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## Production of Pencil Using Graphitized Coconut Fibre

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### ABSTRACT

Pencil is one of the most used writing materials and is of unquantifiable demand in the economy. Graphite a major component used in the production of pencil is not commercially available in Nigeria and thus creates the need of finding an alternative to graphite from locally available materials such as graphitized coconut fiber black. This project aims at using graphitized coconut fiber as an alternative to graphite which is the primary component in the production of pencil. The materials used for the production for pencil includes: graphitized coconut fiber, clay (Kaolin) and binder (Achronal and top bond). The graphitized coconut fiber was obtained through the process of pyrolysis of coconut fiber at 500 °C, in an air tight furnace, after which it was calcinated at a temperature of 1200 °C and finally graphitized (temperature - 1000 °C , pressure - 8.4KN, time - 24 hours). The clay was also prepared by drying it inside the sun for several days to remove moisture content and to allow grinding to powder, after which it was sieved to eliminate any foreign particle present. The graphitized coconut fiber, clay and binder were mixed thoroughly in varying proportions into three samples; Sample A (60% Graphitized coconut fiber, 20% clay, 10% binder and 10% water), Sample B(40% Graphitized coconut fiber, 40% clay, 10% binder and 10% water), Sample C (20% Graphitized coconut fiber, 60% clay, 10% binder and 10% water). After mixing to form a stiff dough, they were fed into the fabricated lead extruder and were extruded to form a thin straight lead. The extruded lead was left to dry at room temperature for a duration of 30 minutes after which it was baked at a temperature of 250 °C for another 2 hours. After baking, the lead was allowed to cool at room temperature. The pencil lead obtained was glued into the pencil slat. The three samples were used to write on paper to observe their legibility, erasing ability and ease of sharpening. The pencil gotten from the different samples were found to be of various qualities in terms of erasing ability, ease of sharpening and legibility. Sample B was found to be the best possessing the three aforementioned characteristics followed by sample C with lesser ability to write properly and sample A was found to be the least preferable of the three samples. We can therefore conclude that graphitized coconut fiber can fairly serve as an alternative material for graphite in the production of pencil.

**Keywords:** Production, Pencil, Graphitized Coconut Fibre, Slat and dough

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## 1. INTRODUCTION

In Germany, at the beginning of the 19<sup>th</sup> century, about 50 million quills were used every year before the advent of a new writing technique which was established from the middle of the 16<sup>th</sup> century, the lead-pencil writing (FABER-CASTEL, 2002). Various types of writing instrument exist out of which the most widely used is the pencil. A pencil is an instrument for writing or drawing, consisting of a thin stick of graphite or a similar substance enclosed in a long thin piece of wood or fixed in a cylindrical case. (Oxford Dictionaries, 2015) Pencils by abrasion can cause marks on object and make a trail of solid core material that adheres to a sheet of paper or other surface. They are different from pens, that disperse a trail of liquid or gel ink that stains the light color of the paper. Most pencil cores are made of graphite mixed with a clay binder which leaves grey or black marks that can be easily erased. Graphite pencils are used for both writing and drawing and result in durable markings; though writing is easily removable with an eraser, it is otherwise resistant to moisture, most chemicals, ultraviolet radiation, and natural aging (Wikipedia, 2015).

They are commonly called lead pencil, because the first time a large deposit of graphite was found, metallurgists thought it was some sort of lead and it was called black lead, but the term “lead” pencil is a misnomer in that the pencil contains no lead, rather is composed of three primary ingredients in varying proportions: graphite, clay and waxes. The case (commonly wood) helps prevent the core from breaking, and also from marking the user’s hand during use. Apart from the field of art where various kind of pencil is used by artists for different form of drawing, almost everyone uses the pencil to write. The pencil also finds usage in the art of fashion (as eye pencil) and it is used by artisans for making all manner of inscriptions. Graphite is a mineral allotrope of carbon. It is dark gray to black, opaque, and very soft. Its layered structure, with rings of six atoms arranged in widely spaced parallel sheets, gives it its slippery quality. It occurs in nature and is used (mixed with clay) as the “lead” in pencils. It is also used in lubricants, crucibles, polishes, arc lamps, batteries, brushes for electric motors, and nuclear reactor cores. (Britannica, 2008.) Graphite and graphitized coconut fiber are of the same element ‘carbon’. They have unique resemblance in that they are both allotropes of carbon. They have different atomic arrangement. With graphite having crystalline structure while graphitized coconut fiber is amorphous. Graphitized coconut fiber is virtually pure elemental carbon in the form of colloidal particles that are produced by incomplete combustion or thermal decomposition of gaseous or liquid hydrocarbons under controlled/uncontrolled conditions. Its physical appearance is that of a black, finely divided pellet or powder. Coconut fiber if taken through series of control heat treatment process, can serve as substitute for graphite which is a major material in pencil production.

