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IMPACTS OF COVID-19 PANDEMIC ON NIGERIA'S ECONOMY: EFFECTIVE FOUNDRY TECHNOLOGY AS A SUSTAINABLE SOLUTION

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ABSTRACT

This study considered the effect of the Covid-19 pandemic on the economy of Nigeria and investigated the effective application of foundry technology to proffer a sustainable solution to the problem. Domestication of production of motorcycle components, being a significant means of transportation that is required for the development of any society was considered. Aluminium scraps from a waste dump and Belle and Oyun natural moulding sands in Kwara State, Nigeria, which have been previously recommended for non-ferrous casting in previous studies were considered and used for casting of motorcycle/tricycle parts (centre stand and brake pedal) using AFS guidelines. The scraps' chemical compositions were analysed. Thereafter, some mechanical properties with the microstructure of the aluminium casts and that of commercially obtained imported types were examined using appropriate ASTM standards. Cast aluminium alloy produced using scrap had no casting defects and had some mechanical properties comparable to those available on the markets (imported). Thus, effective usage of naturally available moulding sands in Nigeria for foundry applications would help to proffer sustainable solutions to the nation's economic problem as a result of the adverse effects of the Covid-19 pandemic.

KEYWORDS: Covid-19, Aluminium alloy, Casting, Foundry, Moulding sand

1. Introduction

The effects of the Coronavirus pandemic (Covid-19) in combination with a decline in the oil price are generating Nigeria's financial and economic collapse (economic crises or recessions) [1-4]. According to Saliu (2021), the recent Nigerian economic recession is the worst recorded in almost four decades by the West African nation [1]. The economy of Nigeria, which had earlier been fragile is being crumbled and traumatic as a result of the sharp decline in productivity, jobs, and income due to the Covid-19 pandemic lockdown [3, 4]. The economic activities have been destabilized due to disruption in the supply chain across sectors, collapse in capital flight, commodity prices, and turmoil in the capital market during and after the lockdown.

National Bureau of Statistics (NBS) data (as of September 2020) revealed that Nigeria's trade stood at -14.95% as of the second quarter of the year 2020 with a decrease of -17.97% if compared with that of the year 2019. The nominal gross domestic product (GDP) growth in manufacturing was 0.14%, which was -37.92% lower than that of 2019; the agricultural sector recorded a decrease of -0.21% and -0.62% compared to that of 2019 and 2018 respectively [5].

The oil and gas sector, which is the main source of revenue for the Nigerian government has also been significantly affected by the spread of the Covid-19 pandemic. The oil prices rapidly decreased in value by 60%. Thus, the Nigerian economy is expected to be weakening as a result of the pandemic [6]. In the year 2020, negative cumulative GDP (-2.48%) was recorded for the first nine months [1]. The National Bureau of Statistics revealed that negative growth was recorded for two consecutive quarters in Nigeria in the year 2020. NBS reports have shown that the results of COVID-19 with a significant low volume of exports rendered over 21 million Nigerians unemployed (27% of the labor force) and such resulted in Nigeria's economy being contracted by 6.1% year on year in the second quarter of the year 2020, which is the steepest in the last ten years [7].

Nigeria as a country needs to rapidly embark on the economic diversification of its economy from oil and gas, which can be achieved through local production of goods (like engineering products, tools and devices, vehicle parts, among others) and effective utilization of its resources. This will also help in the establishment and sustainability of Small and Medium Scale Enterprises (SMSE) that are required to provide a sustainable solution to the problem of the economic downturn due to the lockdown as a result of the COVID-19 pandemic and the issue of unemployment among the nation’s youth [8]. Industrialization is an essential factor in achieving Nigeria’s desired development [9,10]. Production capacity from the availability of raw materials to the technology used in transformation of the raw materials to finished products determines the success of industrialization [9].

For the development of any society, transportation is significant as it facilitates community development, optimum utilization of resources, allows and enhances the movement of people, and offers accessibility to hitherto inaccessible areas easy [11]. The economic development of many nations could be hindered due to a lack of transport facilities since transportation forms the basis of all socio-economic interaction [12, 13].

The three main modes of transportation in Nigeria are road, air, and marine. Road dominated the means of transportation in urban areas of Nigeria [14]. Road transport in Nigeria is said to account for more than 90% of the movement of goods and passengers in the country as of now [12]. Ezeife and Bolade (1984) revealed that the road as a mean of transportation had the greatest influence on the socio-economic development of Nigeria [15]. Road transportation is the most prevalent and effective form of transportation in Nigeria [12, 13, 16, 17].

Road transportation in Nigeria involves the use of bicycles, tricycles, motorcycles, cars, buses, and different types of trucks among others. Recently, the use of tricycles and motorcycles for transporting goods and services for private and commercial purposes is prevalent in Nigeria, due to population rise, unemployment and the lack of an effective urban transport infrastructure scheme [11]. The collapse of the public intra-city transport system is another factor that increased the use of motorcycles in commercial transportation by about 70% and this sector is dominated by private entities [14, 18]. One of the various means of transportation currently available in this country is the tricycle (KEKE NAPEP) which is also a source of empowerment for the youth and a source of living for a large number of people in this country [19].

Through several studies of motorcycles and tricycles usage in public transportation for commercial or personal uses in Nigeria, it was discovered that a decrease in the supply of new vehicles, economic depression, rapid rate of urbanization with inadequate transport facilities, unemployment, relative lucrative nature of using motorcycle and tricycles or bicycle for transportation, enhance mobility and accessibility to areas with bad road network or where there is traffic congestion, low fuel consumption, fastness, reliability and flexibility, a government programme in eradicating poverty in the country are significant factors that contributed their usage in the country [11, 14, 20-23]. Brands of the motorcycle were diffused into the Nigerian market as an initiative of the Federal Government in the year 2002 to ease transportation problems and create an avenue for self-employment for the unemployed and the jobless Nigerians [24]. For transportation in recent times, the use of paratransit (motorcycles and tricycles) is popular and becoming a mean of full public transport in some areas of the country, due to the failing mass transit infrastructure and road network [25]. Low initial cost, low maintenance cost, ease in modifying, reliability, and fuel efficiency contribute to a rapid increase in their use for commercial purposes [25-28].

The demand for motorcycles / tricycles and their components (parts) in Nigerian markets is tremendously high. The components (such as brake pedal, stand, clutch handle, etc.) need replacement due to failure in service. The motorcycles and tricycles with their components are imported to Nigeria mostly from Hong Kong (China), Japan, and the United States of America and some of these motorcycle parts are manufactured and produced using materials like aluminium alloys or metals. Cast-iron, mild steel, aluminium, composite materials, and polymeric materials were employed in the manufacture and production of brake pedals [29-33]. The brake pedal is one of the major parts of the tricycle, which are imported into Nigeria over the year that normally fails [19]. The center stand is used to prevent the loading of the tires of the motorcycle

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when maintenance works are required on a motorcycle to prevent leakage [27].

The appropriate use of a country’s foundry technology plays an important role in the development of the nation’s industrial sector development which in turn contributes to its economic growth [34]. Production of castings is essential for the development of every nation in transportation, farming, construction, and mining [35]. Among all foundry materials for casting, sand has been found to be very important because sand is abundant, cheap, readily available, and suitable for casting all kinds of metal [36]. In metal casting manufacturing processes, sand casting is extensively used since almost all metals can be produced by sand casting.

