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EFFECT OF PURE ALUMINUM ON THE MECHANICAL PROPERTIES AND STRUCTURE OF THICK ALUMINUM SCRAPS FOR THE PRODUCTION OF MOTORCYCLE BRAKE-PAD

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Abstract

The increasing demand for aluminium-based products, coupled with globalization in the aluminium industry, has significantly heightened the consumption of aluminium scraps for the reproduction of aluminium alloys. This research investigated the effect of adding pure aluminium on the mechanical properties and structure of thick aluminium scraps, commonly used for the production of motorcycle brake pads. The first step of this work involved casting the materials using a crucible furnace. Samples were produced with and without pure aluminium, and their properties and structures were compared. The results of the mechanical tests showed the best performance in samples containing pure Aluminium scrap. The microstructure of the sample with pure Aluminium revealed refined grains, while that without pure Aluminium exhibited a coarse grain structure. This research provides insights into producing long-lasting motorcycle brake pads in the industry, aligning with Aluminium production objectives

***Keywords**: Thick Aluminium scraps, pure Aluminium, motorcycle-brake pad, mechanical properties*

1. Introduction

Aluminium is the most abundant metal and also the third most abundant element constituting about 7.3 to 8.0 percent by mass of the earth crust as oxides and silicates being exceeded by only silicon and oxygen [1]. Aluminium and aluminium alloys are gaining huge industrial significance because of their outstanding combination of mechanical, physical and tribological properties over the base alloy. These properties include high specific strength, high wear and seizure resistance, high stiffness, better high temperature strength, controlled thermal expansion co-efficient and improved damping capacity [1,2]. Aluminium has about one third density and stiffness of steel. It is easily machined, cast, drawn and extruded. These properties make it to acquire increased demand in industrial applications.

Aluminium alloys are alloys in which aluminium (Al) is the predominant metal, that is it is of higher percentage by mass. Elements which can be alloyed with aluminium are copper, manganese, magnesium, silicon, zinc, etc. All these may be added to improve the structure and mechanical properties of alloy the matrix [4]. Aluminium alloys are ideal materials to be used for car tanks, automobile engines, and bodies, motor cycle brake pad, etc., because of good formability, excellent corrosion resistance, high strength-stiffness to weight ration and recycling possibilities. [5].

In recent years, abundantly of waste of aluminium alloys increased thereby replacing the primary aluminium alloys to secondary (recycled) aluminium, which is used in many industrial applications. Secondary aluminium alloys are made out of aluminium scraps and workable aluminium garbage by recycling. Application of secondary aluminium alloys is important because production of primary aluminium alloys consume about 45kWh/kg of metal while secondary aluminium alloy's production requires only about 28kWh/kg of metal. The re-melting of recycled metal saves almost about 95% of the energy to produce prime aluminium from ore and thus trigger associated reduction in pollution and green house emission from mining, ore refining, and melting. Increasing the use of recycled aluminium alloy is quite important from an ecological standpoint since producing aluminium product using recycled scraps creates 5% CO_2 which is the same as for primary production [6, 7, 8]. The future growth offers an opportunity for new recycling technologies and practices to maximum scrap quality, improve efficiency and reduce cost.

This research work aims at using scrap aluminium and pure (99.5%) secondary aluminium in the production of motorcycle brake pad and comparing their mechanical properties with the existing pad.

2. **Materials and Method**.

2.1 **Materials and equipment used.**

The basic raw materials used for this research were aluminium scraps commercially known as thick aluminium, ex-factory aluminium materials (factory reject-99.5% Al) and cast commercial motorcycle brake-pad. Equipment used in the cause of this work include; bailout crucible furnace, ingot mould, hardness testing machine, universal tensile testing machine, spectrometer, skimming tools, ladle, thermocouple, pouring cup, crucible pot, etc.

b) Melting and casting: This operation was carried out to produce two separate samples. To begin with, the crucible furnace was preheated for about 20minutes. 27kg of thick aluminium scraps only was charged into the crucible pot and covered to reduce heat loss. The temperature of the crucible furnace was increased to about 690^{o}C. At this temperature the un-melted scrap material presence in the furnace were easily seen on the surface of the melt. The un-melted materials were removed and discarded. Preheating of the ingot mould, together with test piece mould was done using gas torch and was followed by spraying respective mould with releasing agent (sodium silicate solution) for easy removal of the castings after solidification. The molten metal was poured into the ingot mould as well as test piece mould using a ladle. Immediately after solidification which lasted for 10 minutes the billets and test pieces were removed from their respective moulds with the help of tong and they were allowed to cool at room temperature. The billets and test piece samples produced from the first operation were labelled sample A. In the second operation, 7kg of pure secondary aluminium (99.5% Al) was mixed with 20kg molten thick aluminium scrap in the crucible pot. The melting and casting procedure of metallurgical casting described above was repeated and the billets and test piece samples obtained were labelled sample B.