## 2. METHODOLOGY

### 2.1 Materials

The materials used for the production of pencil includes: Graphitized coconut fiber, clay (Kaolin), Binder and Wax. The constituent of HB pencil according to Steadtler Product Information (2015) is 68% Graphite, 32% Binder (Clay and Polymer Binder). Eventually the total percentage composition of the finished pencil will contain approximately 10% by weight wax which will penetrates into the microcellular structure of the baked pencil. (Staedtler ,2015)

### 2.2 Method

The graphitized coconut fiber was mixed in varying proportion with finely ground clay. Continuous pressure was applied in mixing until the mixture has the consistency of stiff dough. The plasticized mass was extruded under pressure through the fabricated pencil lead extruder. The extruded pencil was heated for two hours at 250 °C and allowed to cool at room temperature. The extruded material is then encased in the wooden case and glued. Changes in the proportion of clay and the graphitized coconut fiber gives rise to the production of various degree of hardness. The higher the clay content, the harder the pencil and vice versa.

### 2.3 Graphitized coconut fiber powder preparation

The graphitized coconut fiber was obtained by pyrolyzing coconut fiber at 500 °C in inert furnace, after which it was calcined at 1200 °C and finally graphitized under pressure at a temperature of 1000 °C for 24 hours.

### 2.4 Clay powder preparation

The clay was dried inside the sun for several days to remove moisture contents. It was grind into powder after which it was sieved to remove any foreign particles present.

### 2.5 Mixing preparation

Properties such as fine particle sizes, plasticity must be possessed by the clay. The clay powder was soaked for a week to improve its plasticity and binding property. During that period a constant stirring of the mixture was maintained to allow for proper circulation of water and improve its gumming properties. The clay mixture was subjected to pressure to remove its water content. Both graphitized coconut fiber and clay was then measured according to the intended ratio.

### 2.7 Baking

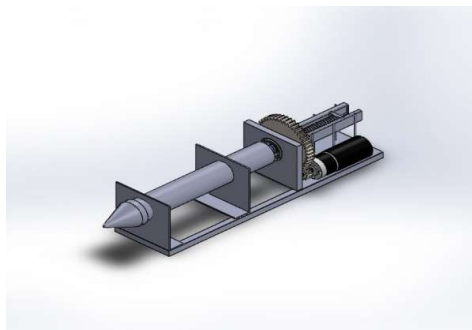
Heat is applied to the produced pencil to evaporate the wax and allow infusion at temperature of 250 °C for a duration of two hours and then cooled to room temperature.

### 2.8 Casing

Softwood popularly called *malana* in Yoruba dialect was used to encase the produced pencil with grooves. The pencil produced were inserted into the grooves on one slat and then a second slat with empty grooves was glued on top of the paste filled slot. The wood was given surface finish and cut into sizes.

### 2.6 Extrusion

An extruder was designed and used to extrude a thin rod (2mm) of pencil from the paste. The extruder consists of 12V DC geared motor with a speed of 90rpm. The shaft, being restricted by the rail on the frame, can only move in a linear direction and compressed the composition in the barrel of the extruder, which forces its way through the opening of the die.



