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Formulation, Manufacture And Characterisation Of The Resistivity Proprety Of Carbon Brush Using Palm Kernel Shell (Pks) As Source Carbon.

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Abstract: *The manufacture of carbon brush (CB), a critical motor and generator component has been in existence for over a century in which various materials like: copper metal, graphite, retort coke, petroleum coke and other amorphous carbon have been used in the production of CB. Most carbonaceous materials are good sources of amorphous carbon of which Palm Kernel Shell (PKS) is a typical example. This study is aimed at developing a formulation for the manufacture of CB using PKS as a source of carbon and characterization pf its resistivity property.*

Core components of CB were identified from the literature. Pilot study was conducted to identify material types and mix in CB using particle accelerator model 5SDH. Carbon being the major constituent was extracted from Palm Kernel Shell (PKS), coconut shell and coconut husk through pyrolysis using furnace at 500 °C. The carbon content was determined using particle accelerator model 5SDH. Carbonaceous material with highest carbon content was chosen and calcined at 1200 °C. The amorphous carbon was graphitized at 1.74 KN with a soaking temperature of 1000 °C for 5, 10, 15 and 24 hours, respectively. Copper, zinc, silica and the graphitized material were ground, sieved and mixed together with resin binder. Taguchi experimental design was used to determine the formulation. Samples of carbon brushes were produced. Hardness (H), Resistivity (R) and Bulk density (B) were used as responses and their values were determined and compared with sample of commercial brush.

The carbon contents for PKS, coconut shell and coconut husk are 84.84%, 76.38% and 77.60%, respectively. PKS has the highest carbon content. The mean resistance of graphitized PKS and standard graphite are 3.60 and 2.40 μΩ, respectively. The optimal values of the factors at desirability value of 0.65 were: H= 65.59kgf, R= 4998.19Ωcm and B = 3.06kg/cm^3 with corresponding percentage composition of 60.00% C, 30.00% Cu, 2.00% Zn, 2.50% S and 5.50% binder. It was observed that copper has the highest effect on the resistivity of carbon brush and the least is Carbon. The one factor graph of resistivity to carbon, copper, zinc and solid lubricant were plotted.

It is concluded that, the manufacture of carbon brush with Palm kernel Shell as replacement raw material for graphite is achieved and the resistivity of the carbon brush is affected by all of the raw materials used in the manufacture.

***Keyword**: Resistivity, Graphtisation, Carbon brush, Taguchi Experimental Design*

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I. Introduction

A carbon brush is an electrical component which makes contact between a stationary and a moving electrical circuit. A carbon brush has both an electrical and a mechanical functions within a system; it is a conductor of current in an electrical circuit and is subjected to mechanical forces as it makes physical contact with a surface in motion. (Jeff 2006) Electrical carbon brushes were invented a century ago in England and the development of them was accompanied with that of motors (XIA Jin- Tong et al. 2007).Brush performance greatly determines the performance of rotary equipment such as motors and generators, therefore brushes must be carefully selected.(Schunk 2013) Their production requires very high attention to quality control and production process control throughout all steps of the production process. Manufacturing of carbon brushes requires a very high knowledge of materials and experience in mixture compositions. Very small changes in brush contents by just a few percent of component by weight can significantly change the properties of brushes on their applications. There are just a handful of brush developing companies in the world, which are mostly specialized on certain types of brushes. The major chemical constituents of carbon brush are carbon (C), copper (Cu), Lead (Pb) and Tin (Sn), while the minor constituents are Silica (SiO_2), Iron (Fe) and Molybdenum (Mo). (Nahar et al. 2008) Graphite, amorphous carbon, petroleum coke and resin or pitch binder are the raw materials used in the production.

Graphitisation is the re-alignment of amorphous carbon into graphitic structure using high temperature, pressure or catalyst.