In the manufacturing of metallic engineering wares, vehicle parts, tools, devices, and equipment such as engine blocks, valves, cylinder heads, pump cases, and machine tool bases, metal casting is found suitable [37]. Foundry technology is appropriate for all metals of different sizes and sand cast is found suitable [38, 39]. In the present manufacturing process, the sand-casting process is the most commonly used in metal casting [39]. In the foundry, moulding sand is an important material [40], as the properties of the sand used in casting, largely determine the quality of the cast products [34, 41-44].

In Nigeria, moulding sands have been said to be available but underutilized due to a lack of information about their properties [45, 46]. Studies have revealed that Nigeria is endowed with natural resources like foundry sands which were available and scattered all over the towns and villages in Nigeria in large quantities [9, 34, 47]. These resources (sands) have been used for the production of expensive high-performance engineering equipment; the casting of aluminium cooking utensils, decorative ornament and others for these last decades [34, 47]. Most foundries in Nigeria embark on sand casting without appropriate properties information of the sands used for casting, which will affect the physical, chemical and mechanical properties of the cast [48]. Proper characterization of moulding sand will help eradicate desirable fixtures and produce quality cast. Belle and Oyun natural moulding sand abundantly available in Kwara State have been characterized and found suitable for foundry applications [45, 46].

Aluminium scraps are now becoming more available as a result of an increase in the use of aluminium in many industry sectors especially the automotive and packaging sector [49]. In the automobile sector, aluminium is used in the production of parts, these parts have their service life which is then replaced with another. After which the failed aluminium parts become scrap. While in the packaging sector, aluminium has found increased use as foils and cans due to its chemical inertness, after the products are used [49]. Manufacturing of parts from aluminium scrap requires about 95% less energy than the production of aluminium from its ore [50]. Using these scraps in re-manufacturing aluminium utensils, automobile parts and packaging items will help improve the economy of the country. Hence, proper utilization of the abundantly available moulding sand and aluminium scraps in the production of some of the motorcycle parts will help in reducing the level of importation, reduce the level of unemployment and in turn help the nation’s economic growth and development. Therefore, in this study application of some locally sourced moulding sands and aluminium scraps for the production of motorcycle parts through foundry application to proffer a sustainable solution to the effect of Covid-19 on Nigeria’s economy through industrialization. According to Bala *et al.*, industrialization serves as the only means that Nigeria aims to become one of the twenty most developed nations [51].

The production of the motorcycle’s components can be domesticated in Nigeria due to the abundant availability of the required mineral resources needed in the processes of such parts, such as moulding sand and aluminium. Nigeria is well blessed with viable moulding sands that can be used to cast both ferrous and non-ferrous metals [45, 46].

This paper provides an overview and suitability of available natural moulding sands in Belle and Oyun communities in the Kwara State of Nigeria, which have been characterized [45, 46] for the casting of tricycle brake pad and motorcycle centre stand using aluminium scraps. Successful application of the moulding sands to produce the motorcycle stand and tricycle brake pedal will help to reduce the level of importation of such cycle parts into Nigeria and help to curtail the effect of the Covid-19 pandemic on Nigeria’s economy by facilitating their local production and a long-run boost for the economic growth of the country.

2. Materials and methods

2.1. Materials

Samples of the natural moulding sands used in this study were collected from the Belle community, near the river Niger in Bacita and Oyun river bank in Ilorin East of Kwara State. The American Foundry Standard (AFS) for moulding sand sample collection and preparation procedures were adopted in collecting and preparing the moulding sands’ samples for the study (Details in [45, 46]). Figures 1 (a and b) show

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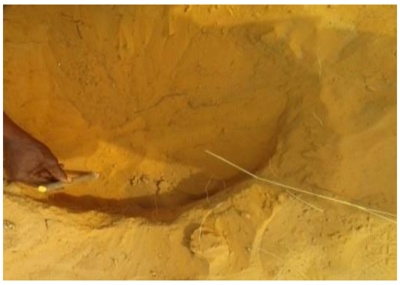
the deposits where the natural moulding sands were obtained.



a

b

Fig. 1. *(a) Belle natural moulding sand deposit (b) Oyun natural moulding sand deposit*

Fig. 2. *Samples of the Aluminium scraps*

The aluminium scraps (Figure 2) used for the casting were procured from a Metal Scraps Seller at Popo-Igbona Area, Ilorin, Nigeria. The aluminium scraps of 10 kilograms were purchased. Commercially available PVC pipe of 20 mm diameter was also obtained and cut to a length of 110 mm and used in the preparation of the pattern for the casting of the specimen.

2.2. Methods

The elemental chemical compositions of the Belle and Oyun natural moulding sands were carried out using X-Ray Fluorescence (XRF) Analyser (Shimadzu 720, Shimadzu Cooperation, United Kingdom made) at Materials Testing Laboratory, University of Lagos, Nigeria in accordance with America Foundrymen’s Society (AFS) recommendation in line with practices of earlier researchers as earlier described in previous studies [45, 46, 52].

The properties of the moulding sands, such as the grain fineness number, permeability, refractoriness, green compressive strength, dry compressive strength, specific gravity, moisture content, clay content, and flowability were determined at the Soil Testing Laboratory, Department of Civil Engineering, The Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria. The procedures used were in accordance with the guidelines in AFS Standards for the determination of these properties as previously discussed in Shuaib-Babata et al. [45, 46].

Determination of the chemical compositions of the Aluminium scraps used in this study was carried out using Positive Material Identification (PMI) on Olympus Delta Professional (serial number: 5407234) at Midwal Engineering Services Limited, Lekki, Lagos State, Nigeria. The test was done using the principle of Energy Dispersive X-Ray Spectroscopy (EDS). The sample specimen surface was ground and smoothened to remove any debris on the surface and give a very fine-smooth surface, thereafter analysed with the use of a computer system interface.

The steps in the production of the sand cast are illustrated in Figure 3.

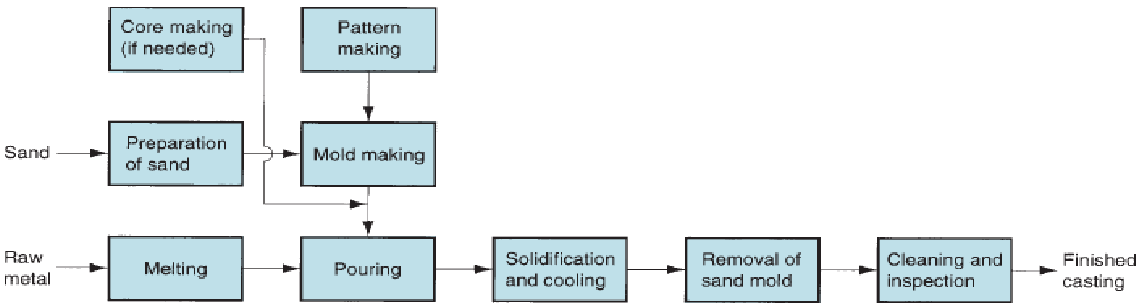


Fig. 3. *Production sequence for sand casting* [53]