**Fig. 2.1: The Pencil Lead Extruder**

## 2.9 Design of the Extruder Machine

The components include:

### Motor

The motor used in the design of the extruder is a 12V Dc Geared Motor with a torque of 0.098Nm and a power rating of 0.01 Hp



Fig. 2.2: A 12V Dc Motor

### Lead Screw

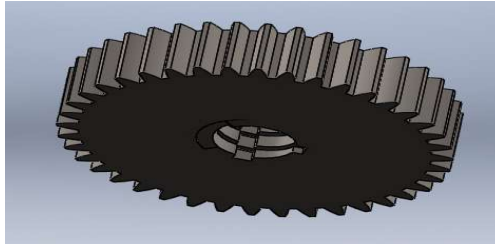
A lead screw is a power screw and the thread type adopted for the purpose of this project work is the square thread. The lathe machine was used to fabricate the lead screw.



Fig. 2.3: The Power Screw

### **Gear**

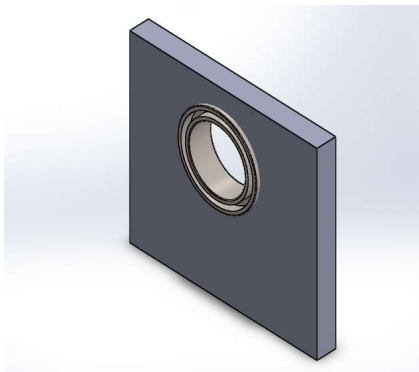
The two gears used in the design of the extruder in this project work are both spur gears of 45 teeth and 15 teeth.



**Fig. 2.4: A Spur Gear**

### **Bearing and Bearing Holder**

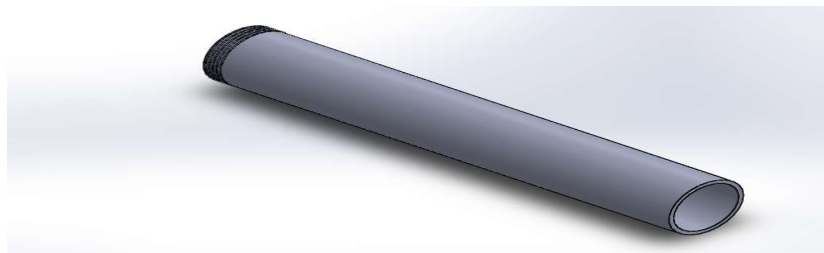
The bearing and bearing holder is used to permit a relative motion between the contact surfaces of the members and thereby reduces friction.



**Fig. 2.5: The Bearing and Bearing Housing Assembly**

### **Barrel**

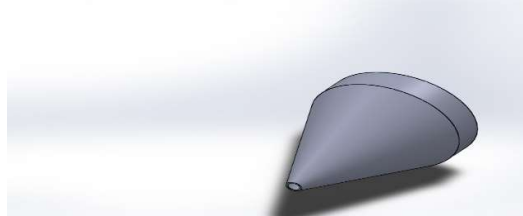
This is the hollow cylinder container that houses the composition. The composition is fed into the barrel manually after which extrusion takes place. The barrel also serves as a passageway for the screw and plunger assembly during the extrusion process. The material used in its manufacturing is stainless steel and its internal diameter is 34mm with a thickness of 2mm. The upper part of the barrel is externally threaded so as to allow for proper assembling with the die which is also threaded internally.



**Fig. 2.6: The Barrel**

**Die**

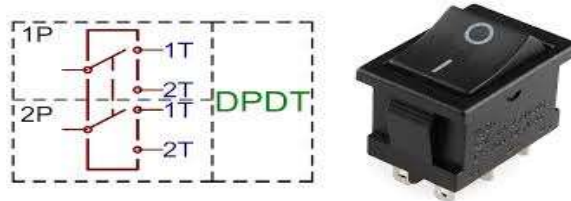
The die used in the design of this extruder is made of mild steel with an opening of 2mm. The die is threaded internally to make for proper assembling of the casing, that is, the barrel- die assembly.



**Fig 2.7: The Die**

**Switch**

The switch used in the design of the extruder for the purpose of this work is double pole double throw equivalent to two Single Pole Double Throw Switches controlled by a single mechanism.



