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DETERMINATION OF THE SUITABILITY OF LOCALLY AVAILABLE ALUMINUM SCRAP FOR PRODUCTION OF MOTORCYCLE BRAKE SHOE

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Abstract

High demand for motorcycle and its spare parts in the country necessitate production of some of its parts locally to conserve foreign exchange and create jobs. Brake shoes are one of the frequently replaceable parts in the motorcycle, and hence, need for domestication to reduce pressure on importation. In this paper, aluminum scraps were obtained from two local aluminum companies and were characterized via chemical analysis with positive material identification machine, tensile test with Instron 300DX, hardness test with Wolpert Wilson instrument MLIE/TL/003, and fatigue test with Mitsubishi A200. The results were compared with the composition and properties of aluminum 360, 380, 383, and B390 standards selected from previous research to be suitable for motorcycle brake shoe production. Appropriate master alloy was selected based on the chemical composition of the target metal obtained from literature, chemical composition of the scraps and oxidation of elements during the process of melting. Appropriate quantities of charge required was calculated analytically. The results obtained shows that the scraps conformed to the 6xxx series of aluminum alloy with hardness of 44-69% less, yield strength of 57-75% less, ultimate tensile strength of 78-80% less, percentage elongation of 57-79% less, and fatigue strength of 6-43% higher when compared with aluminum 360, 380, 383, and B390 standards. It was observed that the local scraps were not suitable to produce motorcycle brake shoe. Therefore, some quantities of Al - Si 50 and Al – Cu 33 should be incorporated into the scrap to meet up with aluminum 360, 380, 383 and B390 standard.

1.0 INTRODUCTION

Brake shoes are essential parts of brake drum system used mostly in motorcycles, which hold and support the frictional materials by providing strength against the walls of a rotating drum wheel when brake is applied intermittently. The motorcycle brake shoe (Figure 1) are two mechanical devices, curved in shape with friction lining that inhibits motion by absorbing energy from a moving system (Bhandari, 2010). The cam is a simple machine that actuates the brake shoe by forcing them against the rotating drum. When the brake pedal is applied, the two curved brake shoes, which have a friction material lining, are forced by hydraulic wheel cylinders or by the cam against the inner surface of a rotating brake drum. By the tribological action between the frictional materials and the walls of the drum, the motorcycle is slowed down or completely brought to rest (Thompson, 2013).

Hence, materials used to produce brake shoes should have stable and reliable strength and fatigue properties under some conditions of load, velocity, and environment, and high durability (Afolabi and Kehinde, 2019).

Worldwide demand for motorcycle is forecast to increase six percent annually, with over 132 million units, in 2018, valued at 120 billion USD Tiwari (2014). World bank forecasted a considerable number of motorcycles, 7.2 million units on Nigeria roads by 2020 (Cervigni *et al.*, 2013). According to Afolabi and Kehinde (2019), this tremendous increase will consequently have a negative influence on the economic downturn of Nigeria if all parts are basically imported, hence the need to produce some of its part locally. Afolabi and Kehinde (2019) wrote on the application of selection software for materials selection for motorcycle brake shoe using the Granta software and their results was validated with some brake shoe samples in the market, the authors selected the following materials suitable for motorcycle brake shoe; Al 360, Al 380, Al 383, Al B390.

In this study, locally available aluminum scraps were characterized, their results were compared with Al B390, Al 380, Al 383, Al 360 standards as found suitable for motorcycle brake shoe production and the aluminum scraps were upgraded analytically to meet the appropriateness of the brake shoe.