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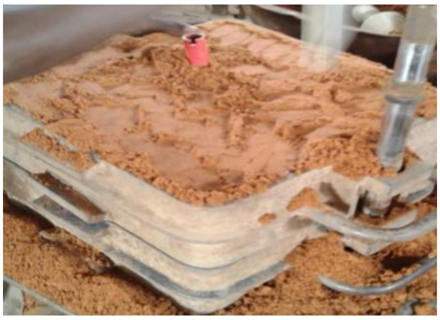
Each of Oyun and Belle natural moulding sand was separately sieved and used in preparing a mould, having the desired motorcycle centre stand and tricycle brake pedal cavity respectively. A sample of each of the natural moulding sands was then thoroughly washed and sun-dried to remove the excess moisture. Thereafter, each sand sample was mixed with water in separate containers. Two full head pan of silica sand was mixed together with one litre of water to produce adequate bonding of the mixture which yield the strength required of the sand. Thereafter, a mould was prepared with this sand mixture along with the PVC pattern to form the specimens' cavities in the mould. The mould contained 5 cavities for the specimens (5 pieces) used to carry out the necessary testing of the final cast. Figures 4-6 show some of the mould making processes.

a

b

Fig. 4. *(a) Sample of Oyun natural moulding sand (b) Sample of Belle natural moulding sand*

a



b

Fig. 5. *After filling the mould with the moulding sand*

The aluminium scrap was melted into a molten metal stage in a crucible furnace at the Foundry Workshop of the Materials and Metallurgical Engineering Department, University of Ilorin, Nigeria. It was allowed to melt at about 700 ^oC which is above its normal melting temperature to minimise the drop in the molten metal temperature that would occur as a result of transporting the molten metal from the furnace to the mould cavity. The molten aluminium was poured into the prepared moulds and left to solidify and thereafter, the castings were removed from the moulds. Excess materials in the castings were machined to attain precision. The major common commercially available (imported) tricycle brake pedal models are shown in Figure 7, while details of the casting processes are shown in Figures 8-17.

(a) Bajaj tricycle model brake pedal

(b) TVS tricycle model brake pedal

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(c) Samples of imported TVS tricycle brake pedal with the wooden pattern made

Fig. 7. *The major common tricycle brake pedal models in Nigeria*

Fig. 8. *Wooden patterns used to produce the casts (tricycle brake pedal and motorcycle centre stand)*

Fig. 9. *Cavity of the motorcycle centre stand and tricycle pedal patterns in the mould*

Fig. 10. *The cope and drag after removal of patterns*

Fig. 11. *The moulds ready for pouring*

Fig. 12. *Pouring of the molten metal in to the specimen mould and knocking out operation*

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Fig. 13. *Solidification of the specimen in the mould*

Fig. 14. *The cast specimens before machining*

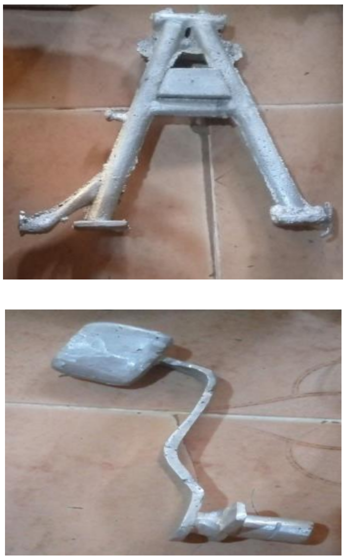

Fig. 15. *After removing the excess material from the cast specimens (machined casts)*

Fig. 16. *The produced casts (tricycle brake pedal and motorcycle stand)*

Fig. 17. *The cast specimens from the mould for various tests*

The cast products and that of the commercially obtained tricycle brake pedal and motorcycle centre stand were evaluated for tensile, impact, and hardness properties. The tensile and hardness tests were carried out at National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria using the Testometric Materials Testing Machines (UTM) (Model No 0500-10080, Win test analysis; 100 KN capacity, England made).

The specimens from each of the casts using Belle and Oyun natural moulding sands for the tensile test were machined and tested following procedures in America Standard Test for Materials ASTM E8/E8M and ASTM, B 557M – 02a standard [54, 55] for dimension and procedures for tensile testing of non-ferrous metals as a guide. Figure 17 shows both (a) diagrammatical representation of the tensile samples with dimension, (b) samples of the specimens machined for the tensile test, and (c) samples of the specimens after the test.

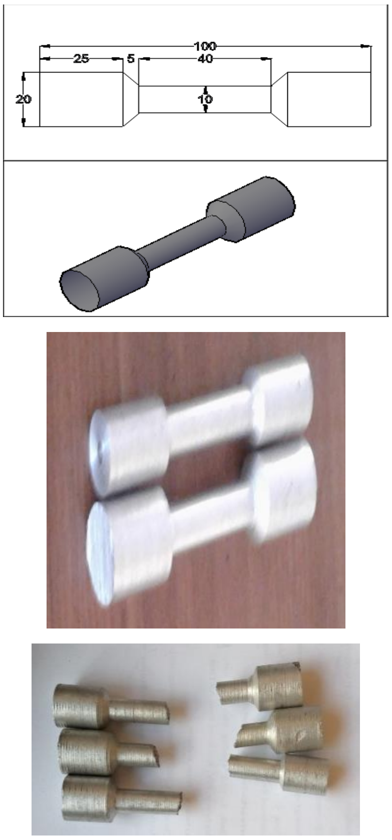

Fig. 18. *Samples of the specimens used for the tensile test (All dimensions are in mm)*

Each of the specimens used for hardness tests was machined to 6.0 mm in length and 20 mm in diameter. The specimens’ surface was ground to remove any debris or impurities on the surfaces. On the UTM, a hardened indenting steel ball was pressed between 10 to 15 seconds to indent the specimen to a specific depth into the surface of the specimen but with a different gripping device from that of the tensile test. After removing the ball and load, the diameter of the indentations was measured and input into the UTM. The Brinell Hardness Number (BHN) was automatically determined and obtained as displayed on the computer screen attached to the Testometric machine. Samples of the specimens (a) before the test and (b) after the test (with indentation) are shown in Figure 19.

Fig. 19. *Specimens for the hardness tests*

The impact test was carried out at the Department of Mechanical Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin, Nigeria using the Charpy method. The specimen was machined to ASTM standard of 2.0 x 2.0 mm for V-notch. The specimen was held unto the machine and a pendulum was released from a specific height to hit and deform the specimen and the sudden energy absorbed by the specimen was recorded directly from the gauge on the machine. This was done using the methods specified in ASTM E23-18 [56] and E2298-18 [57]. Figure 20 shows (a) the impact testing machine with one of the specimens for the impact test and (b) some specimens after the test.

a

b

Fig. 20. *The impact testing machine and samples of specimens for impact test*

The microstructures of the aluminium cast products were determined through microstructural analysis of the cast specimens. The test was carried out at Engineering Materials Development Institute (EMDI), Akure, Ondo State, Nigeria. The cast aluminium test piece was cut and polished to a good smooth surface using a Belt Grinder with fine grades of abrasive papers to ensure a better surface finish. The aluminium test specimen was then washed in warm water, rinsed thoroughly and allowed to dry. Etching was done using a chemical reagent (Keller's reagent). After which it was allowed to dry before placing the specimen under the microscope (OMAX microscope) with the specification of 14 MP to view and record the microstructure of the surface at a magnification of x100 µm, x400 µm and x 1000 µm.

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Thereafter, the surface was observed with the use of an optical microscope.