**Fig. 2.8: A pictorial representation of a double pole double throw switch**

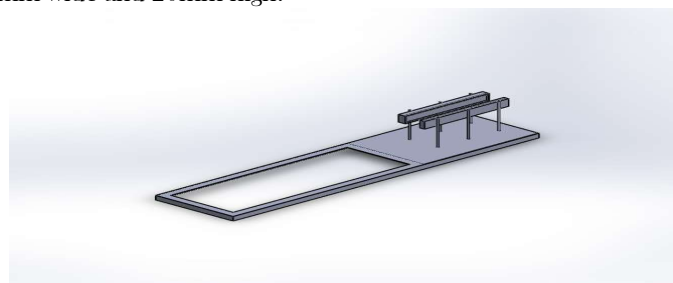
**Battery**

The battery used to drive the extruder is a 12V Dc Battery with a 7.2A rating.

**Fig 2.9: A 12V Dc Battery**



**ix Frame:** The frame is the major form of support in this design and it directly carries the braces, the bearing holder and the rail. The frame is made of a mild steel material with a dimension of 902mm long, 155mm wide and 20mm high.



**Fig 2.10: The Frame**

### 2.10 Design Calculation

It is assumed that for a small scale extrusion process, a motor with a speed rating of 80rpm-120rpm is appropriate. Pitch of the Driven Gear is 7.5, Speed of the Driven Gear in rpm is 30

$$\begin{aligned} \text{Motor Speed} &= 90\text{rpm} \\ \frac{\text{Speed of the Driven Gear in rpm}}{\text{Number of Teeth of the Driven Gear}} &= \frac{\text{Speed of the Driver Gear in rpm}}{\text{Number of Teeth of the Driver Gear}} \end{aligned}$$

$$\begin{aligned} \text{Pitch Diameter (D) of the Driven Gear} &= \frac{\text{Number of Teeth of the Driven Gear}}{\text{Pitch of the Driven Gear}} \\ &= \frac{45}{7.5} \\ &= 6 \end{aligned}$$

$$\begin{aligned} \text{Pitch Circumference of the Driven Gear} &= \pi D \\ &= 3.142 \times 6 \\ &= 18.852 \\ \text{Gear Velocity of the Driven Gear} &= \text{Pitch Diameter of the Driver Gear} \times \\ &\quad \text{Speed of the Driven Gear in rpm} \\ &= 18.852 \times 30 \\ &= 565.56 \text{ inches per minute} \\ &= 0.239\text{m/s} \end{aligned}$$

$$\begin{aligned} \text{Torque generated by the motor} &= \text{Torque transmitted by the Drive Gear} \\ &= 0.098\text{Nm} \end{aligned}$$

$$\begin{aligned} \text{Torque transmitted by the Driven Gear} &= \text{Driven Gear Torque} \times \text{Gear ratio} \\ &= .098 \times 3:1 \\ &= 0.294 \text{ Nm} \end{aligned}$$

$$\text{Torque transmitted by the screw} = 0.294 \text{ Nm}$$

$$\text{Torque} = \text{Force} \times \text{Distance}$$

$$\begin{aligned} \text{Extrusion force} &= \frac{\text{Torque}}{\text{Distance (Axial length of the barrel + Axial length of die)}} \\ &= \frac{0.294}{(210 + 70) \times 10^{-3}} \\ &= 1.05\text{N} \end{aligned}$$

$$\begin{aligned} \text{Extrusion Pressure} &= \frac{\text{Extrusion Force}}{\text{Area of the plunger } (\pi D^2/4)} \\ &= \frac{1.05}{(\pi \times 0.034 \times 0.034/4)} \\ &= \frac{1.05}{0.0009} \\ &= 1166.4.89 \text{ Nm} \end{aligned}$$

### 2.11 Composition of the Pencil lead

The pencil lead is composed of graphitized coconut fibre, Kaolin clay and binder (Achronal and top bond). They were mixed in various ratios in which three samples were obtained, the samples were extruded and heated.

