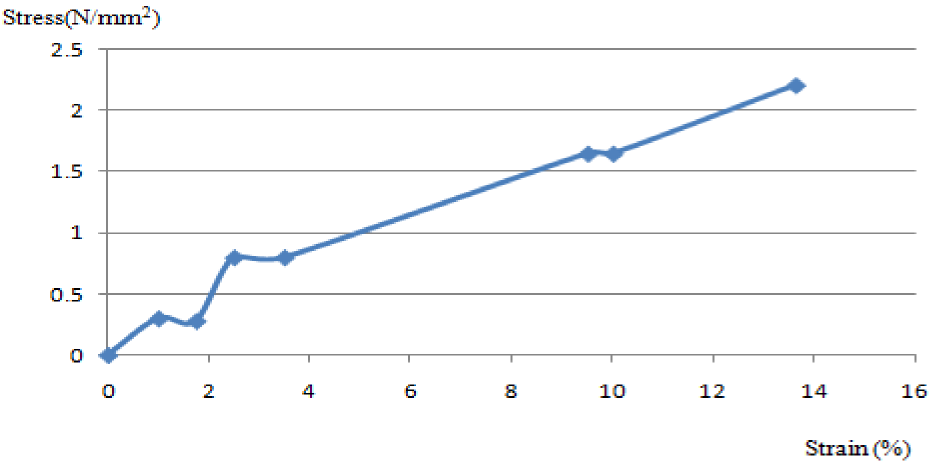
Specimen 3 = 2% of mg

Diameter (mm)	10.000
Energy to break (N.m)	23.067
Stress at break (N/mm^2)	2.5072
Elongation at break (mm)	6.0990
Strain at peak (%)	15.247
Force at peak (N)	7089.0
Stress at peak (N/mm^2)	2.5072
Force at yield (N)	2971.0
Force at break (N)	7089.0
Strain at break (%)	15.247
Elongation at yield (mm)	1.7670
Elongation at peak (mm)	6.0990



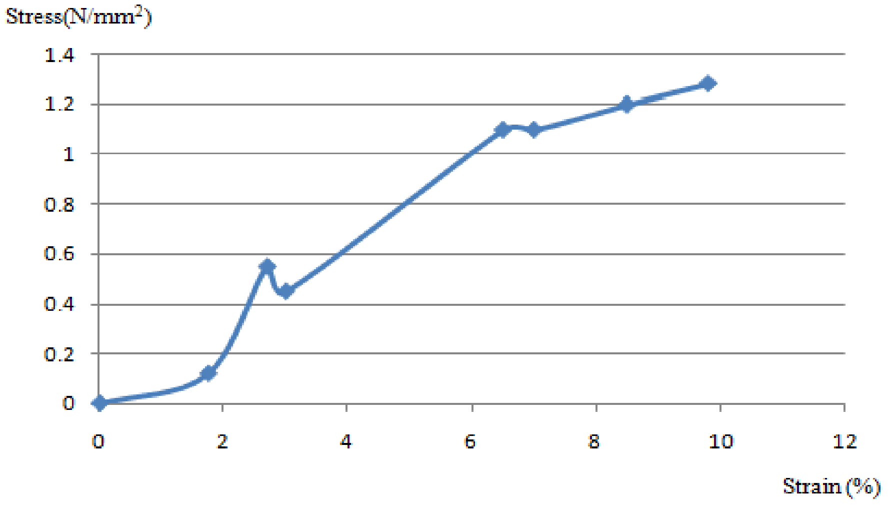
Specimen 4 = 3% of mg

Diameter (mm)	10.000
Energy to break (N.m)	16.233
Stress at break (N/mm^2)	2.2123
Elongation at break (mm)	5.4490
Strain at peak (%)	13.622
Force at peak (N)	6255
Stress at peak (N/mm^2)	2.2123
Force at yield (N)	2349.6
Force at break (N)	6255
Strain at break (%)	13.622
Elongation at yield (mm)	1.7820
Elongation at peak (mm)	5.4490