3. Results and discussions

The chemical constituents present in the sands are displayed in Table 1. Silica (SiO_2) constitutes the main element in the sands, with 92.93% and 83.79% weight for Belle and Oyun natural moulding sand, followed by Alumina (Al_2O_3) which accounted for 4.8% (Belle) and 11.2% (Oyun sand). The sands were found to be of high-quality silica sand. Thus, the sands belong to the Alumina-silicate group of sand. Since the sands were found to be silica sand through their chemical compositions values which were within the AFS acceptable range values for moulding sands, thus it was recommended to be suitable for casting of metals, most especially metals with low melting temperatures [45, 46].

Silica is very important in moulding sand because it determines the sand refractoriness and chemical inertness. A higher percentage of silica shows the higher refractoriness of the sand [58], which serves as an indication of the likeness of its good refractoriness. High quality silica sand with uniform physical characteristics is the foundry sand for metal casting [38].

The Fe_2O_3 contents in Oyun sand are reflected in its fairly brownish sand colour with a sub-angular shape. Oyun sand had no ZnO which is one of the significant constituents of the clay content in the sand [45]**.** Thus, it may have little effect on the strength of the sand because clay serves as a binder in the moulding sand which holds the grains of the sand together [59]. However, this effect can be eliminated through the addition of a binder and some other additives to the sand [60]. Likely suitability of the two moulding sands for sand casting of both ferrous and non-ferrous metals, especially aluminium through chemical analysis and the likely need for improvement of Belle sand before use had been earlier revealed by Shuaib-Babata *et al.* [39, 40].

Table 1. *Elemental composition of the moulding sand* [45, 46]

S/N	Constituents	Weight (%)		Recommended values for moulding sand
		Belle	Oyun	
1	SiO_2	92.93	84.58	80 to 90% [61]
2	Al_2O_3	5.130	7.22	4-8% [61]
3	CaO	0.010	0.21	
4	MgO	0.068	0.20	
5	Na_2O	0.780	2.06	
6	Fe_2O_3	0.030	4.06	2-5% [61]
7	K_2O	0.385	1.45	
8	MnO	0.006	0.02	
9	ZnO	0.300	-	

The levels of silica, alumina and iron oxide were within the standard specified values for moulding sands [61]. The presence of any of CaO, K_2O, and NaO_2 in moulding sand serves impurities which lowers the refractoriness [58] and the suitability of the sand for casting of ferrous casting may be affected. The refractoriness and suitability of the sand for ferrous casting can be enhanced by adding Zircon to the sand [62]. The chemical constituents of the sands and that of the recommended mould sand in literature [36, 61, 63] were compared.

Adequacy and suitability of the moulding sands for foundry applications had been adequately discussed in detail in previous studies [45, 46]. The moulding sands' properties such as GFN, clay content, compressive strengths (wet and dry), permeability, shatter index, refractoriness, specific gravity, bulk density and flowability shown in Table 2 were found adequate and suitable (met AFS standard) for non-ferrous casting, especially aluminium casting.

The sands' physico-mechanical properties were also found suitable for metal casting since the properties favourably agreed with the AFS recommended values for casting some metals, most especially non-ferrous metals.

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Table 2. *Physico-mechanical properties of the sands against recommended/standard values*

S/N	Parameter	Average obtained Values		Recommended Standard Values	Satisfactory moulding sand properties for Aluminium casting [34]
		Belle	**Oyun**		
1	Moisture content	7.66%	11.31%	5-8% (for the casting of Aluminium, brass & bronze, malleable iron and medium grey iron) [60, 64].	4.5-5.5
2	Specific gravity	2.64	2.57	2.6-2.8 [65]	
3	Bulk density	1765.2 Kg/m^3	1406.25	1100 Kg/m^3 to 1800 Kg/m^3 as AFS standard for sand casting process [9].	
4	Permeability	0.10 cm/sec	0.072	0.001 cm/sec and above [65]	10-30 (permeability number)
5	Flowability	65.22%	64.29	65% [for casting of Aluminium] [64]	
6	Grain fineness number	69.01	143.02	36-90 [for non-ferrous metals [60, 64]	
7	Green compressive strength	51 kN/m^2	100.25	50-70 kN/m^2 and above [for the casting of Aluminium, brass and bronze, light grey iron and malleable iron] [60, 64]	50-70
8	Dry compressive strength	209 kN/m^2	69.73	200-500 kN/m^2 [for casting of Aluminium, brass & bronze and light grey iron] [60, 64]	200-550
9	Clay content	10%	13.42	10-12% (for the casting of Aluminium, brass & bronze, light grey iron, malleable iron, heavy steel, light steel and heavy grey steel) [60, 64]	8-10
10	Shatter index	79%	24.03	12% and above [60]	
11	Refractoriness	>900 °C	> 1000 °C	1100 °C and above [60]	

The elemental compositions of the aluminium scraps are shown in Table 3. The scrap contains a high percentage of aluminium (94.85%) followed by Silicon (2.413%), Iron (0.8281%), Zinc (0.6717%), Copper (0.6226%) and Magnesium (0.38%). Other elements such as titanium, Vanadium, Manganese, Nickel, Zinc, Lead, and Zirconium are also present in small compositions.

Aluminium was found to be the main constituent of the melted scrap, with other elements such as silicon, iron, titanium, magnesium, and zinc among others in smaller proportions. Thus, the aluminium alloy belongs to the Al-Mg_2Si class of aluminium. Moreover, the presence of silicon in the alloy gives the aluminium scrap good castability. Aluminium when used for casting offers the following advantage which includes high fluidity, low melting point, low tendency for hot cracking, good castability and as-cast surface finish [63]. The presence of iron makes the aluminium hard and brittle [50].

Table 3. *Elemental chemical compositions of the aluminium scrap*

Element	**Mg**	**Al**	**Si**	**Ti**	**Cr**	**Mn**	**Fe**	**Ni**	**Cu**
Composition (%)	0.38	94.85	2.413	0.0533	0.0175	0.0708	0.8281	0.0331	0.6226
Element	**Zn**	**Zr**	**Sn**	**Pb**					
Composition (%)	0.6717	0.0019	0.013	0.0253					

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The mechanical properties of the casts (tricycle brake pedal and motorcycle centre stand) are as presented in Tables 4-6. The mechanical properties of the casts produced have much to do with the properties of the sand used for its production [66, 67]. The properties of the aluminium casts examined include tensile, hardness and impact properties.

Tensile test was carried out on the samples of the tricycle brake pedal (TBP) and motorcycle centre stand (MCS) and the average tensile properties results are given in Figures 21-26, which include the stress at yield, stress at peak, stress at break, energy to break, elongation at yield, and young modulus of the casts.

The average stress at yield is the average yield strength exhibited by the tricycle brake pedal (TBP) and motorcycle centre stand (MCS). This is the amount of stress required to cause plastic deformation in the TBP and MCS casts and commercially available (imported) TBP and MCS. Moreover, the average stress at peak amounts to the average ultimate tensile strength (UTS) of the aluminium TBP and MCS casts and that of the commercially available (imported) TBP and MCS. It is the highest amount of stress that can be withstood before the devices' failure start to occur. The average stress at break is the stress at which the cast will totally fail. The samples of the tricycle brake pedal (TBP) and motorcycle centre stand (MCS) exhibited the same values for these stresses which are graphically presented in Figure 20 as average tensile strength.