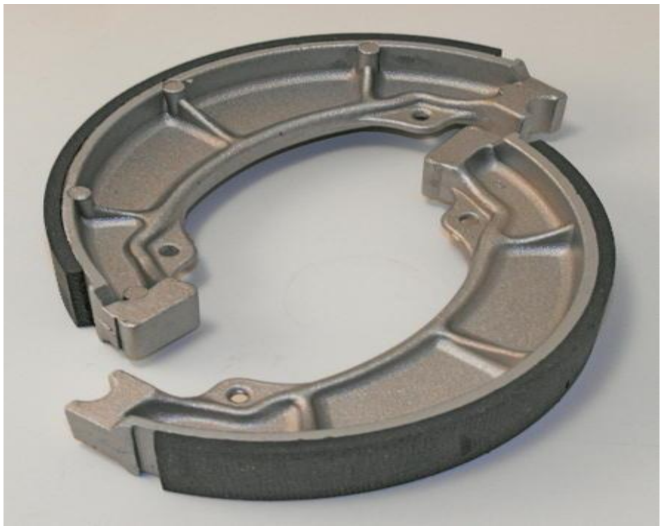

Figure 1: Motorcycle Brake Shoe

The success of the research work shall have a positive effect on the gross domestic product of Nigeria as it will determine the suitability since aluminum scraps will be sourced locally and from domestic aluminum industries for the production of motorcycle brake shoe. In addition, the production of motorcycle brake shoe in Nigeria has received little or no attention in the literature. Therefore, the results of this research will provide data base line on domestication of production of motorcycle brake shoe in Nigeria.

Table 1: Chemical compositions of Aluminum B390, 380, 383, 360 (NADCA, 2015)

Element	B 390(%)	Al 380(%)	Al 383(%)	Al 360(%)
Si	16.0-18.0	7.5-9.5	9.5-11.5	9.0 - 10.0
Fe	0.1 max	2	1.3	2
Cu	4.0-5.0	3.0-4.0	2.0-3.0	0.6
Mn	0.5	0.5	0.5	0.35
Mg	0.45-0.65	0.1	0.1	0.40-0.6
Ni	0.1max	0.5	0.3	0.5
Zn	1.5	3	3	0.5
Sn	-	0.35	0.15	0.15
Ti	0.1	-	-	
Others	0.2	0.5	-	0.25
Al. Balance (Avg)	75.65	81.05	92.65	85.65

2.0 MATERIALS AND METHOD

2.1 Materials

Aluminum scraps were gotten from two local aluminum industries in Lagos with weight of 5 kg and 2 kg and labelled scrap T and Scrap N respectively.

2.2 Characterization of Aluminum Scrap

2.2.1 Chemical analysis

To determine the chemical compositions of the scraps (labelled N & T) obtained from the local aluminum industries, the scraps were machined into 1 inch by 1 inch samples, chemical analysis of the samples were carried out using the PMI (Positive Materials Identification) machine in compliance to ASTM E1476 (standard guide for metals identification, grade verification and sorting) and ASTM E572 (standard test method for analysis of stainless steels and alloy steels by dispersive x-ray fluorescence spectrometry).

2.2.2 Tensile test

To determine the scraps resistance to tension, the scraps were sectioned and machined into round tensile samples according to ASTM A370, dimension with an overall length of 50 mm and diameter of 12.5 mm, and the tensile test was performed with the use of universal testing machine (Instron 300DX).

2.2.3 Hardness test

To determine the material resistance to indentation, the scraps were sectioned and machined into square tensile samples of 30 mm by 40 mm and Wolpert Wilson Instrument was used for the hardness test.

2.2.4 Fatigue test

Fatigue test was performed to determine the maximum load that a sample can withstand for a specified no of cycles. The test was performed according to ASTM E466 standards.

2.3 Selection of Master Alloy

To meet the chemical composition standard of Al 360, Al 380, Al 383, Al B390 as given in Table 2. Selection of appropriate master alloy was done based on the following

i. Chemical composition of Al 360, Al 380, Al 383, Al B390;

ii. Chemical composition of the available scrap N and scrap T;

iii. Oxidation of elements during the process of melting (Nwajagu,1994).

The following master alloys were selected to be suitable for this purpose, Al – Si 50(wt. %) and Al – Cu 33(wt. %).

2.4 Charge Estimation

Charge calculation was done based on the available materials and the selected master alloys.

To meet up the deficiency in the alloying element of the scraps when compared with the chemical composition standard of Al 360, Al 380, Al 383, Al B390 as shown in Table 2. The oxidation loss for silicon and copper in a crucible furnace according to Nwajagu (1994) are 1% and 1.5% respectively. Al – Si 50(wt. %) and Al – Cu 33(wt. %) were selected based requirements above. The total content of the target element is given by the relation

$$X_c = \frac{K * 100}{100 - M} \quad \text{(i)}$$

Where X_c is the total content of the target element;
K is the chemical composition value of the target aluminum alloy; M is the melting loss target element in the furnace.

