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Ageing Effect on the Strength to Weight Ratio of Aluminium Alloy

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ABSTRACT: This work takes into cognizance t he effect of Ageing on the strength to weight ratio of aluminium alloys. Three samples of aluminium alloy obtained from extracts of Pressing Iron, Reciprocating engine piston and window Frame were used .The alloys were grouped into three sample groups and used for three different methods of ageing heat treatment (annealing, quenching in water and quenching in oil). The samples were subjected to four different temperatures which are 100^{o}C, 150^{O}C, 200^{O}C and 250 ^{O}C . All the samples were heated at these temperatures and socked for periods of 90 mins, 120 mins, 180 mins, and 240 mins both for the annealed and quenching processes respectively. Cleaning was done according to international standard; hardness test was carried out on the different samples. The values of the hardness, increased until 10 hours,. After the 10 hour period, the hardness value started declining. For annealing samples, it was 26VHN, 44VHN, 41VHN, 38VHN and 36VHN at 5 hours interval. For quenching water, it was 27VHN, 45VHN, 43VHN, 39VHN and 37VHN and for quenching in oil, it was 29VHN, 47VHN, 52VHN, 46VHN, and 41VHN at 5 hours interval respectively. The hardness increased with time up to 10hours, then declined steadily. This is attributed to the state of liquid us of the aluminium alloys as ageing period increases with time. The results showed a significant difference in the strength of the three samples.(hardness value). Also the strength of the samples when heat treated with the three different methods of as stated above reveals significant differences. When quenched in oil, the ageing treatment had the highest value of hardness. It is therefore recommended that in order to increase the strength of aluminium alloy, by way of heat treatment, the quenching in oil heat treatment should be considered and further test should be conducted to determine the yield strength of aged alloys.

Keywords: Ageing, Aluminium alloys, Quenching Strength, Temperature.

I. INTRODUCTION

In recent years due to promising structural materials and automotive and manufacturing industries and aerospace applications, aluminium alloys have attracted attention of many engineers, designers and other researchers. Due to their high strength to weight ratio aluminium alloys have been widely used in automobiles, marine and aerospace (1).As a result of improvement in the fuel efficiency and carbon footprint, reduction in power consumption and economy, a decrease in weight of these alloys is beneficial in various applications. Due to benefits such as formability, weld ability, medium strength, corrosion resistance and low purchasing cost, studies have been carried out on 6061 aluminium alloys when compared to other aluminium alloys (2,3). The excellent combination of a wide range of these different properties of aluminium alloys makes it most widely used metal after steel and cast iron. The most common method to increase the strength of the heat treatable aluminiumalloys is precipitation hardening. As a result of this, aluminium alloys received great attention in the last few decades for joining and brazing various components of automotive such as heat exchanger, boiling and cooling devices, etc. because of their outstanding properties like corrosion and oxidation, resistance, high strength, mach inability and workability, improved damping capacity in various applications over the base alloys. According to (4) , this method includes a solution heat treatment at high temperature to maximize solubility, followed by rapid cooling or quenching in water to obtain a solid solution super saturated with the solute elements (Mg and Si), followed by ageing heat treatment (which may include either natural ageing or artificial ageing) to produce finely dispersed precipitates. Solution heat treatment is designed to maximize the solubility of soluble elements which are precipitated during subsequent ageing. In the automotive industry, for the manufacture and fabrication of many types of automotive and mechanical parts, such as panels, vehicle structures and wheels (5-8), the 6061 alloy has been used. The energy economy, recycling and life- cycle cost will be of great improvement if steels are substituted with these aluminium alloys. For further application within the industry, it is necessary to improve the strength and formability of these alloys. (9). The corrosion behaviour of aluminium alloy, because of the uniform distribution of fine precipitates can be enhanced by the ageing treatment and precipitation hardening and also the phases and homogenization of microstructure (10-11). Ageing time(AT), temperature and alloying element/chemical composition are the main affecting factors on microstructures of aluminium alloy. (12-14). Corrosion is in no doubt a very important factor which is responsible for the failure of materials. Based on this ugly fact, scientist, corrosion experts and other researchers have engaged themselves in the study of on the corrosion properties of aluminium alloys. Emphasizing further, (14)explain that copper dissolves in the α-Al matrix which increases corrosion potential after the T6 heat treatment of aluminiumalloy, Al_2Cu phase forms having the α-Al solution resulting in increases in driving forces for Cathodic nature as relating to pitting corrosion (15) .