The average tensile strength value exhibited by TBP and MCS cast is given as 124.563 and 98.795 N/mm² respectively (Figures 20). Meanwhile, the samples of commercially available (imported) TBP and MCS also exhibited an average tensile strength of 100.223 and 93.583 N/mm² respectively. The tensile strength values for both cast and commercially available (imported) TBP and MCS were comparable and the differences in their values were close, thus the casts could suitably perform well for the desired applications. The tensile strength exhibited by the TBP cast was within the minimum performance strength requirement of 65 N/mm² for a tricycle brake pedal [68]. This is an indication that the tensile properties of the brake pedal cast were suitable for its application.

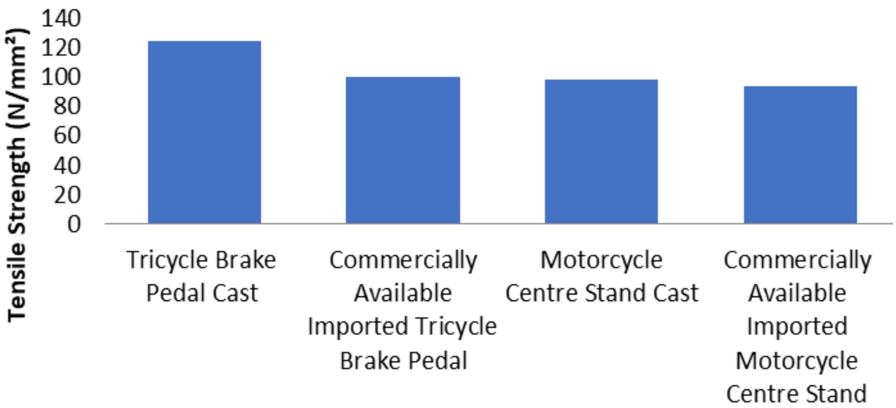

Fig. 21. *The samples of tricycle/motorcycle cast parts and commercially available (imported) parts' tensile strengths*

The energy to break is the toughness value of the cast; the amount of energy the materials can withstand or absorb before failure. The toughness value exhibited by the TBP and MCS cast is 7.870 and 11.922 Nm respectively, while the commercially available imported TBC and MCS exhibited 9.210 and 10.149 Nm respectively (Figure 22). The TBC and MCS cast has ductility values of 2.394 and 2.782 mm respectively, while commercially available imported TBC and MCS possessed 0.345 and 2.312 mm respectively (Figure 23). The strain at break is the total deformation the material will undergo before failure occurs. The value is given as 0.690% and 6.956 % for TBP and MCS cast respectively. The commercially available (imported) TBP and MCS also possessed strain at yield/break values of 5.779 and 5.985% respectively (Figure 24). The young modulus is the measure of the stiffness any of the motorcycle/tricycle cast or commercially obtained would exhibit and is given as 5789.65 and 1746.19 N/mm² for TBP and MCS cast respectively; 1776.90 and 1909.41 N/mm² for the commercially available (imported) TBP and MCS respectively (Figure 25). All these parameters are important in designing so as to determine the working conditions to which the cast products will conform. The properties exhibited by the cast products (TBP and MCS) are comparable (and even better) to that of commercially available properties.

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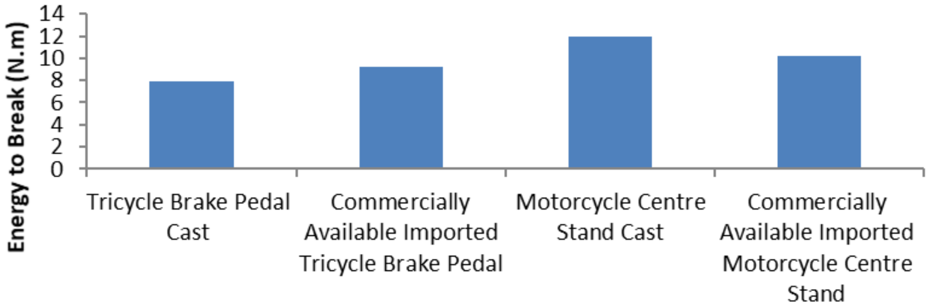

***Fig. 22.** The samples of tricycle/motorcycle cast parts and commercially available (imported) parts' toughness values*

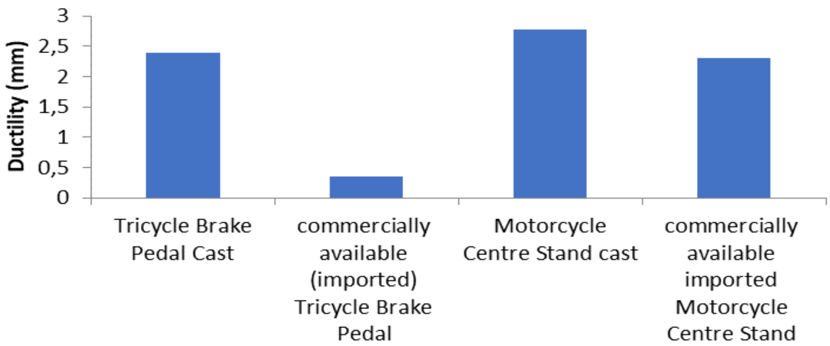

***Fig. 23.** The samples of tricycle/motorcycle cast parts and commercially available (imported) parts' ductility values*

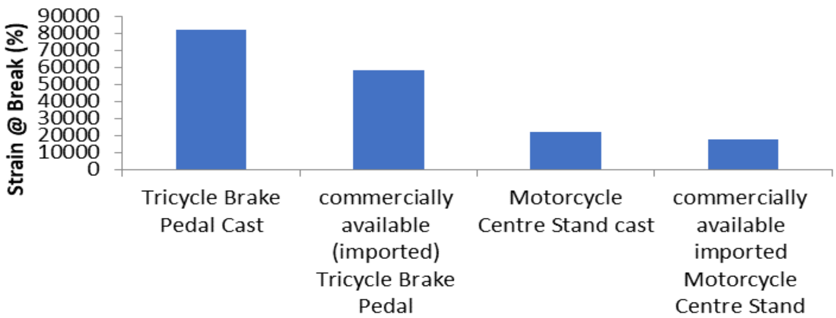

***Fig. 24.** The samples of tricycle/motorcycle cast parts and commercially available (imported) parts' strain at break*

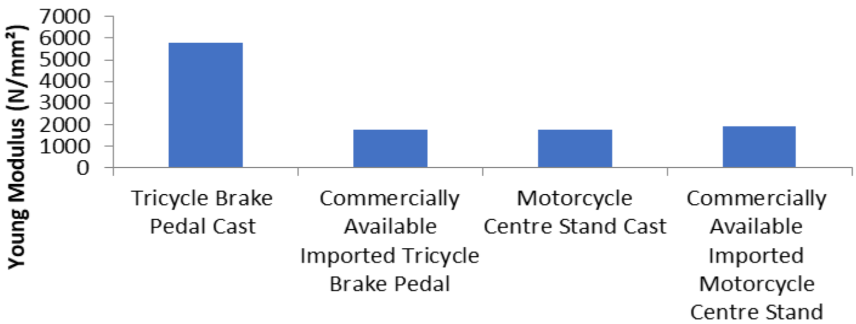

***Fig. 25.** The samples of tricycle/motorcycle cast parts and commercially available (imported) parts' young moduli*

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The average (mean) hardness values for the cast products (motorcycle centre stand cast, MCP and tricycle brake pedal, TBP) and that of the imported motorcycle centre stand cast and tricycle brake pedal are presented in Figure 26. The mean hardness value exhibited by MCS cast and TBP cast was found to be 21823.00 and 81954.60 Kg/m², which are greater than the exhibited mean hardness value for MCS (21823.00 Kg/m²) and TBP (111679.000 Kg/m²).

