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DISCOVERY

An investigation on the mechanical properties of heat treated A384 Aluminium alloy

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ABSTRACT

Research has been done to study the effect of heat treatment on the mechanical properties of A384 aluminium alloy. Aluminium scraps were collected, melt and cast to cylindrical rods of 20x300 mm. The first set of the produced alloy was annealed at 470°C for 3 hours, while the second set of samples were hardened by heating it to a solutionizing temperature of 470°C, followed by quenching in warm water and subsequently ageing to 120°C for 5 hours. The as-cast and heat-treated samples were then subjected to mechanical tests. The results revealed that the as-cast, precipitation hardened and annealed sample had a tensile strength of 75Mpa, 128Mpa and 93.4Mpa with hardness values of 37HRF, 91.50HRF, and 12HRF respectively. It was observed that the tensile strength of precipitation hardened sample is 71.8% greater than that of the as-cast, while the tensile strength of the annealed sample is 24.6% greater than the tensile strength of as-cast samples. From the result obtained, Heat treated samples have higher ultimate tensile strength, hardness and elongation values as compared with the as-cast. It can be concluded that the heat treatment operations have improved the mechanical properties of the aluminium alloy under investigation.

Keywords: A384 aluminium alloy, Precipitation hardening, Annealing. Mechanical Properties

1. INTRODUCTION

The rapid growth in the aluminium industry is attributed to its unique combination of properties, which makes it one of the most versatile engineering and construction materials (Prashant and Purohit, 2013). Aluminium is light, non-toxic, ductile and corrosion resistant, with good electrical and thermal conductivity (Cevik et al., 2012). As a key trend the material for engine blocks, which is one of the heavier parts, is being switched from cast Iron to aluminium resulting in significant weight reduction. Aluminium castings have been used for pistons, cylinder heads, intake manifolds, wheels and transmission cases (Mohammed and Samuel 2012). However, relatively low strength and unstable mechanical properties are some of the drawbacks for its application, and this can be improved through alloying and heat treatments. Cast aluminum parts if subjected to internal stresses in continuously heated condition during service results in distortion such as cracking of piston and warping of overheated aluminium top cylinders in automobile (Aqeel, et al., 2016). The change in microstructure of the material when heat treated can influence the mechanical properties and the microstructure of cast Aluminium part (Jing et al., 2017; Kaya, et al., 2012; Noor, 2013). By carrying out heat treatment, Aluminium elements will be resistance to failures experienced under service condition (Balamugunda, et al., 2014; Chuanjun et al., 2017; Kaustubh, 2015). Thus, the aim of the present study is to prepare A384 aluminium alloy using sand casting method and determining the effect of annealing and precipitation hardening treatments on the prepared samples.

2. EXPERIMENTAL SETUP

Scraps of automobile component such as pistons, top cylinder, engine block were purchase from a local shop in Bauchi State Nigeria. They were melted and cast into a cylindrical rod using sand casting method. The first set of the produced samples was subjected to spectroscopy, while the second set was annealed at 470°C for 3hours and furnace cooled. The final set of samples was hardened at a heating temperature of 470°C for 2hours and rapidly quenched in water then aged at a temperature of 120°C for 5hours.All samples were prepared in accordance with ASTM standard and shown in Figures 1 and 2.

Figure 1 Tensile test specimen

Figure 2 Hardness test specimen

Chemical composition analyses of the samples were carried out using optical light emission spectrometer and shown in Table 1. Tensile testing was done on a universal testing machine while Rockwell hardness tester was used for hardness measurement respectively.

Table 1 Weight percentage of different elements in the specimens

Element	% wt.
Al	87.50
Si	9.15
K	0.02
Ca	0.01
Ti	0.03
V	0.007
Cr	0.02
Mn	0.11
Fe	0.63
Ni	0.07
Cu	1.81
Zn	0.45
Zr	0.005
$AS_2 0_3$	0.007
Te	0.03
Pb	0.03

3. RESULTS AND DISCUSSION

The results of mechanical test obtained in this study is presented in Table 2.The precipitation hardened samples had an ultimate tensile strength value of 128.86Mpa which is 71.8% higher than that of the as-cast sample, while the annealed samples had a value of 93.44Mpa for ultimate tensile strength which is 24.6% higher than that of the as-cast samples with 75.01Mpa.