c) Chemical composition test: Samples for alloy composition analysis were prepared by grinding their surface using three lathe machine. This was done in order to expose the interior surface of the samples to obtain an accurate analysis of the elements present. This analysis was carried out twice on each sample at different spots of the surface because metal compositions at different parts of metal do differ in most case. The chemical composition of each sample was determined using a Spark Emission Spectrometer (SES) of Model-W6. The spectrometer analysis was conducted at First Aluminium Company, Port Harcourt, Rivers State, Nigeria.

d) Mechanical test

The tensile test was conducted using horizontal bench top Mansanto Tensometer machine (SRNO0723) and the test carried out at room temperature. Specimens for this test were machined to a dumbbell shape which is required standard specifications so as to fit the grips as showed in Fig.1.

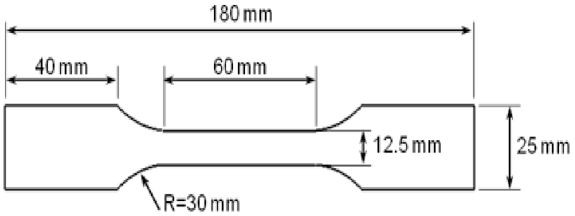


Fig.1 Standard tensile specimen

The hardness of the specimens was determined using a Brinell hardness machine, specifically the model B3000 (H). Each specimen, with a diameter of 20mm, was polished and placed on an adjusting table beneath the control panel individually. The table was then raised to the focal point of the microscope to accurately position the specimen for indentation. Upon pressing the start button, the microscope automatically returned to its initial position, and a spherical indenter was carefully placed on the surface of the specimen. A predetermined force was applied and maintained for approximately 15 seconds, after which the indenter returned to its original position. The indentation created was visible on the monitor of the Brinell testing machine. The diameter of the indentation was measured by placing four metric lines along the edges of the indentation using a hand control knob. The machine then utilized the obtained diameter and the applied force to calculate the Brinell hardness of the work piece.

The equation $BHN = \frac{P}{\left(\frac{\pi D}{2}\right)(D-\sqrt{D^{2-}d^{2}})}$ was used in calculating the result of the hardness, where BHN: is the Brinell hardness number, P: is applied load (N), D: ball (indenter) diameter (mm), d: notch diameter (mm).

Metallography

The sample material was prepared through grinding, polishing, and etching to enable examination of its structure using an optical metallurgical of Model L2003A. Grinding was performed using a series of emery papers ranging from 220 to 1200 grits, followed by polishing with fine α-alumina powder. Subsequently, the samples were etched with iron (III) chloride acid before being mounted on the microscope for microstructural examination and photography.

3. Results and Discussion

The chemical analysis was conducted using a spark emission spectrometer for two samples: sample A, without pure aluminium, and sample B, with pure aluminium. Each sample was subjected to testing twice, and the average value was recorded. Additionally, sample C, representing an existing commercial motorcycle brake pad, was used as a control during the experiment, with only mechanical tests performed on this sample. The results presented in Table 1 show the percentage of elements present in the produced alloys. It was notable that the presence of pure aluminium in the thick scraps led to an increase in the percentage of aluminium and copper, and a slight reduction in the percentage of other elements.

Table 1. Chemical Composition of the developed alloys

Elements	Sample A (wt. %)	Sample B (wt. %)
Fe	3.854	1.893
Si	0.002	0.069
Cu	4.506	4.707
Mn	0.234	0.222
Mg	0.136	0.052
Zn	2.324	0.873
Ti	0.036	0.310
Cr	0.028	0.025
Ni	0.152	0.134
V	0.005	0.005
Pb	0.096	0.096
Al	88.617	92.292

Mechanical Properties

The tensile test was conducted on all three samples: Samples A (Al-88.617%, Cu-4.506%), Samples B (Al- 92. 292%, Cu-4.707%), and Sample C (control). This test aimed to determine the ultimate tensile strength, percentage elongation, and proof stress (0.5% MPa). The results are presented in Table 2.Additionally, a hardness test was performed, and the average hardness values of the three samples are provided in Table 3. The average values were obtained from two tests conducted on each sample

Table.2. Mechanical Properties of the samples

Samples	UTS (MPa)	Yield strength (MPa)	% elongation
A	396	210	31
B	478	236	34
C	340	189	29