Taguchi's parameter design (PD) methodology has proved to be an effective approach to producing high-quality products at a relatively low cost. The objective of parameter design (also known as robust design) is to determine the best settings of the process parameters, thereby making the process functional performance insensitive to various sources of variation. In the optimization process of multiple quality characteristics, the objective is to determine the best factor settings which will simultaneously optimize all the quality characteristics of interest to the experimenter. (J. Antony, 2001) The Taguchi's design was chosen based on the fact that it is suitable for improvement of product quality and process performance. It is also good for settings of process parameters. Taguchi's design can also be used for optimization of process of multiple quality characteristics.

II. Methodology

Sample of Palm Kernel Shell (PKS), coconut shell and coconut husk were washed, dried and pyrolysed using a pyrolysis furnace in order to obtained the amorphous carbon from them . The amorphous particle obtained from the pyrolysis of PKS, coconut shell and coconut husk were taken to the laboratory to determine the percentage of carbon in them using particle accelerator model 5SDH. It was calcined to 1200 degree Centigrade to remove the remaining carbonaceous materials. The calcined amorphous material was subjected to pressure using torque wrench and a temperature of 1000 degree centigrade for 5, 10, 15 and 24 hours at constant pressure of 1.7 KN. This process was used to graphitized the amorphous carbon to become graphitic structure to some extent. After which copper, zinc iron and graphite were added and mixed together. The Taguchi L16 experimental design model with the following factors: percentage of carbon, copper, zinc, iron and solid lubricant. Resistivity, hardness and bulk density, were used as response for this experiment. They were measured and the result was analysed.Table 2.1 shows the number of factors and levels used in the L16 Taguchi for the production of carbon brush.

Table 2.1: L16 Factors and Levels for the production of the carbon brush.

Factors	Level 1	Level 2	Level 3	Level 4
Carbon	30	40	50	60
Copper	30	40	50	60
Zinc	2	3	5	7
Solid Lubricant	1	2	3	4
Iron	1	2	3	4

2.1 BULK DENSITY

The bulk density is defined by the equation:

Bulk density = $\frac{m}{v}$ …………………………………………………….. 2.1

Where m is the mass of test specimen (dry)
v is the volume of the material.
Measurement and weight method is adopted in this experiment.

2.2 HARDNESS

There are two methods use for determining the hardness of carbon brush: rebound and indentation methods. The indentation method was used and Rockwell hardness test apparatus was used.

2.3 RESISTIVITY

The methods frequently used for production control are :voltmeter-ammeter and Kelvin bridge methods. The voltmeter – ammeter method was used in this experiment. The resistivity is calculated in accordance to the given equation:

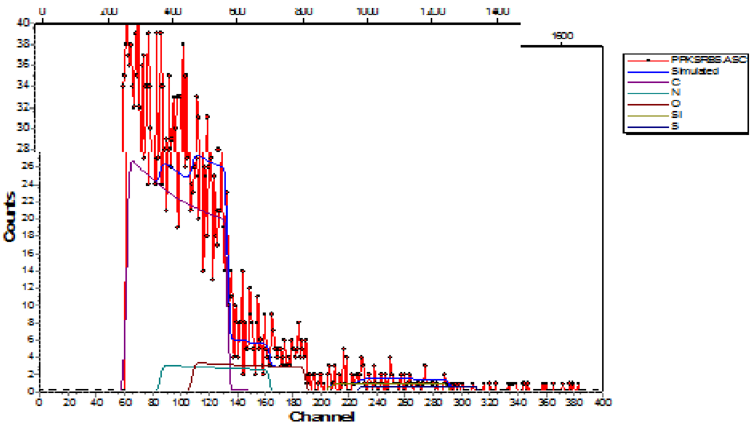
Resistivity = $\frac{U\ x\ b\ x\ w}{I\ X\ l}$ …………………………………… 2.2

Where U is the voltage drop between the potential pointers in volts
b is the thickness of the test specimen
w is the width of test specimen
I is current through the test specimen
L is the distance between the potential pointer in the meter.