Aluminium alloys, because of their excellent properties such as high strength to weight ratio, high corrosion resistance and low density, are widely used in the application of automobile and aircraft structural components. (16). A popular one is the LM 12 aluminium alloy which is has good mechanical properties at high and low temperature ranges leading to various potential application in automotive parts such as hydraulic brakes etc.(17). Mechanical properties such as high strength and good toughness can be obtained by applying optimum melting and casting methods and required heat treatment procedures according to (18). According to (19), Age- hardening treatment consists of solution zing, quenching and ageing. This age- hardening methods as explained by (20) are widely used to strengthen heat treatable aluminium alloys. During solution heat treatment, the alloy exists as a homogeneous α-Also lid solution but on cooling becomes saturated with respect to the second phase θ ($CuAl_2$). To retain the high temperature single-phase α-Also lid solution at room temperature, the solution zed alloy is quenched, because the rapid cooling suppresses the separation of θ (21). The effect of ageing time and temperature on the microstructure and mechanical properties of 6082 aluminium extrusion was studied by (22).The study shows that the optimum ageing temperature was 175^{o} C at 4 hours. The tensile and yield strength also reached their peak value of 350MPa and 320MPa respectively. The tensile strength and hardness of the aluminium increased with ageing time which depends on the alloy composition and ageing temperature according to (23). Studies have recorded that precipitation hardening is the most common technique used to enhance the strength of heat treatable aluminiumalloys. Although many works have been carried out on the effect of heat treatment on the mechanical and properties of different aluminium alloys, work on the ageing effect on the strength alloys from different of aluminium components is rare. Therefore this work tends to address the effect of ageing on the strength to weight ratio of aluminium alloys from different components.

II. MATERIALS AND EXPERIMENTAL PROCEDURE

2.1 Materials

Different samples of aluminium alloys were selected from mile 3 ultramodern mechanic park in Port Harcourt, South –South Nigeria. The alloys were parts from reciprocating engine pistons, pressing iron, and window frames. The reciprocating engine piston aluminium was labeled sample l, that of the pressing iron was labeled sample 2 and the window frame aluminium was labeled sample 4, samples 5, sample 6 and sample 7. The experiments were conducted at Turret Engineering Service LTD laboratory. The chemical composition for the received samples (As) taken from the Positive Identification Test is as shown below in Table 1.

Plate1: PMI (X-MET7000) Instrument

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Table1: Chemical composition of the as received samples

s/n	Aluminum Gradetype	Elements									
		Cr%	Mn %	Fe%	Ni%	Cu%	Zn%	Pb%	Ti%	Zr%	Sn%
1	AA-6061	0.10	0.05	0.54	0.16	0.28	0.16	0.15	0.00	0.02	0.00
2	AA-4343	0.03	0.07	0.60	0.05	0.08	0.13	0.01	0.22	0.00	0.00
4	AA-4032	0.08	0.13	0.64	0.53	0.14	0.12	0.06	0.03	0.01	0.01

2.2 Experimental procedure

The three different samples of aluminium alloys as acquired were cleaned up properly and were cut into three more equal parts for this experiment. The instruments used were the PMI meter (Model X-Met 7000), Mobile Hardness tester (MH 180 model), Ultrasonic Thickness gauge (MI 160 model), Electric Heat Treatment Furnace (Model ESM 9920) Claw bar and Plastic bowls.

2.3 Ultrasonic test

The thickness test for the different samples of aluminium alloys were conducted using the Ultrasonic thickness gauge (MI160 model) as shown in plate1.below.

Plate2**:** Ultrasonic Thickness Gauge

2.4 Heat treatment

The aluminium alloy samples were labeled using numbers and alphabets before the heat treatment and then taken for the heat treatment. They were divided into three groups; group 1, group 2and group 3. This was according to the heat treatment method to be adopted, which is Annealing, Quenching using cold water and Quenching using oil. The Annealing samples were labeled 1a, 2a, and 4a respectively. The samples for quenching in water and Quenching in oil were labeled 1w, 1o, 2w, 2o, 4w and 4o respectively. The samples were heat treated in the furnace at temperatures of 100^{o}, 150^{o}, 200^{o}and 250^{o}