Table 3 Brinell's hardness value

Samples	HB1	HB2	Average (BHN)
A	150	161	155.5
B	147	145	143.0
C	148	147	153

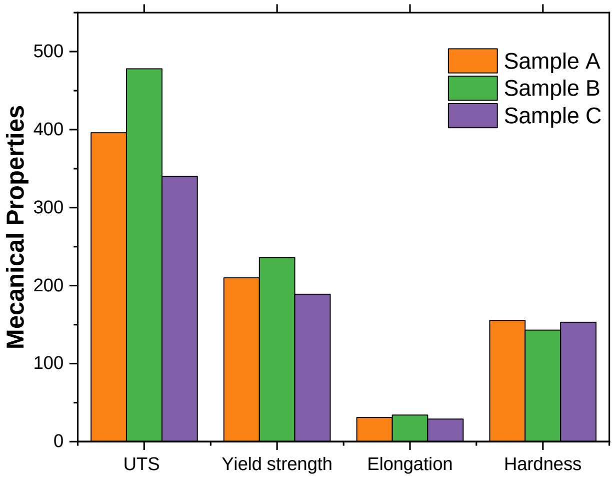
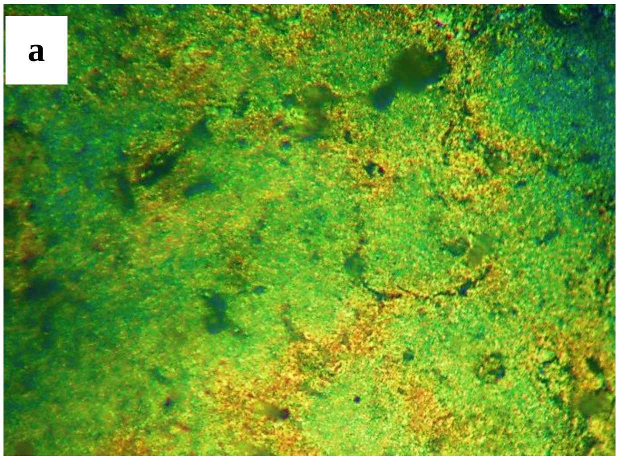


Fig 2: Plots of the mechanical properties of the samples

The chemical analysis results for alloys A and B revealed higher percentages of Al and Cu in alloy B, while alloy A contained higher amounts of Fe and other minor elements. The elevated Al and Cu content in alloy B likely contributed to its improved mechanical properties compared to sample A. This suggests that alloy B is more suitable for use in the production of motorcycle brake pads. The results of the tensile test also indicated that sample B exhibited higher tensile properties compared to samples A and C. Copper plays a significant role in enhancing strength and hardness of aluminium ng alloys. It improves the machinability of alloys by bolstering the matrix strength and ductility [10]. The higher Cu content in sample B led to increased ultimate tensile strength and ductility. Copper contributes to strength enhancement through solid solution hardening and the formation of Guinier-Preston zones [8-11]. The results presented in Table 3 indicate distinct differences in the hardness properties of the three sample alloys. Sample A exhibits superior hardness compared to samples B and C. This disparity could be attributed to the increased Fe content present in the thick aluminium scraps. Iron (Fe) is known to reduce ductility, as observed in various research publications [11-14]. During solidification, iron forms complex intermetallic compounds with impurities of other elements, which can adversely affect mechanical properties, particularly ductility, consequently leading to higher hardness values in sample A. The formation of such phases may also induce embrittlement as elements cluster together in a single-phase during solidification [12, 13].



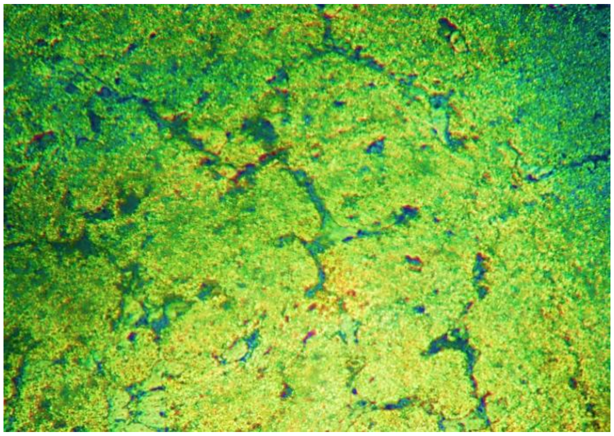


Fig 3. Optical microstructure of samples (a) without pure Al (b) with pure Al

3.2 Microstructures

Figure 3 presents the microstructures of the samples with and without pure Al content. Microstructure analysis of sample A (Fig. 3a) revealed coarse interconnected intermetallic α-phase without any Al-rich phases. The coarse nature of the structure contributed to the suboptimal performance observed in this sample. In contrast, the microstructures of sample B showed Al-rich phase dendrites surrounded by α+γ2 phases, presenting a distinct morphology from sample A. The microstructures exhibited homogeneous, uniform fine grains with twins within the grains evenly distributed. The presence of finely dispersed precipitates acted as obstacles to the movement of dislocations and grain boundary motion. This phenomenon effectively pinned down the movement of dislocations, contributing to the enhanced mechanical properties observed in sample B [14].