The mixing ratios is depicted in the table below;

**Table 2.1: Composition of various pencil lead samples**

Sample	Graphitized coconut fibre (%)	Kaolin Clay (%)	Binder (Achronal and Top bond) (%)	H <sub>2</sub> O (%)
A	60	20	10	10
B	40	40	10	10
C	20	40	10	10

### 2.12 Baking of the pencil lead

The Pencil leads obtained were baked at same temperature and timing

**Table 2.2: Baking temperature and time of the pencil**

Sample	Temperature (°C)	Time (Hours)
A	250	2
B	250	2
C	250	2

### 2.13 Casing the pencil leads

Cases for the pencil lead were improvised using Softwood popularly called *malana* in Yoruba dialect was used to encase the produced pencil. The leads were glued to the casing with top bond and little pressure was applied at the ends to ensure an appreciable close up of the casing.

## 3. RESULT AND DISCUSSION

### 3.1 Physical assessment

Physical assessment was carried out on the extruder and the following were deduced as regards the ease of extrusion.

**Table 3.1: Ease of extrusion**

Sample	Ease of extrusion
A	Very Good
B	Good
C	Good

### 3.2 Testing of the samples

The samples were made to go through various checks and they were found to perform differently.

### 3.3 Erasing Ability

The various samples of the pencil were used to write on a white sheet of paper after which an eraser was used to check for their erasing abilities. The corresponding results are shown in the table below



**Table 3.2: Erasing ability**

Sample	Erasing ability
A	Poor
B	Good
C	Fair

### 3.4 Ease of Sharpening

The samples, after the production of pencil, was sharpened using a sharpener and a blade. The table below shows their various responses.

**Table 2.3: Ease of sharpening**

Sample	Ease of sharpening
A	Poor
B	Poor
C	Fair

### 3.5 Legibility

The pencils from the various samples were used to write on a white sheet of paper and they gave different levels of legibility.

**Table 3.4: Legibility**

Sample	Legibility
A	Fair
B	Very Good
C	Good

### 3.6 Discussion

Table 3.1 shows the ease of extrusion. It was noticed that the higher the percentage of graphitized coconut fibre the higher the ease of extrusion. The extruder designed was able to force the various samples of composition through the extrusion die. The motor employed was also powerful enough to provide the needed extrusion speed, force and torque.

Table 3.2 shows the erasing ability of the various samples with sample B being the most preferable followed by sample C and sample A

Table 3.3 shows the ease of sharpening of the aforementioned samples. Sample C, being the hardest, is the only sample that is good using this criterion. The other two samples didn't sharpen at all.

Table 3.4 shows the legibility. They gave various results upon writing on a white sheet of paper. They all gave various shades with sample C as the darkest followed by sample B and the sample A.

## 4. CONCLUSION AND RECOMMENDATION

### 4.1 Conclusion

From the results obtained from the design construction of the extruder and the composition of the pencil lead it can be deduced that

1. The extruder machine has enough energy to push the pencil lead composition through a 2mm extrusion die
2. Graphitized coconut fibre can appreciably be used as an alternative for graphite in the production of pencil lead
3. Pencils can now be produced locally here in Nigeria

### 4.2 Recommendations

Having completed the project, we make the following recommendations to enhance and better the production of pencil leads using alternative material for graphite;

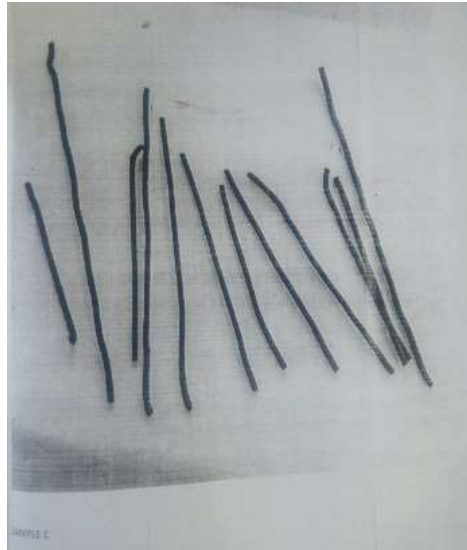
1. A cavity to instantly receive the extruded pencil lead should be constructed to reduce wastage
2. The sample variants should be increased
3. The microstructure of the pencil leads should be considered.
4. The amount of the binder in the composition should be varied.



