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Effect of Marula Seed Cake on the Mechanical Properties of Aluminium Alloys for the Production of Brake Pad

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ABSTRACT

Reinforcing composites with different agricultural byproducts is cost highly effective and friendly to the environment due to their abundant availability, low cost, renewability and biodegradability. The awareness of environmental sustainability drives composite industry in such for natural reinforcement materials. In this research, the effects of marula seeds cake (MSC) on the mechanical properties of Al–Mg–Si/carbonized marula particulate composites for the production of brake pads were investigated. The compositions of the composite include a matrix of Al–Mg–Si with carbonized marula cake particulates as reinforcement ranging from 0% to 14% at an interval of 2%. Physical and mechanical properties of the composites were examined. The results revealed that with increasing the reinforcement content, density decreased while yield, ultimate tensile strength and hardness values increased progressively, but the impact and percentage elongation decreased. The results, it showed that marula seeds cake (MSC) as a promising material can be used as reinforcement material for the production of composites in automotive and other related industry.

Keywords : Al-Mg-Si, Composite, Marula Seed Cake, Mechanical Properties

I. INTRODUCTION

The history of mankind has witnessed several surges in the field of research and development in Science, Engineering and Technology. According to Bryan, (1999) and Chawla, (1998) that many of our modern technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics, and polymeric materials. This is especially true for materials that are needed for aerospace, underwater like submarine and transportation applications. As we were aware, that engineering applications require materials that are stronger, lighter, and less expensive with excellent abrasion and corrosion resistance like composite.

A composite material is a material made from two or more constituent materials with different physical or chemical properties that, when combined, produce a material with characteristics different from individual components. There are three types of man-made composites, these are: ceramic matrix composite; metal matrix composite and polymer matrix composite. Chawla (1998), Bryan (1999) and Lubin (1992) explained that reinforcements for composite materials can be in the form of fibres, particles, or flakes embedded in a matrix. Each has its own unique application, although fibres are the most common in composites and have the most influence on properties (Lubin, 1992). According to Robert Quaarshie and Joe Carruthers (2009), research efforts put in place to resolve these problems are mostly channeled towards selecting the right choice of reinforcing materials. This is an indication that the reinforcing materials play significant role in determining the overall performance of the composites.

There have been researches for the production of biocomposite materials by many researchers like Alwani et al (2014), Averousa and Boquillon (2004) who investigated the methods of using agricultural waste for biocomposite applications on thermal and mechanical behavior of reinforced agro-materials respectively. Supriya Mishra et al (2004) investigated the use of lignocellulosic fibres, pineapple leaf fibre (PALF) and sisal as reinforcements in thermoplastic and thermosetting resins for developing low cost and lightweight composites as an emerging field of research in polymer science and technology. Sunil et al (2012) undertake an experimental study to determine the effect of sisal fibre as agro-waste and its utilization on bending properties of sisal fibre reinforced composites, for the improvement of its static and dynamic properties. Fidelis et al (2013) worked on maize stalk as reinforcement in natural fibre composites and concluded that maize stalk will be beneficial as reinforcement for the production of automobile interior parts.

The mechanical properties of composites or biocomposites are generally affected by the size, shape and volume fraction of the reinforcement, matrix material and the reaction at the interface were reported by researchers like Robert Quaarshie amd Joe Carruthers (2014),who explained that hemp, jute and flax are common natural fibre reinforcements in biocomposites and have good mechanical properties and further stated that the fibre quality is influenced by the harvesting and processing steps and there is a move to reduce the on-field processing to improve consistency and reduce cost, while Cullen et al (2013) investigated sunnhemp, coir, banana and sisal fibres reinforced hybrid composite and made the findings that these reinforced biocomposie had significant strength increase to be used in the production of automobile parts. Amar et al (2005) investigated series of fibres as viable alternative to glass fibre composite particularly in automobile, packaging, building and consumer product industries and becoming one of the fastest growing additives in thermoplastic.

The literature shows that most the researchers on marula seeds were on its nutritional and medicinal values, in addition to cosmetics and make-up formulations. However, there was little research on the possibility of using marula seed cake by-products as a protein supplement for goats fed grass hay and as a protein source in commercial cattle fattening diets as reported by Victor Mlambo et al (2011 and 2016), but there were research on using these by-products for other industrial purposes.

The purpose of this research is therefore to exploit the usefulness of marula seed cakes, the by-product from the oil extraction for the production of biocomposite material. The ever increasing demand for low cost reinforcement material stimulated this research. Marula tree (sclerocarya birrea) (Fig. 1), its seeds and extracted kernel is a multi-purpose tree found mostly in tropical region, mostly in sub-Sahara Africa. It is an indigenous tree found in Northern Nigeria..