The percentage quantity of Scrap T, Scrap N, Al-Si 50(wt. %), and Al-Cu 33(wt. %) required is estimated in section 2.4.1.

2.4.1 Estimation for Al B390 and scrap N

Assuming 100% of brake shoe required. The average silicon and copper content in Al B390 is 17% and 4.5% respectively. Therefore, from Equation (i)

$$Si_c = \frac{17*100}{100-1} = 17.172$$

$$Cu_c = \frac{4.5*100}{100-1.5} = 4.569$$

Let the required quantity of scrap N be X_1
Let the quantity of Al-Si 50 be Y_2
Let the quantity of Al-Cu 33 be Z_3

$$X_1 + Y_1 + Z_1 = 100 \quad \text{(ii)}$$

$$\frac{0.8049}{100} X_1 + \frac{50}{100} Z_1 = 17.172 \quad \text{(iii)}$$

$$\frac{0.0118}{100} X_1 + \frac{33}{100} Z_1 = 4.57 \quad \text{(iv)}$$

Solving Equation (ii), Equation (iii) and Equation (iv) simultaneously,

$$\begin{pmatrix} 1 & 1 & 1 \\ 0.8049 & 50 & 0 \\ 0.0118 & 0 & 33 \end{pmatrix} \begin{pmatrix} X1 \\ Y1 \\ Z1 \end{pmatrix} = \begin{pmatrix} 100 \\ 1717.2 \\ 456.9 \end{pmatrix} \ldots\ldots\ldots \text{(v)}$$

Let A be $\begin{pmatrix} 1 & 1 & 1 \\ 0.8049 & 50 & 0 \\ 0.0118 & 0 & 33 \end{pmatrix}$

Then $|A| = \begin{bmatrix} 1 & 1 & 1 \\ 0.8049 & 50 & 0 \\ 0.0118 & 0 & 33 \end{bmatrix} = 1622.85$

$|A_x| = \begin{bmatrix} 100 & 1 & 1 \\ 1717.2 & 50 & 0 \\ 456.90 & 0 & 33 \end{bmatrix} = 85487.4$

$|A_y| = \begin{bmatrix} 1 & 100 & 1 \\ 0.8049 & 1717.2 & 0 \\ 0.0118 & 456.90 & 33 \end{bmatrix} = 54358.93$

$|A_z| = \begin{bmatrix} 1 & 1 & 100 \\ 0.8049 & 50 & 1717.2 \\ 0.0118 & 0 & 456.90 \end{bmatrix} = 21679.29$

$$X_1 = \frac{85487.4}{1622.85} = 52.67$$

$$Y_1 = \frac{54358.93}{1622.85} = 33.50$$

$$Z_1 = \frac{21679.29}{1622.85} = 13.83$$

2.4.2 Estimation for Al B390 and Scrap T

Assuming 100% of brake shoe required. The average silicon and copper content in Al B390 is 17% and 4.5% respectively. Therefore, from Equation (i)

$$Si_c = \frac{17*100}{100-1} = 17.172$$

$$Cu_c = \frac{4.5*100}{100-1.5} = 4.569$$

Let the required quantity of scrap T be X_2
Let the quantity of Al-Si 50 be Y_2
Let the quantity of Al-Cu 33 be Z_2

$$X_2 + Y_2 + Z_2 = 100 \quad \text{(vi)}$$

$$\frac{1.2092}{100} X_2 + \frac{50}{100} Y_2 = 17.172 \quad \text{(vii)}$$

$$\frac{0.1868}{100} X_2 + \frac{33}{100} Z_2 = 4.569 \quad \text{(viii)}$$

Solving Equation (vi), Equation (vii) and Equation (viii) simultaneously

$$\begin{pmatrix} 1 & 1 & 1 \\ 1.2092 & 50 & 0 \\ 0.1868 & 0 & 33 \end{pmatrix}\begin{pmatrix} X2 \\ Y2 \\ Z2 \end{pmatrix} = \begin{pmatrix} 100 \\ 1717.2 \\ 456.90 \end{pmatrix} \quad \text{(ix)}$$