Table2**:** Thickness of the aluminum alloy samples

Sample	Readings
1	4.71
2	2.89
4	1.32

Plate3:Aluminumalloys samples used for the testing

The samples in group one) (1), were those aluminium alloys labeled 1a, 2a and 4arespectively. They were grouped into four (4) different subgroups according to the temperatures to be applied. The first subgroup was put in the furnace at a temperature of 100^{o}C and held at a socking period of 90 minutes and then furnace turned off and annealed. The second subgroup was heated at a temperature of150^{o}C and and left to sock for 120 minutes, the furnace put off and the samples allowed to cool to room temperature. The third subgroup was heated for 200^{o}C and held for 180 minutes and allowed to cool to room temperature. The last subgroup i.e. subgroup four, was heated to 250^{o}C and held for 240 minutes at room temperature.

2.5 Quenching

The group two (2) also was divided into four subgroups. These are the samples that were quenched in water. Each subgroup was heated for 100^{o}C, 150^{o} C, 200^{o}C and 250^{o}can d held for a period of 90 minutes, 120 minutes, 150minutes, 200minutes and 240minutes respectively. They

were all quenched in water.
Also this pattern was repeated for the subgroups of group three (3) and were quenched in oil

Plate 4: Heat treated Sample

Plate5: Heat treated Samples quenched in oil quenched in water

2.6 Hardness Test

After carrying out the heat treatment on the aluminum alloy samples as grouped, hardness test was done on the musing the mobile hardness tester (MH180).Thegroup1 which was the annealed samples was tested first followed by the group 2 which is the samples quenched in water and finally the group 3 samples quenched in oil.

III. RESULTS AND DISCUSSION

The tables as shown in tables 2, 3 and 4 represents the hardness values of the hardness test results for the different samples in the different times from 0 to 20 hours. Also the figures 1,2 and 3, explains the pattern displayed by the different aluminium alloys when they undergo the various heat treatment methods.

3.1 Age hardening

Hardness against ageing time is shown in tables 2, 3 and 4. it is attested from the tables that as the aluminium samples increases, hardness properties of the materials increases to appoint and then successively decreases. The ageing time at hours shows the greatest increase in hardness and the lowest reading for the hardness was at the time period of 20 hours. From the results it could be said that as the time increases from 5hours, the resistance to the precipitation of the aluminium alloy samples increases up to 10 hours when the resistance to slippage becomes stronger, making the samples harder. As the time increases, exceeding 10hours, the slippage of the materials started increasing upwards going from 15hours to 20hours due to the precipitation some elements in the crystal grain structure, making the aluminiumalloy samples to decrease in hardness drastically.

It was obvious from figures1, 2 and 3 that the samples experience the maximum hardness when it was quenched in oil and the lowest is when annealed. For sample 4, the maximum hardness was observed at 10hour period socking time for all the three different methods of heat treatment, whereas, for the samples 1 and2, that was not the case.

Table 2: Hardness Test Results for Sample 1

Time (Hour)	Hardness for Annealing(VHN)	Hardness for Quenching in Water(VHN)	Hardness for Quenching in Oil (VHN)
0	26	27	29
5	44	45	47
10	41	43	52
15	38	39	46
20	36	37	41

Table 3: Hardness Test Results for Sample 2

Time (Hour)	Hardness for Annealing (VHN)	Hardness for Quenching in Water(VHN)	Hardness for Quenching in Oil (VHN)
0	24	30	31
5	35	36	48
10	32	46	57
15	29	41	51
20	28	37	46

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Table 4: Hardness Test Results for Sample 4

Time (Hour)	Hardness for Annealing (VHN)	Hardness for Quenching in Water (VHN)	Hardness for Quenching in Oil(VHN)
0	76	82	87
5	102	105	108
10	109	110	118
15	94	102	107
20	87	93	98