Figure 1. Marula tree with its seeds and extracted kernel

II. METHODS AND MATERIAL

2.1 Sample Collection

Marula trees were identified at the permanent site of Kebbi state University of Science and Technology, Aliero, Kebbi State in Nigeria. Ripened fresh fruits were collected from marula trees within the premises of the Faculty of Engineering. The aluminium alloy (6061) was obtained from Nigerian Aluminium Smelter company in Akwa Ibom state, Nigeria..

2.2 Metal Matrix Material

In the present experimental investigation, the matrix material used is an aluminium alloy (6061) whose chemical composition (in weight %) is listed in Table 1. Al6061 is a precipitation hardening aluminium alloy, containing Mg and Si as its major alloying elements. It has good mechanical properties. The melting point of aluminium 6061 is low (710°C).

Table 1. Chemical composition (wt %) of Aluminium alloy used

All oy	Chemical composition								
	Mg	Si	Cu	Mn	Zn	Fe	Ti	Cr	Al
6061	1.15	0.70	0.20	0.14	0.24	0.45	0.20	0.15	Bal.

2.3 Reinforcement Material

The role of the reinforcement in a composite material is fundamentally to increase the mechanical properties of composite. The reinforcements used in this experimental investigation is carbonized marula seeds cake.

III. Experimental

3.1 Method of oil extraction and cake removal

The marula seed nuts were sun dried in yards and mechanical decorticated to expose the kernels. The kernels were roasted at temperatures between 45^0C and 47^0C to make oil extraction easier and reduce the moisture content (Shone, 1979). Oil from kernels is extracted by using mechanical (traditional) method of extraction, with separating oil and the cake. The expressed oil was collected for analysis, while residual marula seed cake (MSC) that remains after oil extraction was dried and grinded with a ball mill at 250 rpm into marula cake powder (uncarbonized particles) used as reinforcement for the production of biocomposite.

The powder particles were packed in a graphite crucible and was heated in an electric resistance furnace at 950^0C to form marula ash (carbonized particles). The particle size analysis of the marula cake particles was carried out in accordance with BS1377-1990 (Sunil et al, 2014). These particles were placed onto a set of sieves that was arranged in descending order of fineness and shaken for 15 minutes as recommending time to achieve complete classification the particles that was retained in BS. 100 μm was used in this study.

3.2. Methodology

The fabrication of metal matrix composite used in the present study was carried out by stir casting method. Stir casting is the simplest and the most economical method for the fabrication of metal matrix composite (Bryan Harris, 1999 and Suong, 2009). A stir casting setup consists of a resistance muffle furnace and a stainless steel stirrer which is connected to a variable speed vertical motor arrangement with range of 80 to 890 rpm by means of a steel shaft as shown in Figure 2. In this present experimental method the molten aluminium matrix metal AL6061 is melted at a definite temperature nearby 710^0C in the muffle furnace and then a preheated reinforcement material with a (wt % of 0 to 14% at an interval of 2% each of marula particulate is mixed with molten Aluminium 6061 and then stirrer is used to mix the mixture. In order to achieve the uniform properties of the composite, the distribution of the reinforcement material in the matrix alloy must be maintained. The inert gas (nitrogen) is used to prevent the oxidation of mixture. The mixed molten MMC is then poured into a mould and is then allowed for the solidification for some time. The schematic diagram shows various parts of stir casting machine as well as process.

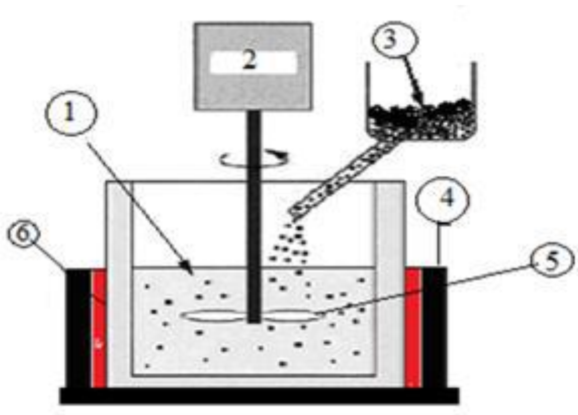

Figure 2. Stir casting setup. 1. Aluminium liquid, 2. Electric motor, 3.Marula seed cake, 4. Insulated board, 5. Blades, 6. Crucible

The density of the composite production was determined in order to study the effect of the MSC wt% on the densities of the composite produced. The density for each composite sample was determined by accurately weighing the sample using a high precision electronic weighing balance.