Let A be $\begin{pmatrix} 1 & 1 & 1 \\ 1.2092 & 50 & 0 \\ 0.1868 & 0 & 33 \end{pmatrix}$

Then $|A| = \begin{bmatrix} 1 & 1 & 1 \\ 1.2092 & 50 & 0 \\ 0.1868 & 0 & 33 \end{bmatrix} = 1600.76$

$|A_x| = \begin{bmatrix} 100 & 1 & 1 \\ 1717.2 & 50 & 0 \\ 456.90 & 0 & 33 \end{bmatrix} = 85487.4$

$|A_y| = \begin{bmatrix} 1 & 100 & 1 \\ 1.2092 & 1717.2 & 0 \\ 0.1868 & 456.90 & 33 \end{bmatrix} = 54092.25$

$|A_z| = \begin{bmatrix} 1 & 1 & 100 \\ 1.2092 & 50 & 1717.2 \\ 0.1868 & 0 & 456.90 \end{bmatrix} = 22032.39$

$X_2 = \frac{85487.4}{1622.85} = 53.40$

$Y_2 = \frac{54358.93}{1622.85} = 33.96$

$Z_2 = \frac{21679.29}{1622.85} = 13.54$

2.4.3 Estimation for Al 380 and scrap N

Assuming 100 g of brake shoe required. The average silicon and copper content in Al 380 is 8.5% and 4.5% respectively. Therefore, from Equation (i)

$Si_c = \frac{8.5*100}{100-1} = 8.596$

$Cu_c = \frac{3.5*100}{100-1.5} = 3.553$

Let the required quantity of scrap N be X_3
Let the quantity of Al-Si 50 be Y_3
Let the quantity of Al-Cu 33 be Z

$$X_3 + Y_3 + Z_3 = 100 \quad \text{(x)}$$

$$\frac{0.8049}{100} X_3 + \frac{50}{100} Y_3 = 8.596 \quad \text{(xi)}$$

$$\frac{0.0118}{100} X_3 + \frac{33}{100} Z_3 = 3.553 \quad \text{(xii)}$$

Solving Equation (x), Equation (xi) and Equation (xii) simultaneously

$$\begin{pmatrix} 1 & 1 & 1 \\ 0.8049 & 50 & 0 \\ 0.0118 & 0 & 33 \end{pmatrix}\begin{pmatrix} X3 \\ Y3 \\ Z3 \end{pmatrix} = \begin{pmatrix} 100 \\ 859.6 \\ 355.3 \end{pmatrix} \quad \text{(xiii)}$$

Let A be $\begin{pmatrix} 1 & 1 & 1 \\ 0.8049 & 50 & 0 \\ 0.0118 & 0 & 33 \end{pmatrix}$

Then $|A| = \begin{bmatrix} 1 & 1 & 1 \\ 0.8049 & 50 & 0 \\ 0.0118 & 0 & 33 \end{bmatrix} = 1622.85$

$|A_x| = \begin{bmatrix} 100 & 1 & 1 \\ 859.6 & 50 & 0 \\ 355.3 & 0 & 33 \end{bmatrix} = 118868.2$

$|A_y| = \begin{bmatrix} 1 & 100 & 1 \\ 0.8049 & 859.6 & 0 \\ 0.0118 & 355.3 & 33 \end{bmatrix} = 25986.4$

$|A_z| = \begin{bmatrix} 1 & 1 & 100 \\ 0.8049 & 50 & 859.6 \\ 0.0118 & 0 & 355.3 \end{bmatrix} = 17430.16$

$X_3 = \frac{118868.2}{1622.85} = 73.25$

$Y_3 = \frac{25986.4}{1622.85} = 16.01$

$Z_3 = \frac{17430.16}{1622.85} = 10.74$

This implies that the mass of scrap N, Al-Si 50, and Al-Cu 33 required is 73.25%, 16.01% and 10.74% respectively.