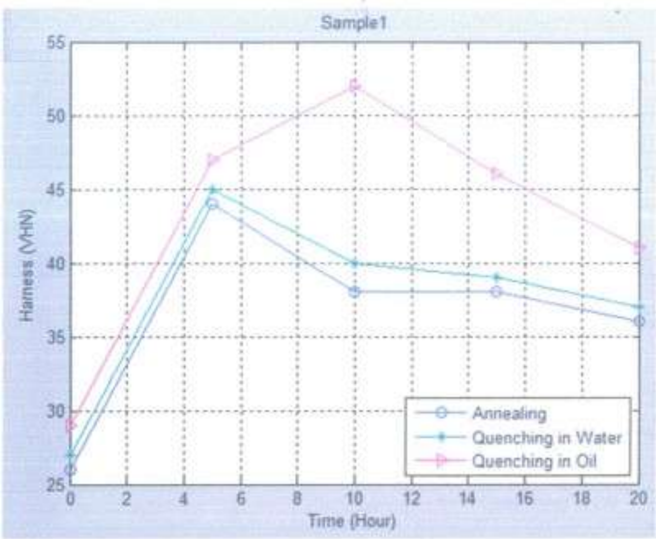

Fig 1: Plot of Hardness against Time for Sample 1

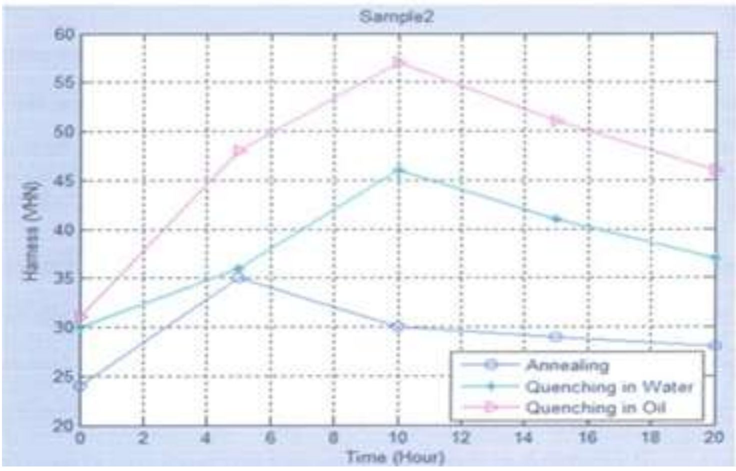

Fig 2: Plot of Hardness against Time for Sample 2

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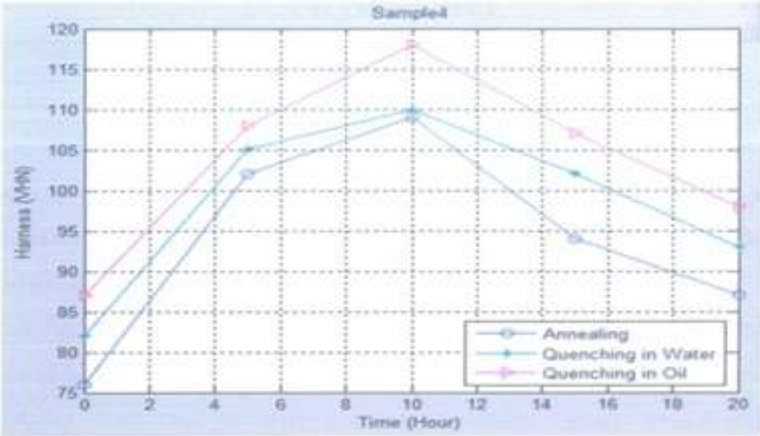

Fig3: Plot of Hardness against Time for Sample 3

IV. CONCLUSION

The results of this work shows that aluminium alloys have a considerable amount of strength compared to its weight. The ageing heat treatment of the various samples considered shows a significant difference in their strength (hardness value). These differences can be attributed to the fact that the samples have composition of materials.Likewise,whenagivensampleisundergoesheattreatment,applyingdifferent heat treatment techniques, (annealing, quenching in water and quenching in oil), difference inthe strength of the alloys are clear.

REFERENCES

[1]. Ilangovan, S.,Srikanthan, R.and Veda, V.G. (2014). "Effect of ageing time on mechanicalpropertiesofsandcastAl-4.5Cualloy".IJRET:InternationalJournal Research in Engineering and technology; 3(5), 37-42.

[2]. Altenpohl,D.G.(1998).:Aluminium,technology,applicationsandenvironment,a profile of a modern metal". 6th ed. TMS; 1998.

[3]. Troeger, L. P.,and Starke, E. A. (2000). Microstructural andMechanical characterizationofasuperplastic6xxxAluminiumalloy.MaterSci.EngA2000;277: 102 - 13.