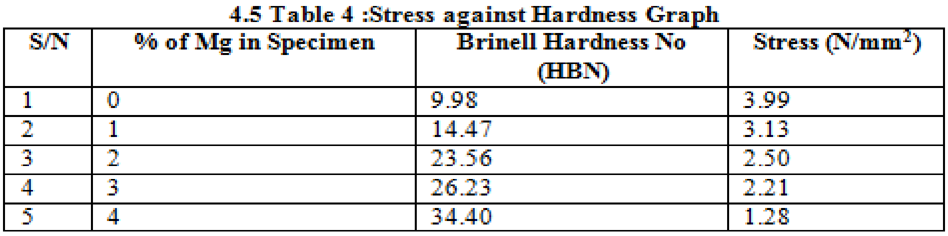


SPECIMEN 5 = 4% of mg

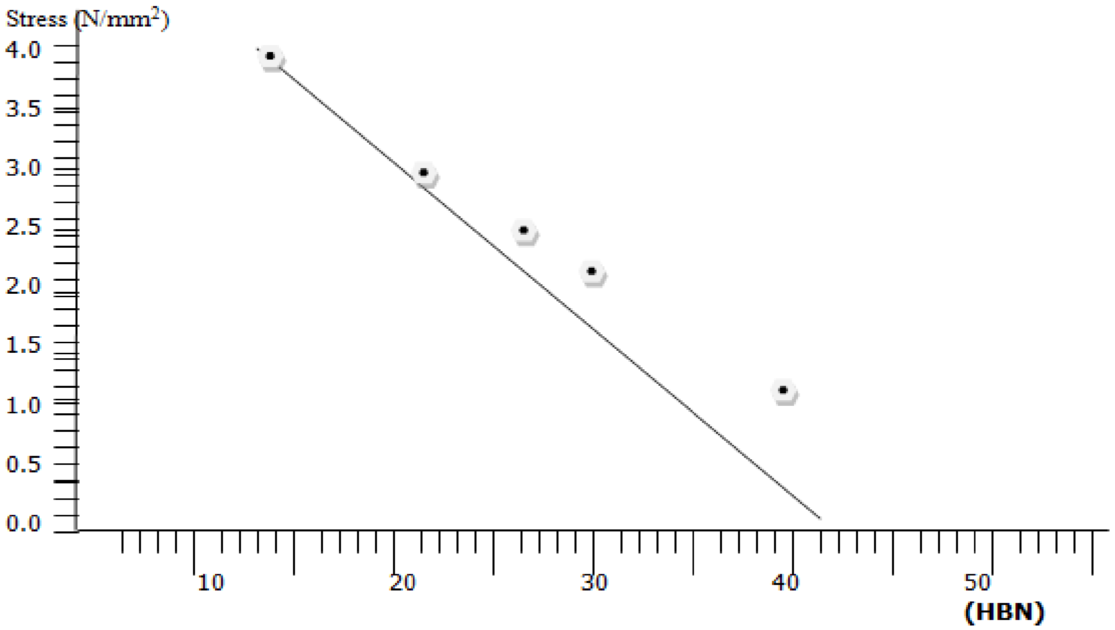
Diameter (mm)	10.000
Energy to break (N.m)	7.5944
Stress at break (N/mm^2)	1.2846
Elongation at break (mm)	3.9270
Strain at peak (%)	9.8175
Force at peak (N)	3632.0
Stress at peak (N/mm^2)	1.2846
Force at yield (N)	2135.7
Force at break (N)	3632.0
Strain at break (%)	9.8175
Elongation at yield (mm)	1.8280
Elongation at peak (mm)	3.9270



4.5 Table 4 :Stress against Hardness Graph


4.5 Table 4 :Stress against Hardness Graph

S/N	% of Mg in Specimen	Brinell Hardness No (HBN)	Stress (N/mm^2)
1	0	9.98	3.99
2	1	14.47	3.13
3	2	23.56	2.50
4	3	26.23	2.21
5	4	34.40	1.28



4.6 Table 5: Summary Results of Mechanical Tests Carried Out:

4.6 Table 5: Summary Results of Mechanical Tests Carried Out:

S/N	% of Mg in specimen	Stress(N/mm^2)	Strain(%)	Elongation at yield(mm)	Hardness (HBN)
1	**0**	**3.9951**	**16.823**	**1.5950**	**9.98**
2	**1**	**3.1396**	**16.570**	**2.4860**	**14.47**
3	**2**	**2.5072**	**15.247**	**1.7670**	**23.56**
4	**3**	**2.2123**	**13.622**	**1.7820**	**26.23**
5	**4**	**1.2846**	**9.8175**	**1.8280**	**34.40**

4.7 Comparison between Mechanical Test Result and that of Donatus et al

From the experiments carried out by [1], specimen undergone cold deformation and the heat treatment adopted was ageing and normalizing.The results showed that normalizing gave the optimum mix of tested mechanical properties with ultimate tensile strength in the range of 235MPa, Elongation of around 60% and Rockwell hardness value of 46.5-63.7HRc, while mechanical results obtained showed that specimen with 1% of mg has the highest elongation at yield of 2.486mm with relatively low hardness of 14.47HBN. Specimen with 4% of mg which was subjected to normalizing has a relatively high elongation at yield of 1.828mm with the highest hardness of 34.4HBN.The hardness test was carried out on a Brinell Hardness Testing Machine while tensile test was carried out on a Universal Tensile Testing Machine.

V. CONCLUSIONS

It was noted from series of experiments carried out that addition of magnesium to aluminum bronze increases the hardness property and yield strength of aluminum bronze. The high value of yield strength of aluminum bronze reduces the cause of failure in engineering designs and constructions. Addition of magnesium will increase the mechanical properties of aluminum bronze which can be used in a substitute for propeller of a sea-going vessel.

Aluminum bronze alloyed with magnesium should be used as a substitute for making component (propeller) in sea-going vessel as against aluminum bronze alloyed with nickel.

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