III. Result And Discussion

3.1 Component Analysis Of Pyrolysed Pks.

The three pyrolysed carbonaceous materials were analysed and the carbon content of PKS was found to be the highest of the three samples. Base on this it was chosen. The Figure 3.1 gives the laboratory analysis of the carbon content in the pyrolysed PKS.



LAYER :THICKNESS 6692.37 X 10^{15} Atoms/cm^2
Compo: C 84.84 %; N 7.70 %; O 6.56 %;
S. 33.07 %; Si 0.59 %;

Figure 3.1: Component analysis of pyrolysed PKS

The analysis revealed that pyrolysed Palm Kernel Shell has 84.84% of carbon, 7.70% of Nitrogen, 6.56% of Oxygen, 33.07% of Sulphur and 0.59% of Silicon.In Table 3.2 the percentage of carbon in PKS, coconut shell and coconut husk is tabulated.

Table 3.1: Percentage of carbon content in the pyrolysed carbonaceous materials.

Materials	Percentage of carbon content(%)
Palm Kernel Shell	84.84
Coconut Husk	77.60
Coconut Shell	76.38

3.2 Experimental Results For L16 Orthogonal Array.

The L16 experiment has five factors: Percentage of Carbon, Copper, Zinc, Lubricant and Iron. While the responses used are Resistivity, Bulk density and Hardness. These were used to produce and analyzed the carbon brush production process.

Table 3.2 :L16 experimental layout table showing the factors and the responses in the production of carbon brush.

Run	% Carbon content	% Copper content	% Zinc content	% Solid lubricant content	% Iron content	Resistivity (ΩCm)	Bulk density (g/cm^3)	Hardness(Kgf)
1	60	50	5	3	3	2230	2.88	65.7
2	50	60	5	2	1	2600	3.29	70.7
3	40	40	7	3	1	5600	4.53	61.5
4	40	30	5	4	2	4900	3.35	70.0
5	50	40	2	4	3	3300	2.74	64.3
6	30	50	3	4	1	2500	3.08	68.8
7	60	60	7	4	4	3500	3.43	67.3
8	30	30	7	2	3	4400	3.31	69.3
9	60	30	2	1	1	2400	2.92	68.3
10	30	40	5	1	4	7000	4.67	68.0
11	30	60	2	3	2	4700	2.86	70.0
12	60	40	3	2	2	9600	4.34	62.0
13	50	30	3	3	4	4500	3.95	64.6
14	50	50	7	1	2	3800	4.00	68.0
15	40	60	3	1	3	2700	4.12	65.5
16	40	50	2	2	4	3000	3.54	65.5

3.3 Model Equation For Resistivity

The model equation developed with respect to other factors is stated below:

Final equation in terms of Actual Factors is:

Resistivity = +6959.65 – 11.52* %Cabon composition -55.17* %copper composition + 99.11 % Zinc Composition - 191.75 & % Solid lubricant + 108.25 * Iron composition.

3.4 Graph Of Resistivity To All Factors Considered In The Production Of The Carbon Brush.

1. Graph Of Resistivity To Carbon Content In The Brush

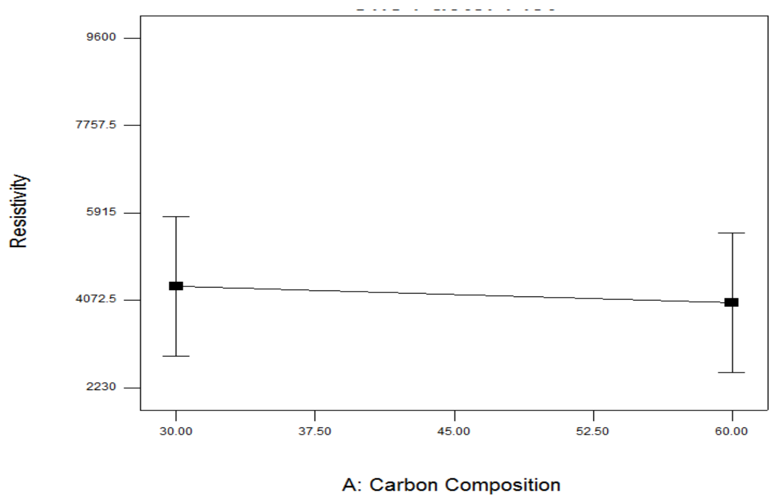


Figure 3.2: Graph of Resistivity versus carbon content in the carbon brush.