[4]. Hossain, A. and Kurny, A. S. (2013)." Effect of ageing temperature on the Mechanical propertiesofAl-6Si-0.5McastalloyswithCuadditionstreatedbyT6heattreatment". Universal Journal of Material Science. I(1), 1 – 5.

[5]. Burger,G.B.,Jeffrey,W.P.,andLloyd,D.J., Microstructuralcontrolofaluminium sheets used in automotive applications. Mater. Charact 1995; 35 ; 23 – 29.

[6]. Cole,G.S.,andSherman,A.M.Lightweight materialsforautomotiveapplications. Mater Charact 1995; 35; 3 – 9.

[7]. Lucas,G.Aluminiumstructuralapplications. Adv.MaterProcess1996;149;29–30.

[8]. Irving,B.Interestinweldedaluminiumautomobilesgathersmomentumworldwideweld J.1998;77; 31 - 35.

[9]. Lee, S. H., Saito, Y., Sakai, T. & Utsunomiya, H. (2002). "Microstructure and Mechanicalpropertiesof6061aluminiumalloyprocessedbyaccumulativeroll–bonding". Mater Eng A 2002; 325: 228 – 35.

[10]. Reis,D.A.P.,Conto,A.A.,DomininguesJr,N.I.,Hirschmann,A.C.,Zepka,S.and de Moura Neto, C." Effect of Artificial Ageingon the Mechanical properties of an Aerospace Aluminium Alloy 2024;" Defect Diffus. Forum; pp. 193 – 635.

[11]. Jang,D.A.,Nam,D.G.Park,Y.H.andPark,I.M.2013."Effectofsolutiontreatment and artificial ageing on microstructure and mechanical properties of Al.Cu alloy". Vol. 23; trans Nonferrous Met. Soc. China; English; pp. 631 – 635

[12]. Ghossh, K. S, Hilal, M. and Bose, S; 2013; "Corrosion behavior ofAl-Cu –Mg alloy of various tempers"; vol. 23; Trans. Nonferrous Met; China (EnglishEdition); pp. 3215 – 3227.

[13]. Panigrahi, S.K.and Jayaganthan, R. 2011; "Effect of ageing on microstructure and mechanicalpropertiesofbulk,cryorolledand roomtemperaturerolledAl7075alloy"; vol.509; J Alloys Comp.; pp.9609 – 9616.

[14]. Liu,Z.,Chong,P.H.,Butt,A.N.,SkeldonP.andThompson,G.E.(2005)"Corrosion mechanism of laser- melted AA 2014 and

International Journal of Advances in Engineering and Management (IJAEM)
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AA 2024 alloys;” Appl. Surf. Sci.; vol. 247;no.1-4;pp. 294 – 299; 2005
[15]. Chong,P.H.,Liu,Z.,Skeldon,P.andThompson,G.E; 2014;:NoTitle”;vol. 3311.
[16]. Akhai, K. T., Sanjivi, A. andSellamuthu, R.(2015). The effect of heat treatment and ageingprocessonmicrostructureandmechanicalpropertiesofA356aluminiumalloy sections in casting. Procedia Engineering, 97, 1676-1682.
[17]. Daliam, Y., Liu, Y. Sogbali, I., Liyong, M. , Chi, L. and Jiuhuo, Y. (2017). Effectsof ageing temperature on microstructureand high cycle fatique performance of 7075 aluminium alloy. Journal 0f Wuhan university of Technology, 32 (3): 677 – 684.
[18]. Hassan, S. B. and Aigbodion, V. S. (2009). The effect of thermal ageing on microstructureandmechanicalpropertiesof Al-Si–Fe-MgAlloys.JournalofAlloysand Compounds,486, (1-2): 309-314.
[19]. Sigworth,G.K.,Kaufman,M.,Rios,O.andHowell,J.(2004).Developmentprogramon natural ageing alloys, AFS Transactions, 112, 387-407.
[20]. Janji, J. H., Nam, D. G., Park, Y. H. and Park, i. m.(2014). Effects of solution treatment and artificial ageing on microstructure and mechanical properties of Al-Cu alloys. Transactions of non-ferrous metals society of China, 23 (2013): 631-635.
[21]. Adeosan,S.O.,Balogun,S.A.,Sekunowo,O.I.andUsman,M.A.,(2010).Effectsof heat treatment on strength and ductility of rolledand forgedaluminium 6063 alloy. Journal of Minerals, Materials Characteristics and Engineering,9(8), 763 - 773.