THE EFFECT OF THERMAL AGEING ON MICROSTRUCTURE AND SOME MECHANICAL PROPERTIES OF Al/2.0% GLASS REINFORCED COMPOSITE.

Ihom A.Paul¹, Nyior G. Bem² & Ibrahim G. Zamanni²
¹National Metallurgical Development Centre, Jos Plateau State, PMB 2116 Jos-Nigeria
²Ahmadu Bello University, Zaria- Nigeria
*E-mail: paulihom@yahoo.co.uk, Tel: +234-8035813571

ABSTRACT
The effect of thermal ageing on microstructure and some mechanical properties of Al/2.0% glass reinforced composite have been studied. The results have shown that thermal ageing of the as-cast composite has effect on the microstructure. Precipitates were formed in the matrix of the composite. The precipitates were the second phase, as distinguished from the aluminum matrix, which was lighter in color. The as-cast composite had a hardness value of 20.1HRB and a tensile strength value of 217.87N/mm². After thermal ageing at 150°C, 170°C, 190°C, and 210°C, the composite showed great improvement in hardness as well as tensile strength. The highest value of hardness of 35.5HRB and tensile strength of 381.87N/mm² were obtained at 190°C, after ageing for 2hrs. The study found that the microstructure of the thermal aged composite was related to the hardness and the tensile strength of the composite. The nature of the precipitates formed determined the hardness and the tensile strength of the composite.

Keywords: Tensile strength, Hardness, Temperature, Microstructure, Composite.

1. INTRODUCTION
Composites combine the attractive properties of the other classes of materials while avoiding some of their drawbacks. They are light, stiff, and strong, and they can be tough [1]. Metal matrix composites (MMCs) reinforced with ceramics or metallic particles are widely used due to their high specific modulus, strength, hardness and wear resistance. MMCs have been considered as an alternative to monolithic metallic materials or conventional alloys in a number of specialized applications [2]. The majority of such materials are metallic matrices reinforced with high strength, high modulus and often brittle second phase in the form of fibre, particulate, whiskers embedded in a ductile metal matrix [2].

The reinforced metal matrix offer potential for sufficient improvement in efficiency, reliability, and mechanical performance over traditional monolithic alloys [3]. In particular, aluminum matrix composites (AMCs) have been reported to possess high specific strength, high specific stiffness, electrical and thermal conductivities, low coefficient of thermal expansion and wear resistance (4). Because of these excellent combinations of properties, AMCs are being used in varieties of applications in automobile, mining, and mineral, aerospace, defense and other related sectors [5-7].

Some composites are normally subjected to thermal action to improve on their structure and properties after production [8-14]. This is called heat treatment; the application of this thermal processes do bring about microstructure changes and sometimes even macrostructure changes, which do determine the properties of the composite. A lot of research work has been done using aluminium metal matrix with different reinforcement materials. Alloys of aluminium have also been used as metal matrices with varying results in terms of strength improvement to wear resistance achieved, further details can be seen in cited works [8-14]. Some of the authors have investigated the effect of thermal ageing on mechanical and microstructural properties, which they claim determines the mechanical and microstructure of the composite [8-14]. The objective of this work is to determine the effect of thermal ageing on some mechanical and microstructural properties of Aluminum matrix-glass reinforced composite. This will likely make it suitable for application like automobile door opener and other components requiring abrasion resistance.

2. EXPERIMENTAL PROCEDURE

2.1 Materials
The materials used for the work included; pure aluminum from electrical cable, etchant, and broken bottles.
2.2. Equipment
The equipment used in the study included; melting furnace (crucible type), gravity metal casting mould, digital weighing balance, mechanical stirrer, oven, cutting saw, Rockwell hardness tester, Denison universal strength testing machine, grinding machine, polishing disk, and metallurgical microscope.

2.3. Methods
The specimens used for the study were produced using the stir-cast method of producing composites. The composite was produced in a crucible furnace where the pure aluminum was melted and the temperature raised to 700°C and the reinforcing agent was introduced and stirred at the rate of 315 rpm before pouring into gravity metal casting moulds. The specimens were allowed to solidify before they were removed and cleaned.