It was observed (figure 3.2) that an increased in the percentage of carbon leads to a decrease in the resistivity of the produced brush. This can only be adduced to the fact that the amorphous carbon was turned to a graphitic structure; hence it has the ability to conduct.

2. Graph Of Resistivity To Copper Content In The Brush

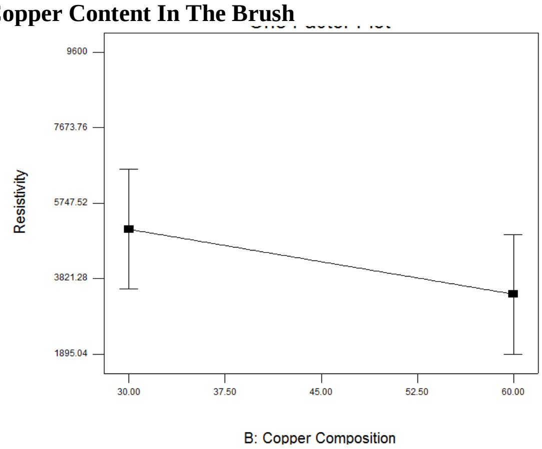


Figure 3.3: Graph of Resistivity versus the copper content in the carbon brush.

The graph of figure 3.3 depicts that more of copper in the brush the decrease in the value resistivity of the carbon brush. This confirms that fact that copper is a good conductor.

3. Graph Of Resistivity To Zinc Content In The Brush

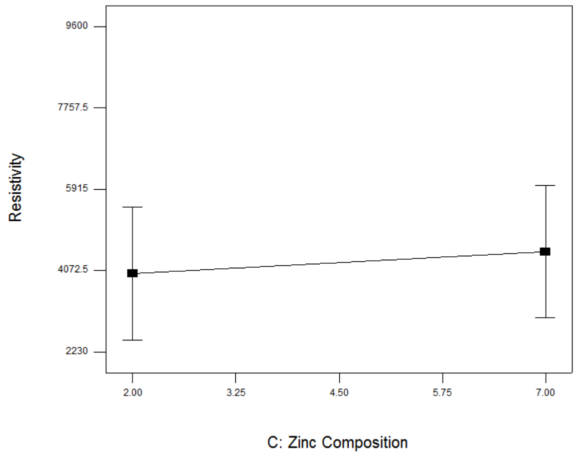


Figure 3.3: Graph of resistivity to zinc content in the carbon brush.

An increase in the content of zinc causes an increase in the resistivity as indicated in figure 3.3. The zinc content acts as corrosion inhibitor and is not as conductive like copper.

4. Graph Of Resistivity To Solid Lubricant Content In The Brush

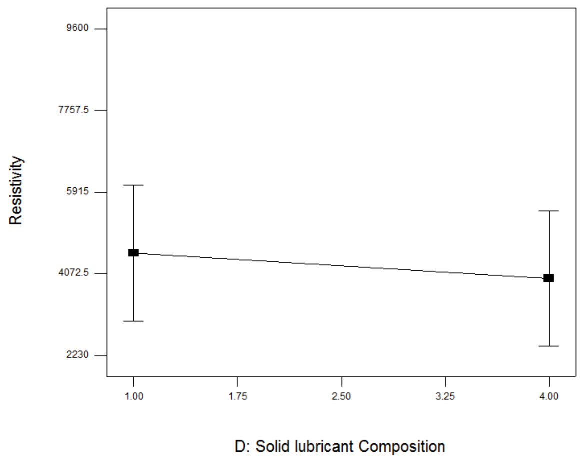


Figure 3.4: Graph of Resistivity to solid lubricant content in the carbon brush

The solid lubricant was added to reduce friction, it is graphitic in nature and the graph of the resistivity versus the solid lubricant shows that the resistivity decreases as the solid lubricant increases as shown in figure 3.4. This reveals that it is a conductor.