2.4.4 Estimation for Al 380 and Scrap T

Assuming 100 g of brake shoe required. The average silicon and copper content in Al 380 is 8.5% and 3.5% respectively. Therefore, from Equation (i)

$Si_c = \frac{8.5*100}{100-1} = 8.586$

$Cu_c = \frac{3.5*100}{100-1.5} = 3.553$

Let the required quantity of scrap T be X_4
Let the quantity of Al-Si 50 be Y_4
Let the quantity of Al-Cu 33 be Z_4

$$X_4 + Y_4 + Z_4 = 100 \quad \text{(xiv)}$$

$$\frac{1.2092}{100} X_4 + \frac{50}{100} Y_4 = 8.586 \quad \text{(xv)}$$

$$\frac{0.1868}{100} X_4 + \frac{33}{100} Z_4 = 3.553 \quad \text{(xvi)}$$

Solving Equation (xiv), Equation (xv) and Equation (xvi) simultaneously

$$\begin{pmatrix} 1 & 1 & 1 \\ 1.2092 & 50 & 0 \\ 0.1868 & 0 & 33 \end{pmatrix} \begin{pmatrix} X4 \\ Y4 \\ Z4 \end{pmatrix} = \begin{pmatrix} 100 \\ 858.6 \\ 355.3 \end{pmatrix} \quad \text{(xvii)}$$

Let A be $\begin{pmatrix} 1 & 1 & 1 \\ 1.2092 & 50 & 0 \\ 0.1868 & 0 & 33 \end{pmatrix}$
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Then $|A| = \begin{bmatrix} 1 & 1 & 1 \\ 1.2092 & 50 & 0 \\ 0.1868 & 0 & 33 \end{bmatrix} = 1600.76$

$|A_x| = \begin{bmatrix} 100 & 1 & 1 \\ 858.6 & 50 & 0 \\ 355.3 & 0 & 33 \end{bmatrix} = 11890.2$

$|A_y| = \begin{bmatrix} 1 & 100 & 1 \\ 1.2092 & 858.6 & 0 \\ 0.1868 & 355.3 & 33 \end{bmatrix} = 24645.50$

$|A_z| = \begin{bmatrix} 1 & 1 & 100 \\ 1.2092 & 50 & 858.6 \\ 0.1868 & 0 & 355.3 \end{bmatrix} = 16561.76$

$X_4 = \frac{118901.2}{1600.76} = 74.26$
$Y_4 = \frac{24645.50}{1600.76} = 15.40$
$Z_4 = \frac{16561.76}{1600.76} = 10.34$

2.4.5 Estimation for Al 383 and scrap N

Assuming 100 g of brake shoe required. The average silicon and copper content in Al 380 is 10.5% and 2.5% respectively. Therefore, from Equation (i)

$Si_c = \frac{10.5*100}{100-1} = 10.606$

$Cu_c = \frac{2.5*100}{100-1.5} = 2.538$

Let the required quantity of scrap T be X_5
Let the quantity of Al-Si 50 be Y_5
Let the quantity of Al-Cu 33 be Z_5

$$X_3 + Y_3 + Z_3 = 100 \quad \text{(xviii)}$$

$$\frac{0.8049}{100} X_3 + \frac{50}{100} Y_3 = 10.606 \quad \text{(xix)}$$

$$\frac{0.0118}{100} X_3 + \frac{33}{100} Z_3 \quad 2.538 \quad \text{(xx)}$$

Solving equation (x), Equation (xi) and Equation (xii) simultaneously

Solving Equation (xviii), Equation (xix) and Equation (xx) simultaneously

$$\begin{pmatrix} 1 & 1 & 1 \\ 0.8049 & 50 & 0 \\ 0.0118 & 0 & 33 \end{pmatrix} \begin{pmatrix} X3 \\ Y3 \\ Z3 \end{pmatrix} = \begin{pmatrix} 100 \\ 1060.6 \\ 253.8 \end{pmatrix} \quad \text{(xxi)}$$

Let A be $\begin{pmatrix} 1 & 1 & 1 \\ 0.8049 & 50 & 0 \\ 0.0118 & 0 & 33 \end{pmatrix}$

Then $|A| = \begin{bmatrix} 1 & 1 & 1 \\ 0.8049 & 50 & 0 \\ 0.0118 & 0 & 33 \end{bmatrix} = 1622.85$

$|A_x| = \begin{bmatrix} 100 & 1 & 1 \\ 1060.6 & 50 & 0 \\ 253.8 & 0 & 33 \end{bmatrix} = 117310.2$