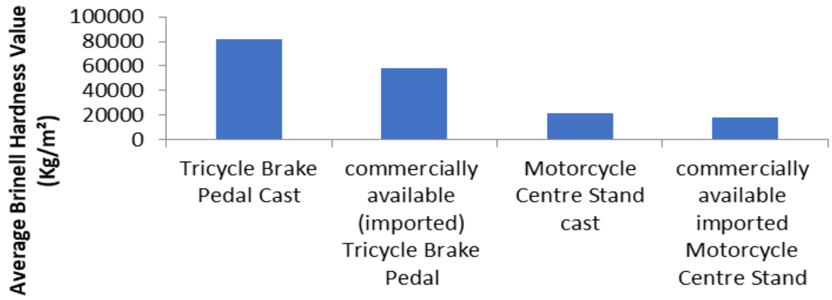

Fig. 26. *The casts and the imported brake pedal average hardness values*

The cast products may be said to be hard enough to withstand abrasiveness or deformation as a result of indentation during service, this is because of the presence of an appreciable amount of Fe in the aluminium melted scrap (as shown in Table 2). The higher the amount of Fe in aluminium the harder and brittle the aluminium will be [69, 70].

The average impact strength exhibited by the tricycle brake pedal cast and the motorcycle centre stand cast was found to be 74 J and 75 J respectively, which were the amount of sudden load each of the cast materials can withstand.

The microstructures of the tricycle brake pedal cast and the motorcycle centre stand cast at different magnifications are presented in Figures 27 and 28.

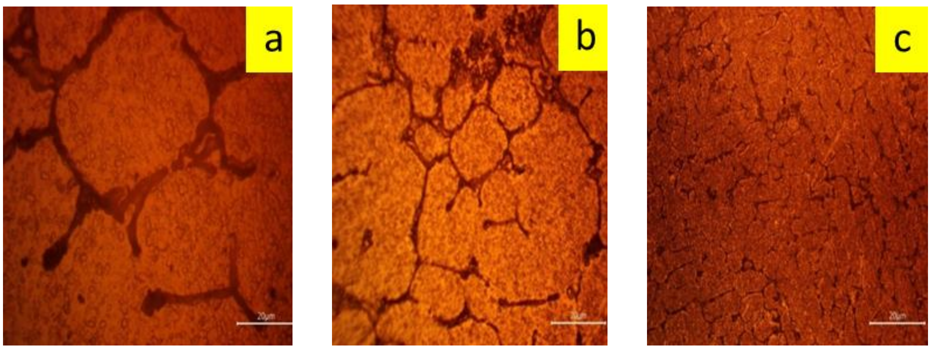

Fig. 27. *The microstructure of the tricycle brake pedal cast at different magnification: (a) x1000, (b) x400 and (c) x100*

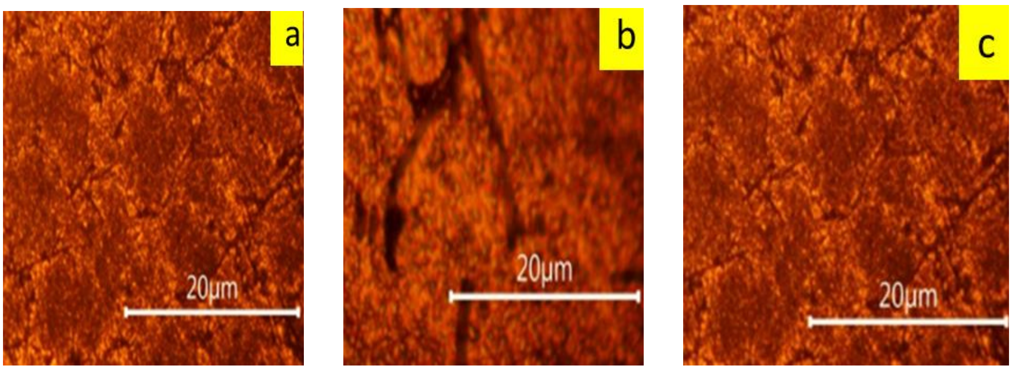

Fig. 28. *The microstructure of the cast at different magnification: (a) x1000, (b) x400 and (c) x100*

The microstructures generally consist of fine crystals of aluminium (Al), magnesium silicide (Mg_2Si), Al-Mg_2Si phases and Al-Fe intermetallic grains. Al, Si and Mg have the highest proportion in descending order, respectively in the aluminium cast. These structures basically consist of a primary alpha solid solution of magnesium silicate in the rich solid aluminium (α) and in a matrix of eutectic magnesium silicate (Mg_2Si). Mg_2Si is the precipitate of the aluminium rich portion of Al-Mg_2Si. Mg_2Si are the dark patches in the micrographs. The casts aluminium belongs to the Al-Mg_2Si class of aluminium alloy as revealed in the chemical compositions results of the aluminium alloy in Table 2.

4. Conclusions

The following conclusions were drawn from the study:

i. Belle and Oyun natural moulding sands were found suitable for casting and production of motorcycle centre stand and tricycle brake pedal (respectively) of acceptable standards using aluminium scraps. The cast products exhibited an adequate tensile strength of 122.563 and 98.795 N/mm² by tricycle brake pedal and motorcycle centre stand sample respectively; and average Brinell hardness value of 21823.00 and 81954.60 Kg/m² by MCS cast and TBP cast respectively, which were greater than the exhibited mean hardness value of 21823.00 and 111679.000 Kg/m² exhibited by commercially available (imported) Motorcycle cycle stand and Tricycle brake pad respectively.

ii. The aluminium tricycle brake pedal and motorcycle centre stand produced through sand casting processes (using locally available moulding sands) exhibited adequate properties like strengths and hardness (wear resistance) to withstand their applications and were found comparable with the commercially available exported ones. Thus, the production of such motorcycle/tricycle and related components can be domesticated in Nigeria, which would enhance the sustainability of small and medium scale enterprises required for job creation, enhance the nation's self-reliance through the reduction in the importation of goods and boost Nigeria's economic status.

iii. The effective utilization of wastes like aluminium scrap in the production of transportation devices components (such as tricycle brake pedal and motorcycle centre stand) will greatly assist Nigeria, as a country, in achieving perfect sustainable waste management and safe health environment. This is due to the fact that the transformation of the raw materials into finished products using locally available raw materials in the development of technology is a significant factor towards successful industrialization.

iv. The consequences of the Covid-19 pandemic, compounded by the over-reliance on the oil and gas industry coupled with excessive proliferation of foreign commodities to satisfy citizenry needs and lack of commitment to other economic sectors, such as insufficient natural resource exploitation and low industrialization contributed to the Nigeria economic recession with negative growth for five quarters. This can be positively addressed by developing Nigeria's foundry technology sector through effective utilization of available natural moulding sands (such as Belle and Oyun moulding sands) for the production of motorcycle/tricycle components.