Tensile test was carried out according to ASTM (A 370-2002). Samples for the test were machined to cylindrical specimen configuration with 6 mm diameter and 30 mm gauge length. Tests were conducted by using Instron Universal Testing Machine-1195 connected to computer to draw the stress-strain curve as shown in Fig. 3. Each tensile specimen is positioned in the Instron universal tester and then subjected to tensile load, as the specimen stretches the computer generates graph as well as all the desire parameters until the specimen fracture. Also, the impact test was conducted with impact testing machine Fig. 5 at room temperature as described in ASTM E23 to determine the toughness of the material. Impact test is a standard method of determining the impact resistance of materials. An arm held at a specific height (constant potential energy) is released. The arm hits the sample and breaks it. From the energy absorbed by the sample, its impact energy is determined. Brinell testing machine Fig. 4 was used for testing the hardness of the samples after grinding and polishing them down to 1 μm. At least 5 indentations on two polished specimens were done to obtain data of hardness.

Figure 3. Experimental set up for tensile test with universal testing machine, Instron 1195

Figure 4. Brinell Hardness Testing Machine

Figure 5. Experimental set up for impact test.

IV. RESULTS AND DISCUSSION

Fig. 6 shows the effect of volume fraction on the tensile strength, yield strength and hardness values of the test specimens. The results revealed that the tensile strength and hardness values increase sharply by 17.5% at 14 wt, % carbonized marula cake and 9.89% uncarbonized marula cake, while the hardness values increased by 24.78% at 14 wt, % carbonized marula cake and 12.95% at 14 wt, % uncarbonized marula cake . Figure 7. Illustrates the influence of volume fraction of MSC on the impact energy and density of the specimens. It shows that impact energy and density values decreases as the volume fraction of MSC increases. The impact energy decreased by 14.43% at 14 wt, % carbonized marula cake and 18.58% uncarbonized marula cake, while the density values decreased by 8.6% at 14 wt, % carbonized marula cake and 6.7% at 14 wt, % uncarbonized marula cake. The increase in tensile strength and hardness values from these results of investigation, we concluded that the carbonized reinforcing marula particulates can be used to enhance the properties of alluminium alloy 6061 for engineering applications.

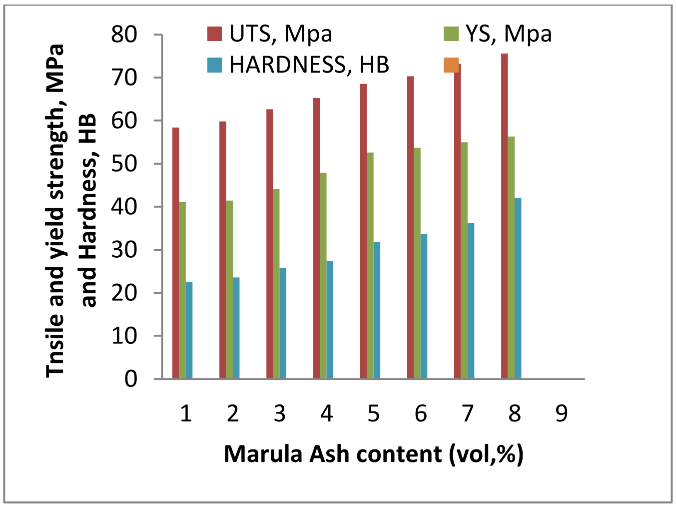

Figure 6. Effect of MSC on the strength and hardness of Al6061

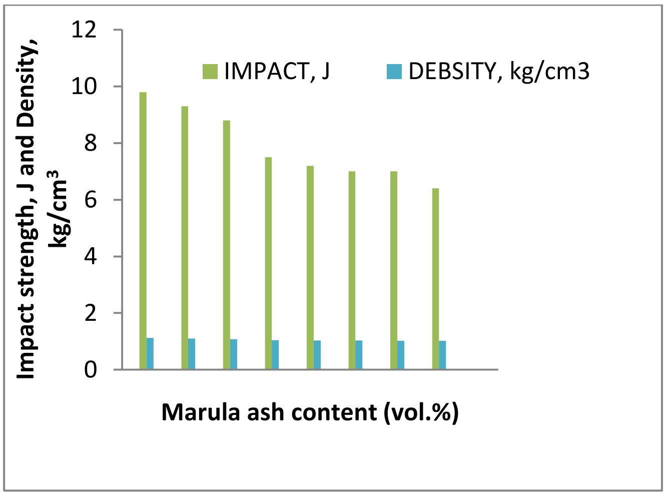

Figure 7. Effect of MSC on the impact strength and density of Al6061.

V. CONCLUSION

From the results of the investigation, the following conclusions were made.

1. Aluminium based metal matrix composites are successfully fabricated by stir casting technique with fairly uniform distribution of marula seed cake.
2. The carbonized reinforcing marula particulates can be used to enhance the properties of Al–Mg–Si (6061) alloy for engineering applications.
3. Addition of by-product marula cake enhanced the existing material.
4. The tensile strength, yield strength and hardness of 6061/MC increased with increase of volume percentage of particulate.
5. An estimated value of particles content needed in order to increase the mechanical properties of existing material.

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