2.3.1. Ageing Treatment
After the cleaning of the cast specimens they were heated to 500°C for solution treatment and held for 45 minutes before quenching in water. The round bars of 20mm diameter and 350mm length were then aged in the oven at different temperatures ranging from 150°C - 210°C. The solution treatment was carried out to enhance the homogenization of the reinforced particles in the matrix of the composite. After the ageing treatment the specimens were ready for hardness test using Rockwell hardness tester, tensile strength test using Denison universal strength testing machine, and microstructure examination and photomicrography was done using metallurgical microscope. The composite selected for the study was the Al/2.0% glass reinforced composite.

3. RESULTS AND DISCUSSION
3.1. Results
The results of the effect of thermal ageing on hardness values of Al-2.0% glass reinforced composite at various temperatures, is shown in figure 1. The effect of thermal ageing on tensile strength of Al-2.0% glass reinforced composite at various temperatures, is shown in figure 2, while the photomicrography of some of the microstructures at some temperatures is shown in Plates 1-5. The untreated composite has a hardness value of 20.4HRB and a tensile strength value of 217.87 N/mm².

![Figure 1: Effect of Thermal Ageing on the Hardness of Al-2.0% Glass Reinforced Composite at Various Temperatures.](image-url)
Figure 2: Effect of Thermal Ageing on the Tensile Strength of Al-2.0% Glass Reinforced Composite at Various Temperatures.

Plate 1: Shows the Microstructure of the As-Cast Al-2.0% Glass Reinforced Composite, With the Second Phase Dispersed within the Aluminum Matrix.x200

Plate 2: Shows the Microstructure of the Thermal Aged Composite at 150°C with Grey-Black Precipitates and Aluminum Matrix which is Lighter. X200
Plate 3: Shows the Microstructure of the Thermal Aged Composite at 170°C the Black Precipitates are the Second Phase of the Reinforcement, while the Light Background is the Aluminum Matrix. X200

Plate 4: Shows the Microstructure of the Thermal Aged Composite at 190°C, the Black Precipitates Are the Second Phase, which are the Reinforcement and the Light Background is the Aluminum Matrix. X200

Plate 5: Shows the Microstructure of the Thermal Aged Composite at 210°C, the Black Areas are the Precipitates Of the Second Phase while the Light Areas Reveal the Aluminum Matrix. X200
3.2 Discussion

3.2.1 Microstructure of the Composite
Plate1 shows the microstructure of the as-cast composite. The second phase can be seen distributed throughout the matrix of the composite. The dark grey phases seen in the grains and at the grain boundaries represent the second phase which is the reinforcement agent. The matrix is lighter, and stands out differently from the second phase. Plates 2-5, shows the microstructure of the thermal aged composite. The microstructure differs from that of the as-cast composite. The second phase precipitates out of the matrix leaving a clear background in most of the areas within the matrix. The microstructure shows that the size and quantity of the precipitates seen is dependent on the temperature and the ageing time. This observation agrees with earlier researchers who investigated on the effect of thermal ageing in some composites [10, 13-14]. Some of the plates have large precipitates while others have small-sized precipitates.

3.2.2 Hardness Test.
Figure 1, shows the variation of hardness values with time at various thermal ageing temperatures. The figure shows that at 150°C of thermal ageing the hardness values increases with the ageing time peaking at 32.5HRB after 5 hours of ageing. At 170°C of thermal ageing the hardness values increased from 23.4HRB after 1 hour and peaked at 28.2HRB after 5 hours of age hardening. At 190°C of thermal ageing the hardness value increased from 27.5HRB after 1hour of age hardening to peak at 35.7HRB after 2hours of age hardening, thereafter the hardness dropped to 28.9HRB after 3 hours of age hardening, and picked up after 4 hours of age hardening attaining 34.1HRB. Thermal ageing at 190°C had a curve that is higher than the other thermal ageing temperatures. At 210°C of thermal ageing the hardness values were fluctuating just as in thermal ageing at 190°C the values however showed a strong tendency of improvement. From 24.5HRB after 1 hour of age hardening the hardness value got to 31.0HRB after which it dropped gradually to 27.5HRB after 4 hours of age hardening and then peaked at 32.5HRB after 5 hours of age hardening. The composite has shown a great improvement in terms of hardness after thermal ageing when compared to the as-cast hardness value of 20.4HRB. Several reasons can be responsible and these include the nature of the precipitates formed, the nature of the interface bonding between the precipitates and the matrix, and the composition of the reinforcement agent [8-10, 15].