References

[1]. Saliu O., *Roundup: Nigeria's economy slips into "worst" recession in decades, with recovery forecast*, Xinhuanet news, Tuesday January 19, 2021.
[2]. Ozili P., *Covid-19 pandemic and economic crisis: The Nigerian experience and structural causes*, SSRN Electronic Journal, p. 1-9, 2020.
[3]. Olatokewa A., *The economic repercussion of coronavirus pandemic on Nigerians*, Pulitzer Centre, 2020.
[4]. ***, *Nigerian economy and traumatic impact of Covid-19 pandemic*, APA News, 2020.
[5]. ***, *Covid-19 Impact Monitoring*, National Bureau of Statistics, https://www.nigerianstat.gov.ng, April-May 2020.
[6]. ***, *Covid-19 Impact Monitoring*, National Bureau of Statistics, Baseline, May 2020.
[7]. Kazeem Y., *Here's how COVID-19 has battered Africa's largest economy*, World Economic Forum COVID Action Platform, 2020.
[8]. Ambali I. O., Shuaib-Babata Y. L., Ibrahim H. K., Abdulqadir L. B., Aremu N. I., Ibraheem T. O., *Production of abrasive sandpaper using periwinkle shells and crab shells*, International Journal of Engineering Materials and Manufacture, vol. 5, no. 2, p. 55-61, 2020.
[9]. Bala K .C., Olabisi B. A., *Deterioration of moulding sand properties with number of castings*, Leonardo Electronic Journal of Practices and Technology, vol. 30, p. 209-220, 2017.
[10]. Chete L. N., Adeoti J. O., Adeyinka F. M., Ogundele O., *Industrial development and growth in Nigeria: Lesson and challenges, leaning to complete working paper No. 8*, African growth initiative at Brookings Institute/African Development Bank Group / United Nations, University UNU-Wider World Institute for Development, 2016.
[11]. Akue L., Dapa I. N., *Separate lane for tricycle intra-urban traffic: A planning strategy for urban transportation system in Nigerian cities*, World Journal of Engineering Research and Technology, vol. 4, issue 6, p. 26-39, 2018.
[12]. Nwafor M. E., Onya O. V., *Road transportation service in Nigeria: Problems and prospects*, Advance Journal of Economics and Marketing Research, vol. 4, issue 03, p. 104-115, 2019.
[13]. Avanenge F., Zizi H. Z., *An analysis of the issues and challenges of transportation in Nigeria and Egypt*, The Business and Management Review, vol. 7, no. 2, 2016.
[14]. Oladipo O. O., *The development and impact of motorcycles as means of commercial transportation in Nigeria*, Research on Humanities and Social Sciences, vol. 2, no. 6, p. 231-239, 2012.
[16]. Mogaji E., *Impact of Covid-19 on transportation in Lagos, Nigeria*, Transportation Research Interdisciplinary Perspectives, 6, 2020.
[17]. Anyanwu J. C., Oaikhena H., Oyefusi A., Dimowo F. A., *The structure of the Nigerian economy (1960-1977)*, Onitsha: Joanne Educational Publishers Ltd., 1997.