5. Graph Of Resistivity To Iron Content In The Brush

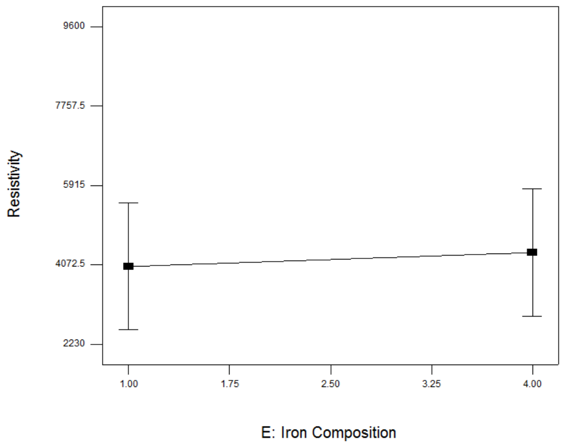


Figure 3.5: Graph of Resistivity to the iron content in the carbon brush

This graph of figure 3.5 depicts that as the iron content in the brush increases the resistivity increases. The iron content serves as a conductor and strengthens the carbon brush.

3.5 Optimisation Of The Factors And Responses In The Production Carbon Brush

The process was optimized based on the following constraints:

Constraints

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Carbon Compos	maximize	30	60	1	1	3
Copper Compos	is target = 30.00	30	60	1	1	3
Zinc Compositio	is in range	2	7	1	1	3
Solid lubricant C	is in range	1	4	1	1	3
Iron Composition	is in range	1	4	1	1	3
Resistivity	minimize	2230	9600	1	1	3
Conductivity	maximize	0.000111	0.000448	1	1	3
Bulk density	minimize	2.74	4.67	1	1	3
Coefficient of fri	minimize	0.52	0.65	1	1	3
Hardness value	maximize	61.5	70.7	1	1	3

The resulting optimized values are shown below at a desirability of 0.65. The corresponding value of the factors and responses were also indicated.

Table 3.3: OPtimisation result at a desirability of 0.65.

% of Carbon	% of Copper	% of Zinc	% of Solid lubricant	% of Iron	Resistivity (ΩCm)	Bulk density(g/cm^3)	Hardness (Kgf)
60.00	30.00	4.66	4.00	1.00	4997.99	3.20	65.59

3.6 Operation Performance

The produced carbon brush was tested using a grinding machine. It was cut and polished to the shape of the carbon brush in the grinding machine and was operated for more than two hours. The original the carbon brush of the grinding machine was also run for two hours and the morphology of the two was compared using the metallurgical microscope. The pitting and the waviness of the carbon brush compared favourably after operating it in the grinding machine.

Figure 3.6: Operational testing of the grinding machine with the produced carbon brush.

Figure 3.7: As purchased brush **Figure 3.8:** Produced brush

Figure 3.7 and 3.8: The brushes placed side by side: As purchased and produced carbon brush.
The diagrams below are the metallurgical view of the surfaces of the As purchased and produced carbon brush after the operational performance.

Figure 4.8a Figure 4.8b

Figure 4.8a: Morphological view of the As purchased carbon brush of the grinding machine after operation for two hours.
Figure 4.8b Morphological structure of the carbon brush produced after two hours of operation in the grinding machine.

IV. Conclusion.

Carbon brush was produced using Palm Kernel Shell as source of carbon and a model for the resistivity developed.

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