Table 2 Result of mechanical testing for as-cast and heat-treated A384 Aluminium samples

Sample	Yield Strength (Mpa)	Breaking strength (Mpa)	Ultimate tensile strength (Mpa)	Percentage elongation (%)	Hardness number (HRF)
As-cast	51.00	67.35	75.01	0.4	37.0
Annealing	49.50	49.50	93.44	1.2	12.0
Age hardening	88.00	90.20	128.86	0.8	91.50

This resulted from of the presence of inter metallic precipitate and coarse grain structure. Thus, the two heat-treated sample will have better mechanical properties (Mohammed and Samuel, 2012; Chee and Said, 2009). These results are in agreement with works elsewhere (Chuanjun et al., 2017, Adeymi et al., 2017 and Odusote et al., 2017).

Figures 3 and 4 show that precipitation hardened sample and annealed sample displayed higher plastic deformation than as-cast sample before the final rupture.

This indicates that the precipitation hardened samples and annealed sample became more ductile than the as-cast samples as a result of inter metallic precipitates and refined grains due to the heat treatment process as stated in Rambabu et al., (2017) (figure 5). Higher plastic deformation usually indicates improved ductility, resulting in ductile failure of such materials (Adeyemi et al., 2013).

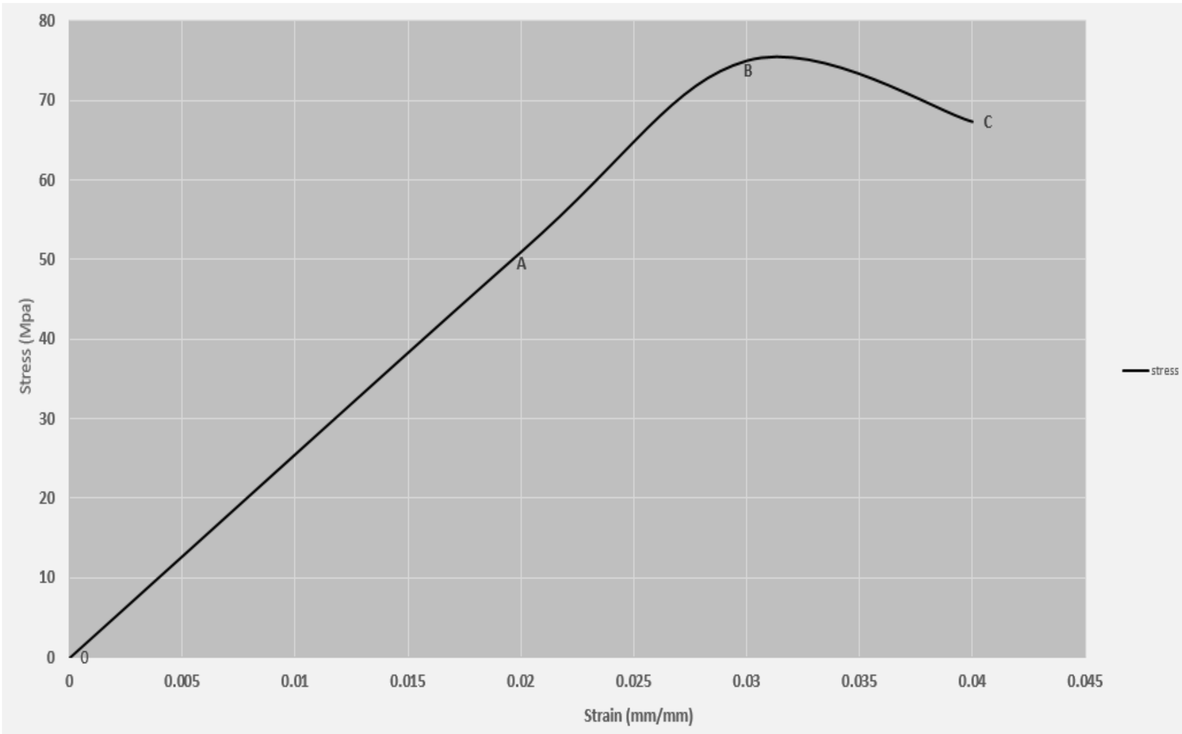

Figure 3 Stress-Strain curves for as-cast sample

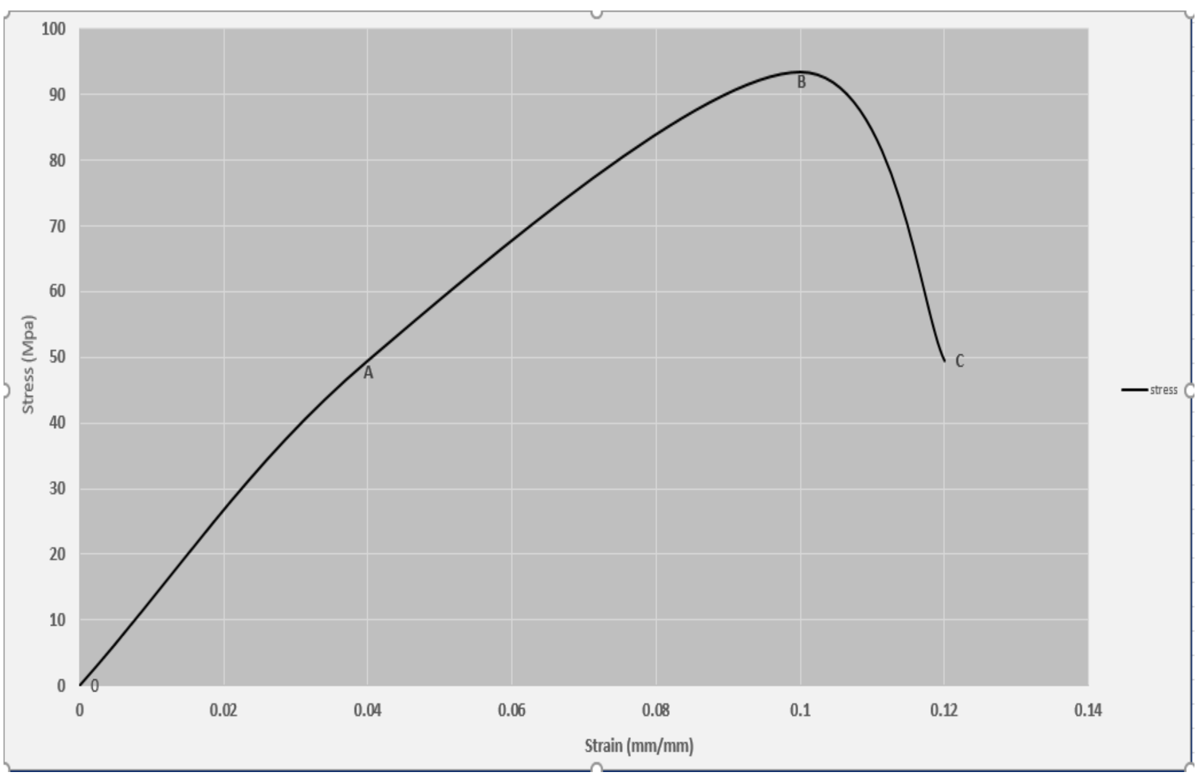

Figure 4 Stress-Strain curves for annealed sample

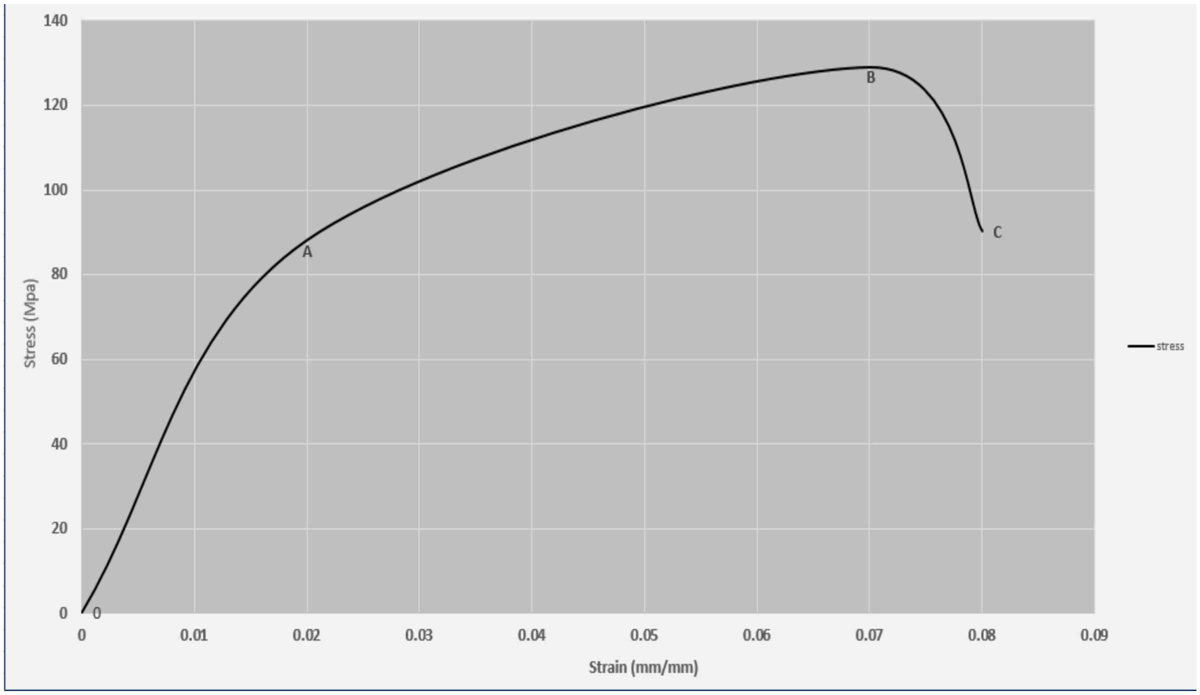

Figure 5 Stress-Strain curves for As-cast sample

Hardness test

The result of hardness test is given in Table 2. The Rockwell hardness (HRF) value obtained in the age-hardened sample, which is 145% higher than the as-cast sample (37.5 HRF). The increased hardness value is as a result of the second phase precipitations that occur during the process of aging performed on the alloy and also as a result of an improved grain size. Isadare et al., (2015) also reported that aluminum alloy possessed better hardness, which was related to the presence of coherent precipitate in the structure of aluminium alloy sample. The result is also in agreement with Kaya et al., (2012) work that reported that age-hardened aluminum alloys with grain structures are harder and stronger compared to the as-cast alloys. The high hardness value will increase the wear and corrosion resistance of parts like the engine block, motor casings, pistons and even engine cylinders (Odusote, 2015).

Also considering the result of hardness test shown in Table 2, the Rockwell hardness (HRF) value obtained for the as-cast sample is 200% higher than that of the hardness number obtain for the annealed sample. This is partly due to increase in grain coarsening which lead to increase in the grain boundary area which increases the amount of energy required for the movement of dislocation require to cause fracture (Adeyemi et al., 2013). The result agrees with the findings of (Guo, 2017).

4. CONCLUSIONS

Generally, the conclusion drawn from the result obtained in the present work shows that:

I. The precipitation hardening heat treatment operation improved the hardness value, yield and ultimate tensile strengths of the A384 aluminum alloy.
II. The annealing heat treatment operation improved ductility but lowered hardness of the part cast aluminium part.

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