[18]. Afolabi O. J., Gbadamosi K. T., *Impact of commercial motorcycle operation on urban mobility in Ogun State, Nigeria*, Logistics & Sustainable Transport, vol. 8, no. 1, p. 62-71, 2017.
[19]. Mgbemena J., *Language, communication on wheels and national development: The inscriptions on tricycle (Keke) example*, International Journal of English and Literature (Academic Journals), vol. 4, no. 10, p. 529-537, 2013.
[20]. Ismaila S., Jatau J. S., Bawa M. A., *Particulate reinforced aluminium alloy matrix composite brake rotor - A review of the mechanical and wear behaviours*, Journal of scientific and engineering research, vol. 6, no.7, p. 29-40, 2019.
[21]. Mukhtar A., Waziri M., Abdulsalam B., Dankani I. M., *Assessment of tricycle as a tool of poverty alleviation in Maiduguri, Borno State, Northeast, Nigeria*, IOSR Journal of Humanities and Social Science (IOSR-JHSS), vol. 20, issue 8, ver. VI, p. 14-18, 2015.
[22]. Oyesiku O. O., *From Womb to Tomb*, 24th Inaugural Lecture, Olabisi Onabanjo University. Ago Iwoye: OOU Press, 2002.
[23]. Ogunsanya A. A., Galtima M., *Motorcycle in Public Transport Service in Nigeria: Case Study of Yola Town, in J.S. Ikya (ed.)*, Urban Passenger Transportation in Nigeria. Ibadan: Heinemann: p. 191-207, 1993.
[24]. Araoye O. A., Muhammed E. O., Muhammed I. A., Bolaji O. K., *Operatıon and management of trıcycle (keke napep) as a means of public transport in Mınna, Nıgerıa*, Asia-Pacific Management and Business Application, vol. 9, no. 2, p. 179-192, 2020.
[25]. Obioma R. N., Ibe C. C., Ukaegbu S. I., *Quality of the paratransit service (tricycle) and its operation in Aba, Nigeria: An analysis of customers' opinions*, Journal of Transport and Supply Chain Management, vol. 6, no. 1, p. 262-276, 2012.
[26]. Adeyemi H. O., Yusuf T. A., *Tricycles for Nigerian public transport unit: Assessment of ergonomics design considerations*, Jurnal Kejuruteraan, vol. 31, no. 1, p. 57-63, 2019.
[27]. Ankitkumar K., Vidyadhar C., Chandratre K., *Design and analysis of standing device for two wheeler*, International Engineering Research Journal (IERJ), vol. I, p. 361-371, 2014.
[28]. Olubomehin O. O., *The development and impact of motorcycles as means of commercial transportation in Nigeria*, Research on Humanities and Social Sciences, vol. 2, no. 6, p. 231-239, 2012.
[29]. Wanyang L., Xuefeng Y., Shouren W., Jupeng X., Qimin H., *Comprehensive analysis on the performance and material of automobile brake discs*, Metals, vol. 10, no. 37, p. 2-18, 2020.
[30]. Ismail N. A., Adeniji T. A., Paul O. J., *Assessment of tricycles operations as an alternative means of urban transport in Lokoja, Kogi State*, Confluence Journal of Environmental Studies, vol. 12, no. 1, p. 53-62, 2018.
[31]. Lawal S. S., Bala K. C., Alegbede A. T., *Development and production of brake pad from sawdust composite*, Leonardo Journal of Sciences, issue 30, p. 47-56, 2017.
[32]. Crăciun A. L., *et al.*, *Composites materials for friction and braking application*, Innovative Ideas in Science, IOP Publishing IOP Conf. Series: Materials Science and Engineering, p. 200, 2017.
[33]. Andrzej B., *Conventional and unconventional materials used in the production of brake pads – review*, Science and Engineering of Composite Materials, (De Gruyter 2020), vol. 27, no. 1, p. 374-396, 2020.
[34]. Shuaib-Babata Y. L., Olumodeji J. O., *Analysis of Ilorin sand moulding properties for foundry applications*, International Journal of Engineering Research and Technology (IJERT), vol. 3, no. 1, p. 1520-1526, 2014.
[35]. Sheidi H. M., *Investigation on properties of local Zircon sand for sand casting: Azara-Lafia deposit, Nigeria*, ResearchJournal in Engineering and Applied Sciences, vol. 1, no. 6, p. 404-407, 2012.
[36]. Shuaib-Babata Y. L., Abegunde A. J., Abdul J. M., *Suitability of Ado-Ekiti (Nigeria) natural moulding sands for use as foundry sands in production of aluminium alloy cast*, Journal of Production Engineering, vol. 20, no. 2, p. 91-100, 2017.
[37]. Shuaib-Babata Y. L., Yaru S., Abdulkareem S., Ajayi S., Busari Y., Ajao K., Ibrahim H. K., Ambali I. O., Mohammed G., *Suitability of some selected Ado-Ekiti natural moulding sands' properties for sand casting*, Covenant Journal of Engineering Technology, vol. 1, no. 2, p. 53-64, 2017.
[38]. ***, *Choosing between green sand, Nobake*, American Foundry Society (AFS), 22 February, 2017.
[39]. ***, *Sand casting*, Sand Casting, 22 January, 2017.
[40]. Nuhu A. A., *Evaluation of the foundry properties of river Niger sand behind Ajaokuta steel company limited, Ajaokuta, Nigeria*, American-Eurasian Journal of Scientific Research, vol. 3, no. 1, p. 75-83, 2008.
[41]. Mishra P., *Manufacturing process: properties of moulding sand in casting*, Mechanical Booster, 2019.
[42]. Oke A. O., Omidiji B. V., *Investigation of some moulding properties of a Nigerian clay-bonded sand*, Achieves of Foundry Engineering, vol. 16, no. 3, p. 71-76, 2016.
[43]. Dhurval P., Vivek D., Ela J., Viral P., Snikunj D., Jay P., *Study of sand composition on mould properties and selection of Taguchi orthogonal array for design of experiments*, International Journal of Current Engineering and Scientific Research, vol. 2, no. 3, p. 31-34, 2015.
[44]. Saikaew C., Wiengwiset S., *Optimization of molding sand composition for quality improvement of iron castings*, Applied Clay Science, vol. 67-68, p. 26-31, 2012.
[45]. Shuaib-Babata Y. L., Ibrahim H. K., Ajao K. S., Ambali I. O., Bello M. O., *Evaluation of the foundry properties of Oyun river (Ilorin) moulding sand*, Adeleke University Journal of Engineering and Technology, vol. 2, no. 1, p. 12-24, 2019.
[46]. Shuaib-Babata Y. L., Nafiu M. B., Ajao K. S., Ambali I. O., Elakhame Z. U., Busari Y. O., Hassan H. K., Aremu N. I., *Characterization of Belle natural moulding sand for foundry applications*, USEP: Journal of Research Information in Civil Engineering, vol. 16, no. 2, p. 2657-2678, 2019.
[47]. Asuquo L. O., Bassey E. N., Ihom A. P., *Characteristics of zircon sand and the effect on foundry casting*, Journal of Mechanics & Industry Research, vol. 1, no. 1, p. 27-32, 2013.
[48]. Aji D., Igu N., Oseni M., Apata A., Baba G., *Characterization of river Niger (Idah deposit), Ochadamu and Uwowo sands for foundry mould production*, Journal of Emerging Trends in Engineering and Applied Sciences, vol. 6(5), p. 295-300, 2015.
[49]. ***, Al Circle, Retrieved from AlCircle Corporation Web Site: http://www.alcircle.com, 2018.
[50]. Kutz M., *Mechanical Engineers* Handbook', 2nd Ed., New York, London: John Wiley & Sons, Inc., 1998.
[51]. Bala K. C., Shuaibu J., Abolarin M. S., *Evaluation of mechanical properties of aluminium casting using sand deposits in Niger State*, Proceedings of the 1st International Engineering Conference held at the Federal University of Technology, Minna, Nigeria, vol. 1, p. 219-225, September 25, 2015.
[52]. Shuaib-Babata Y. L., *et al.*, *Assessment of physico-mechanical properties of clay deposits in Asa Local Government Area of Kwara State, Nigeria for industrial applications*, USEP: Journal of Research Information in Civil Engineering, vol. 16, no. 2, p. 2727-2753, 2019.
[53]. Rajender S., *Introduction to basic manufacturing process and workshoptechnology*, Daryaganj, New Delhi, India: New Age International Publisher, 2006.
[54]. ***, ASTM E8/E8M-16a, *Standard test methods for tension testing of metallic materials*, ASTM International, West Conshohocken, PA, 2015.
[55]. ***, ASTM, B 557M-02a, *Standard test methods of tension testing wrought and cast aluminum- and magnesium-alloy products*, ASTM International, West Conshohocken, PA, 2015.
[56]. ***, ASTM E23-18, *Standard test methods for impact testing of metallic materials*, ASTM International, West Conshohocken, PA, 2015.
[57]. ***, ASTM E2298-18, *Standard test method for instrumented impact testing of metallic materials*, ASTM International, West Conshohocken, PA, 2015.

[58]. Brown J. R., *Sands and green sands*, Foseco Ferrous Foundryman's Handbook, Oxford, kidlington, UK: Butterworth-Heinemann, 2000.

[59]. ***, *ME mechanical team*, http://materialrulz.weebly.com/uploads/7/9/5/1/795167/casting_2nd_half.pdf, on November 8, 2017.

[60]. Mshelia Z. A., Abolarin M. S., Abubakre O. K., Ademoh N. A., *Characterisation of natural moulding sands from selected deposits in Maiduguri-Nigeria for casting applications*, Arid Zone Journal of Engineering, Technology and Environment, vol. 12, p. 110-121, 2016.

[61]. Surupa S., *Moulding sand: types and constituents, casting, metallurgy*, Available online: http://www.engineeringenotes.com/metallurgy/casting/moulding-sand-types-and-constituents-castingmetallurgy/20916, retrieved on January 18, 2019.

[62]. Aweda J., Jimoh Y., *Assessment of properties of natural moulding sands in Ilorin and Ilesha, Nigeria*, USEP Journal of Research Information in Civil Engineering, vol. 6, no. 2, p. 68-77, 2009.

[63]. Otarawanna S., *Casting of aluminium alloys. In Fundamental of Aluminum Metallurgy*, Woodhead Publishing Limited, Cambridge, United Kingdom, p. 141-153, 2011.

[64]. Burns T. A., *Foseco ferrous foundryman's handbook*, New Delhi, India: Butterworth Heinemann, 1989.

[65]. ***, *Foundry sand*, T. F. Technology, Retrieved from www.fhwa.dot.gov, 2016.

[66]. Ayoola W. A., Adeosun S. O., Sanni O. S., Oyetunji A., *Effect of casting mould on mechanical properties of 6063 aluminum alloy*, Journal of Engineering Science and Technology, vol. 7, no. 1, p. 89-96, 2012.

[67]. Datau S. G., Oji J., Elijah I. R., Datau N., *The effect of sand casting process parameters on mechanical properties of aluminum alloy casting*, International Journal of Metallurgical & Materials Science and Engineering (IJMMSE), vol. 2, issue 3, p. 32-41, Sep. 2012.

[68]. Mortimer R. G., ***et al.***, *Brake Pedal Requirement Study: Driver-Vehicle Braking Performance as a Function of Brake System Design Variables*, Washington D.C: Federal Highway Administration and National Highway Safety Bureau, 1970.

[69]. Rana R. S., Rajesh P., *Reviews on the influences of alloying elements on the microstructure and mechanical properties of aluminium alloys and aluminium alloy composite*, International Journal of Scientific and Research Publication, p. 1-7, 2012.

[70]. ***, Retrieved from www.economist.com, on February 4, 2015.