$|A_y| = \begin{bmatrix} 1 & 100 & 1 \\ 0.8049 & 1060.6 & 0 \\ 0.0118 & 253.8 & 33 \end{bmatrix} = 32535.24$

$|A_z| = \begin{bmatrix} 1 & 1 & 100 \\ 0.8049 & 50 & 1060.6 \\ 0.0118 & 0 & 253.8 \end{bmatrix} = 12439.23$

$X_3 = \frac{117310.2}{1622.85} = 72.29$

$Y_3 = \frac{32535.24}{1622.85} = 20.04$

$Z_3 = \frac{12439.23}{1622.85} = 7.66$

2.4.6 Estimation for Al 383 and Scrap T

Assuming 100 g of brake shoe required. The average silicon and copper content in Al 383 is 10.5% and 2.5% respectively. Therefore, from Equation (i)

$Si_c = \frac{10.5*100}{100-1} = 10.606$

$Cu_c = \frac{2.5*100}{100-1.5} = 2.538$

Let the required quantity of scrap T be X_6
Let the quantity of Al-Si 50 be Y_6
Let the quantity of Al-Cu 33 be Z6

$$X_6 + Y_6 + Z_6 = 100 \qquad \text{(xxii)}$$

$$\frac{1.2092}{100} X_6 + \frac{50}{100} Y_6 = 10.606 \qquad \text{(xxiii)}$$

$$\frac{0.1868}{100} X_6 + \frac{33}{100} Z_6 = 2.538 \qquad \text{(xxiv)}$$

Solving Equation (xxii), Equation (xxiii) and Equation (xxiv) simultaneously

$$\begin{pmatrix} 1 & 1 & 1 \\ 1.2092 & 50 & 0 \\ 0.1868 & 0 & 33 \end{pmatrix} \begin{pmatrix} X4 \\ Y4 \\ Z4 \end{pmatrix} = \begin{pmatrix} 100 \\ 1060.6 \\ 253.8 \end{pmatrix} \qquad \text{(xv)}$$

Let A be $\begin{pmatrix} 1 & 1 & 1 \\ 1.2092 & 50 & 0 \\ 0.1868 & 0 & 33 \end{pmatrix}$

Then $|A| = \begin{bmatrix} 1 & 1 & 1 \\ 1.2092 & 50 & 0 \\ 0.1868 & 0 & 33 \end{bmatrix} = 1600.76$

$|A_x| = \begin{bmatrix} 100 & 1 & 1 \\ 1060.6 & 50 & 0 \\ 253.8 & 0 & 33 \end{bmatrix} = 117310.2$

$|A_y| = \begin{bmatrix} 1 & 100 & 1 \\ 1.2091 & 1060.6 & 0 \\ 0.1868 & 253.8 & 33 \end{bmatrix} = 31118.28$

$|A_z| = \begin{bmatrix} 1 & 1 & 100 \\ 1.2092 & 50 & 1060.6 \\ 0.1868 & 0 & 253.8 \end{bmatrix} = 11647.23$

$X_5 = \frac{117310.2}{1600.76} = 73.28$

$Y_5 = \frac{31118.28}{1600.76} = 19.44$

$Z_5 = \frac{11647.23}{1600.76} = 7.28$

2.4.7 Estimation for Al 360 and scrap N

Assuming 100% of brake shoe required. The average silicon content in Al 360 9.5%. Therefore, from Equation (i)

$Si_c = \frac{9.5*100}{100-1} = 9.596$

Let the required quantity of scrap N be X_7
Let the quantity of Al-Si 50 be Y_7

$$X_7 + Y_7 = 100 \qquad \text{(xxiv)}$$

$$\frac{0.8049}{100} X_7 + \frac{50}{100} Y_7 = 9.596 \qquad \text{(xxv)}$$

Solving Equation (xxiv) and Equation (xxv) simultaneously

$$\begin{pmatrix} 1 & 1 \\ 0.8049 & 50 \end{pmatrix} \begin{pmatrix} X7 \\ Y7 \end{pmatrix} = \begin{pmatrix} 100 \\ 959.6 \end{pmatrix} \qquad \text{(xxvi)}$$