The hardness improvement in the as-cast condition can be mainly attributed to dispersion effect and to the pinning down of dislocation movement by the particulate reinforcement, which is distributed throughout the matrix of the aluminum (see Plate1) [10]. The hardness values in the thermal aged composite can be attributed to the nature of precipitates formed (see Plates 2-5). This precipitates tend to distort the structure of the aluminum leading to increased stress and strain.

The interface bonding and the coherency of the bonding is another reason for the increased hardness observed (see Plates 2-5) [12, 14-15]. For most of the microstructures the precipitates appeared to align with the matrix, however in artificial age hardening partial coherent precipitates normally dominate. The diffusion of the atoms of the second phase into the matrix and also the diffusion of the matrix into the second phase gives rise to a very strong interfacial bond, which is responsible for both the hardness and strength improvement of the composite after thermal ageing. The whole process is thermal and temperature controlled and also depends on the ageing time [5, 9-11]. This can be seen in Plates 2-5 the different precipitates formed at different temperatures and ageing time supports this. The age hardening behavior of this composite on thermal ageing may also be explained in terms of the composition of the reinforcement agent which contains magnesium oxide, sodium oxide, silicon dioxide, and calcium oxide and other trace elements. Some of the elements in these compounds are known to be contained in heat treatable aluminum alloys, and their presence in this composite may have been responsible for the precipitation hardening behavior on thermal ageing [10-14]. During the production of the composite, at high temperature some of the elements might have found their way into the aluminum.

3.2.3 Tensile Strength Test
Figure 2, shows the variation of tensile strength with time at various thermal ageing temperatures. The hardness of a material is at most times related to its tensile strength. When the hardness value is high the tensile strength could be equally high [10]. The curve of thermal ageing at 150°C shows that as the ageing time increases, the tensile strength also increases. The curve of the thermal ageing at 170°C shows that as the thermal ageing time increases, the tensile strength also increases. The curves for thermal ageing at 190°C and 210°C did not have the same pattern as thermal ageing at 150°C and 170°C. Higgins [10] and Martin [12] have established that the rate of precipitates formation at higher temperatures is faster than at lower temperatures, however large precipitates are formed at higher temperatures making materials to become [10-14] brittle (see Plates 2-5). Thermal ageing at 190°C showed higher tensile strength because of moderate size formation of precipitates. Thermal ageing is a diffusion controlled process, the higher the temperature the faster the phase precipitation [11-12]. The same reasons responsible for hardness
improvement on thermal ageing can be advanced for the tensile strength improvement. The as-cast tensile strength value of the composite was 217.87N/mm². The thermal aged composite has shown great improvement over this value, with the highest tensile value of 381.28N/mm² occurring after 2 hours of ageing at 190°C. The tensile strength improvement is clearly as a result of the microstructural changes that occurred on thermal ageing [13-15].

4. CONCLUSIONS
The effect of thermal ageing on microstructure and some mechanical properties of Al/2.0% glass reinforced composite has been investigated and the following conclusions have been drawn:

1. Thermal ageing of Al/2.0% glass reinforced composite have produced composite with different microstructures with different precipitates of the second phase formed at different temperatures at different ageing periods.
2. Thermal ageing of the composite has lead to improved tensile strength
3. Thermal ageing of the composite has lead to improved hardness of the composite.
4. The highest tensile strength value of 381.28N/mm² after 2 hours of ageing at 190°C as against the as-cast value of 217.87N/mm²
5. The highest hardness value of 35.7HRB was attained after 2 hours of ageing at 190°C as against the as-cast hardness value of 20.1HRB
6. This composite can be used for automobile door opener and other abrasive resistant components on machines.

5. ACKNOWLEDGEMENT
The authors are highly indebted to the management and staff of the National Metallurgical Development Centre, Jos, for the use of their facilities.

6. REFERENCES