Sample A



Sample B



Sample C

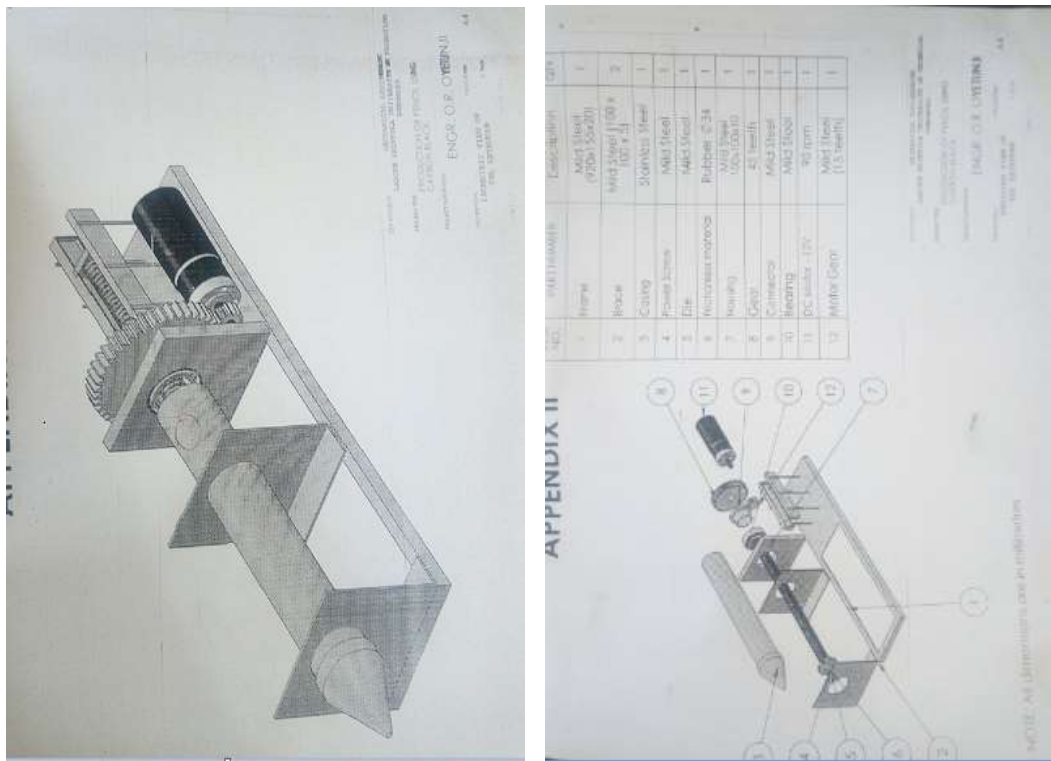


Diagram and exploded view of the extruder



## REFERENCES

1. Oxford Dictionary (2014) Pencil (online) <http://www.oxforddictionaries.com/english/pencil>. (Accessed November 2014)
2. Wikipedia 2014 Pencil (online), <http://en.wikipedia.org/wiki/pencil>. (Accessed November 2014)
3. Britannica (2008). Structure of Graphite, Britannica Concise Encyclopedia, 792
4. Madehow (2015). Pencil (online), <http://www.madehow.com/volume-1/Pencil.html>. (Accessed February, 2015)
5. Petroski, H. (1990). The Pencil, A History of Design and Circumstance, 248, 119-358
6. Pencil (2015). The pencil making process (online), <http://pencils.com/the-unleashed-pencil/> (Accessed February 2015)
7. Encyclopedia Britannica (2014). Kaolin clay (online), The Editors of Encyclopedia Britannica <http://www.britannica.com/science/kaolin> (Accessed November 2014)
8. Mandem (2015). Kaolinite (online), <http://en.mandem.com.tr/service/kaolinite/>. (Accessed May 2015)
9. Suchan, J. (1967). Extrusion of Cosmetic Products. Journal of Cosmetic Science, 19, 893-903
10. Doug, M. (1997). The Pencil Pages (online), <http://www.pencilpages.com/articles/grades.html>. (Accessed November 2014)
11. Draftingmanual (2015). Types of pencil (online), <http://www.draftingmanuals.tpub.com/> (Accessed May 2015)
12. Staedler (2015). Constituent of Pencil (online), <http://www.staedler.com/en/products/>. (Accessed May 2015)