Let A be $\begin{pmatrix} 1 & 1 \\ 0.8049 & 50 \end{pmatrix}$

Then $|A| = \begin{vmatrix} 1 & 1 \\ 0.8049 & 50 \end{vmatrix} = 49.1951$

$|A_x| = \begin{vmatrix} 100 & 1 \\ 959.6 & 50 \end{vmatrix} = 4040.4$

$|A_Y| = \begin{vmatrix} 1 & 100 \\ 0.8049 & 959.6 \end{vmatrix} = 879.11$

$X_7 = \frac{4040.4}{49.1951} = 82.130$

$Y_7 = \frac{879.11}{49.1951} = 17.87$

Assuming 100% of brake shoe required. The average silicon content in Al 360 is 9.5%.

Therefore, from Equation (i)

$Si_c = \frac{9.5*100}{100-1} = 9.596$

Let the required quantity of scrap N be X_8
Let the quantity of Al-Si 50 be Y_8

$$X + Y = 100 \quad \text{(xxvii)}$$

$$\frac{1.2092}{100} X_8 + \frac{50}{100} Y_8 = 9.596 \quad \text{(xxviii)}$$

Solving equation (xxvii) and equation (xxviii) simultaneously

$$\begin{pmatrix} 1 & 1 \\ 1.2092 & 50 \end{pmatrix} \begin{pmatrix} X8 \\ Y8 \end{pmatrix} = \begin{pmatrix} 100 \\ 959.6 \end{pmatrix} \quad \text{(xxix)}$$

Let A be $\begin{pmatrix} 1 & 1 \\ 1.2092 & 50 \end{pmatrix}$

Then $|A| = \begin{vmatrix} 1 & 1 \\ 1.2092 & 50 \end{vmatrix} = 48.791$

$|A_x| = \begin{vmatrix} 100 & 1 \\ 959.6 & 50 \end{vmatrix} = 4040.4$

$|A_Y| = \begin{vmatrix} 1 & 100 \\ 1.2092 & 959.6 \end{vmatrix} = 838.68$

$X_8 = \frac{4040.4}{48.791} = 82.81$

$Y_8 = \frac{838.68}{48.791} = 17.19$

3.0 RESULTS AND DISCUSSION

3.1 Chemical Composition

Table 1 shows the chemical compositions of Aluminum B390, 360, 380 and 383. The major alloying elements in this alloy are copper and silicon while the remaining elements are trace. Table 2 shows the chemical compositions of the of the scraps obtained from the industry labelled scrap N and Scrap T, the results show that the local aluminum scraps conform to the 6xxx series of aluminum alloy and have silicon deficiency of 86-95% and a copper deficiency of 69-100% when compared with Aluminum B390, 360, 380 and 383 standards.

3.2 Mechanical Properties

3.2.1 Tensile strength

Table 3 shows the mechanical properties of Aluminum B390, 360, 380 and 383, Table 4 shows the tensile test results of the scrap N and Scrap T with emphasis on yield strength, ultimate tensile strength, and percentage elongation. The results shows that scrap T and scrap N have yield strength 57-75% lower, ultimate tensile strength of 78-80% lower when compared with Aluminum B390, 360, 380 and 383. Also, scrap T and scrap N have 57% and 79% lower percentage elongation when compared to Aluminum B390, 360, 380 and 383. This reduction in tensile strength is due to the deficient silicon and copper element in the scraps.

Table 2: Chemical compositions of scrap obtained from Scrap T and scrap N

Element	Scrap N (%)	Scrap T (%)
Mg	0.36	0.4
Al	98.56	97.13
Si	0.8049	1.2092
S	ND	ND
Ti	ND	0.009
V	ND	0.027
Cr	0.0177	0.1104
Mn	0.2297	0.7453
Co	0.0066	0.0152
Ni	0.0044	0.149
Cu	0.0118	0.1868
Zn	ND	0.0016
Cd	ND	0.0027
Re	ND	0.0116
LE	Al	Al
Base Name	6063	6061

Table 3: Mechanical properties of Aluminum B390, 360, 380 and 383 (NADCA,2015)

	Yield Strength (MPa)	Percentage Elongation (%)	Ultimate Tensile Strength (MPa)	Hardness (Kgf/mm^2)	Fatigue Strength (MPa)
Al					138
B390	248	87.5	320	120	
Al 380	159	87.5	320	80	138
Al 383	152	87.5	310	75	145
Al 360	172	87.5	300	75	138

Table 4: Yield strength, percentage elongation and ultimate tensile strength of scrap T and scrap N.