4.0 Conclusion

This study demonstrates that adding secondary pure aluminium to thick aluminium scraps during casting enhances mechanical properties compared to those without pure secondary aluminium. Detailed analysis of the results reveals that sample B exhibits the highest percentages of Al and Cu, contributing to improved mechanical properties. Although a high iron content can lead to embrittlement, the presence of nickel and other alloying elements in alloy B mitigates this effect, improving tensile properties and abrasion resistance. Hardness is essential for ensuring material workability, allowing for various designs to optimize brake pad efficiency and reduce failure risks. Overall, samples A, B, and C are suitable for motorcycle brake pad manufacturing, but sample B shows the most significant improvement in this application. The addition of pure Al to commercially thick aluminium scraps transforms the coarse structure into refined equi-axial fine grains.

References

[1] Rama, S. R. Rajesh, P. and Das, S. (2012). Influence of alloying elements on the microstructure and mechanical properties of aluminium alloys and aluminium composites. *International Journal of scientific and Research Publications, Vol. 2, Issue 6, ISSN: 2250-3153, p.1-7.*

[2] Das, S. Mondal, D.P. Sawala, S. Ramkrishan, W. (2008). Effect reinforcement and heat treatment on the two on the body abrasive wear of an Al-Si alloy under varying loads and abrasive sizes wear. *Journal of Scientific and Research Publications, Vol.264, p.47-59*

[3] Wahid, M. A., Siddiquee, A. N., & Khan, Z. A. (2020). Aluminum alloys in marine construction: characteristics, application, and problems from a fabrication viewpoint. Marine Systems & Ocean Technology, 15(1), 70-80.

[4] Kissell, J.R. and Ferry, R.L. (1995). Aluminium structures. *A guild to their specification and design, New York Willey.*

[5] Miller, W.S. Zhuang, L. Bottema, A. Wittebrood, J. Desmet, P. Hazler, A. and Vieregge, A. (2000). Recent development in aluminium alloys for automotive industry. *Material Science and Engineering, A280, p.37-49.*

[6] Sencakova, L. and Vircikova, E. (2007). Life cycle assessment of primary aluminium production. *Acta Metallurgia Slovaca, Vol.e p.412-419.*

[7] Das, K. S. and Gren, J. A. (2010). Aluminium industry and climate change. *Assessment and Responses JOM, Vol.62, No.2, p. 27-31.*

[8] Dases, K. (2006). Designing aluminium alloys for a recycling friendly world. *Material Science forum, Vol.519-521, p.1239-1244.*

[9] *Raabe, D., Ponge, D., Uggowitzer, P. J., Roscher, M., Paolantonio, M., Liu, C., ... & Pogatscher, S. (2022). Making sustainable aluminum by recycling scrap: The science of "dirty" alloys. Progress in materials science, 128, 100947.*

[10] Eva, T. Maria, C. and Lenka, H. (2011). Evolution of phase in a recycled Al-Si cast alloy during solution treatment. www.intechopen.com

[11] Pucher, P. Botcher, H. Kaufman, H. Antrekowitsh, H. and Uggoowitzer, P.J. (2011). Mechanical properties and casting characteristics of the secondary aluminium alloy (AlSi9Cu3Fe A226). *Journal of Material Metal & Materials Society, Vol. 2, p.237-244.*

[12] *Kucharikova, L., & Tillova, E. (2017). Determining the optimal solution treatment temperature of aluminum cast alloys by using quantitative analysis. Archiwum Wiedzy Inżynierskiej, 2.*

[13] Hurtalova, L. Tillova, E. and Chalupova, M. (2011). Optical and electron microscopy study of the mechanical and properties improvement bon recycled AlSi9Cu3 cast alloy along hardening. *MTM. Vol.7, p.48-51.*

[14] http://chemwiki.ucdavis.edu/Inorganic_Chemistry/Descriptive_Chemistry/Elements_Organized_by_Block/2_p-Block Elements/Group_13%3A_The_Boron_Family/Chemistry_of_Aluminum