	Scrap T	scrap N
Yield Strength (MPa)	62.98	65.54
% Elongation	37.72	18.2
UTS (MPa)	137.28	116.93

3.2.2 Fatigue strength

Table 5 shows the fatigue strength and number of cycles to failure of the scrap N and Scrap T. The result shows that the aluminum scrap has a higher fatigue strength in the range of 6-11% higher for scrap T and 40-43% higher for scrap N when compared to Aluminum B390, 360, 380 and 383 standards. This higher fatigue strength is due to the deficiencies of the scraps in silicon and copper contents. While the fatigue strengths of the scraps may be positive attributes, the deficiencies in the respective alloying elements are detrimental to other important properties.

Table 5: Fatigue strength and Number of fatigue cycle of scraps obtained from Scrap T and scrap N.

	Fatigue Strength (Mpa)	Cycle to Failure
Scrap T	154.93	116342.32
Scrap N	240.08	109434.63

3.2.3 Hardness

Table 6 shows the Brinell hardness number of the scraps which was converted from Vickers hardness according to BS EN ISO 18265:2003. The result shows the aluminum scrap has a lower value of 44-69% when compared with aluminum B390, 360, 380 and 383 standards. The decrease in hardness property is due to the lower value of silicon and copper in the scraps which tends to reduce the mechanical property in the alloy.

Table 6: Brinell hardness number of scraps obtained from Scrap T and scrap N.

Hardness Number	Scrap T (Kgf/mm^2)	Scrap N (Kgf/mm^2)
1	43.4	37.2
2	41.4	37.5
3	40.2	35.4
Avg	41.67	36.70

The results of the compositional analysis and property determination clearly show that the locally sourced aluminum scraps would require modifications both in alloying and treatment to meet the requisite attributes for the quality required for the brake shoe.

3.3 Charge Estimation

From the analytical estimation, it can be observed that the mass of scrap N, Al-Si 50, and Al-Cu 33 required to meet up the chemical composition of Al B390 is 52.67%, 33.50% and 13.83% respectively while the mass of Scrap T, Al-Si 50, and Al-Cu 33 required to meet up the chemical composition of Al B390 is 53.40%, 33.96% and 13.54% respectively.

The mass of scrap N, Al-Si 50, and Al-Cu 33 required to meet up the chemical composition of Al 380 is 73.25%, 16.01% and 10.74% respectively while the mass of Scrap T, Al-Si 50, and Al-Cu 33 required to meet up the chemical composition of Al 380 is 74.26%, 15.40% and 10.34% respectively.
The mass of scrap N, Al-Si 50, and Al-Cu 33 required to meet up the chemical composition of Al 383 is 72.3%, 20.04% and 7.66% respectively while the mass of Scrap T, Al-Si 50, and Al-Cu 33 required to meet up the chemical composition of Al 383 is 73.28%, 19.44% and 7.28% respectively.

The mass of scrap N, and Al-Si 50 required to meet up the chemical composition of Al 360 is 82.13% and 17.87% respectively while the mass of scrap T, and Al-Si 50 required to meet up the chemical composition of Al 360 is 82.81% and 17.19% respectively.

4.0 CONCLUSION

Local aluminum scraps obtained were found not suitable to produce motorcycle brake shoe when compared with Al B390, 380, 383 and 360 standards selected to be appropriate for motorcycle brake shoe production. The results of the compositional analysis and property determination clearly show that the locally sourced aluminum scraps would require modifications both in alloying and treatment to meet the requisite attributes for the quality required for the brake shoe.

The scraps require an appropriate quantity of Al-Si 50 and Al-Cu 33 to meet up the deficient alloying elements in Al B390, 380, 383 and 360 standards and improve its mechanical properties.

Analytical estimation of the appropriate charge was done to meet the deficient alloying element in the scrap.

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