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Original Research Article

Development of a Composite-based Emery Polishing Sheet

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ABSTRACT

A composite based Emery paper has been developed. The composite was developed from periwinkle shells grains, silicon dioxide and polyester resin. The composite sample grits were produced with 250 µm and 420 µm sieve sizes. The characterized periwinkle shell grains showed a weight composition of 92 % calcium oxide (CaO). A mechanical non-destructive test of hardness carried out showed that hardness of the composite grains increased with an increase of the binder's weight composition as noticed in the 4 % and 12% polyester resin which yielded hardness of 9 Rockwell hardness value (HRB) and 12HRB respectively. The hardness of the finer grain of 250 µm sieved sized sample grit was found to be higher than that of the 420 µm sieve sized grains. The manufactured sample grits subjected to a polishing machine operation on 500 mm by 500 mm mild steel plate revealed that the 250 µm sieve size grains emery paper polished faster than the 420 µm sieve sized grain. The ANOVA result conducted showed that developed mathematical model for the polishing time of the 250 µm sieved sized emery paper usage was adequate for a p-value and R^2 (adj) value of 0.0187 and 0.9671 respectively. A statistical probability plot showed that the residual points lay very close to the ideal diagonal distribution line which is clear evidence that the developed mathematical model is adequate without noticeable outliers in the model graphic.

1. INTRODUCTION

In engineering, quality is highly required in the manufacture of components. It is well known that materials are made up of various atoms and molecules. These molecules have various rate of absorbing finishing fluids like paints. This can be well explained by the various ways that light rays fall on metallic substances (Aigbodion, *et al*, 2010). Metallic materials like aluminium, tungsten, silver, gold, iron and copper retain high reflective tendencies more than lead and mercury. The application of emery polishing papers is very key in contributing to the reflective nature of these metallic materials (El-Mahallawi and Shash, 2017). In boosting the mechanical properties of metallic materials, the application of emery papers in surface finishing is very vital. This could lead to improving on the wear resistance as well as corrosion resistance of metals (Aku *et al.*, 2012)

It has been noticed of recent, that appreciative outcome has come to the fore on how the application of emery polishing papers have led to the elimination of imperfection such as point defect, dislocation and surface defect from metallic surfaces (Amit, 2022). It is a known fact that surface imperfections could lead to the fatigue of a material thereby causing colossal damage of fund and investment. Sometimes the initial stages of finishing may not be appreciated until the final stage is accomplished (Bob-Manuel, 2012). The production of emery paper carried out by (Wai and Lily, 2002) used the SiO_2 as the base material and epoxy resin as the binding agent in their study. The emery paper developed was made using locally sourced materials like sand, water, backing paper, sieve, sodium hydroxide and zinc oxide. In their study, a 3-method process which centred on sand preparation, paper preparation and sand paper production was used in developing a locally made emery paper. In another development, Wang and Chen (2021) employed a periwinkle shell, palm kernel and polyester composite in developing emery paper applied in metallography. The composite was found to develop a very high hardness and tensile strength with a low wear rate. A comparison drawn between the periwinkle shell and the palm kernel shell showed that the former had higher compressibility, hardness and density which is as a result of the abundant presence of calcium oxide among its constituents.

Over the years Nigeria has been in the business of importing virtually everything we put in use. This have not meant well for a great country like ours. In maintaining the trend emery polishing paper used in material engineering has always been imported. But these days, reprieve is almost coming our way as some many researchers have beginning to cut their teeth in the production of materials used in surface finishing (Jain et al. 2019). This study is necessarily geared towards building local content and indigenous capacity. The aim of this study is to develop emery polishing sheet applied in Metallographic laboratory in Welding and Fabrication engineering.

The work will focus on the creation of composite based emery polished sheet used for finishing components and microstructural surfaces. A periwinkle shell grain will be used in the composite matrix in this study (Chanakyan and Sivasankar, 2021). This study will promote our knowledge of components finishing in metallurgy and metallography. This is a requisite knowledge necessary for various aspects of components production engineering (Yawas et al., 2016). And it will contribute to how to carry out microstructural test of various metallic substances. It is generally obvious that without good background of micro structure of metallic substances it might be difficult to understand the internal composition of metallic materials (Haftiman et al, 2012).

In the past emery polishing papers have always been imported into this country thereby taking a toll on our scare foreign resources. But this study will afford us the opportunity of developing our local content in terms of producing suitable emery polishing sheets.

2. MATERIALS AND METHODS

2.1. Processing of the Composite Materials

The raw materials employed in the production of the emery paper were silicon dioxide and periwinkle shell grains, while the polyester resin was used as the binding agent (Chanakyan and Sivasankar,2021). The equipment used were Rochester milling machine, Rockwell hardness testing machine, spectrographic testing machine, digital weighing balance, universal testing machine, Standard sieve sizes of 250 μm and 420 μm.

The periwinkle shell purchased from Koko market in Delta State, Nigeria was weighed to be 3 kg. It was washed thoroughly and dried in the sun for 48 hours before been placed in the oven to get dried at 100 ^{o}C for 4 h before being introduced into the ball milling machine for reduction of the shells to grains

(Odior and oyawale, 2011). The milled periwinkle grains were passed through sieve sizes of 250 µm and 420 µm for P40 grit sizes. The batch formulation of the percentage constituents of the materials is shown in Table 1. The materials consist of the periwinkle, silicon dioxide, polyester resin, cobalt naphthalene accelerator and ethyl ketone peroxide which served as the catalyst (Obot *et al*, 2016). The proper aggregate measurements of the raw materials were carried out using the laboratory spring weighing balance. The periwinkle grains of mass 108 g, 102 g, 96 g, 90 g and 84 g which correspond to 90 %, 85 %, 80 %,75 % and 70 % respectively were measured out into a separate plastic containers. In the same vein the silicon dioxide grains of 6.24 g, 9.84 g, 13.44 g, 17.04 g and 20.64 g which correspond to 5.2 %, 8.2 %, 11.2 %, 14.2 % and 17.2 % respectively were added to the five separate containers accommodating the periwinkle grains. Furthermore, the polyester resin which served as a binder had mass of 4.8 g, 7.2 g, 9.6g, 12 g and 14.4 g which correspond to 4 %, 6 %, 8 %, 10 % and 12 % respectively was equally added to the separate containers followed by 0.4 % of cobalt naphthalene and methyl ethyl ketone peroxide to the five containers. The overall mixture of the constituents in each container was thoroughly mixed into a composite paste for 3 minutes using a mechanical mixer. A composite sample from each container was formed using the hydraulic press through the compression moulding technique. The samples were used to carry out characterization and hardness test. The chemical composition of the periwinkle grains was ascertain using ultramodern electron scanning microscope. The magnification of the scanning microscope was programmed at >1000xx. The specimen was placed on the sample holder for easy accessibility of the electron beam excited with a voltage of 13 kV (Kalacska, 2013).

Table 1: Constituents of the raw materials

Materials	Varied weight composition (%)				
Periwinkle	90	85	80	75	70
Silicon dioxide	5.2	8.2	11.2	14.2	17.2
Polyseter resin	4	6	8	10	12
Cobalt napthalene	0.4	0.4	0.4	0.4	0.4
Ethyl ketone peroxide	0.4	0.4	0.4	0.4	0.4
Total	100	100	100	100	100

2.2. Mould Development

The mould development was done by compression. A constant pressure of 10 N/mm^2 was applied in developing a mould dimensioned 20.5 mm diameter by 20.5 mm depth used for the emery paper production (Pujari and Srikiran, 2019). The schematic of the mould development is shown in Figure 1.

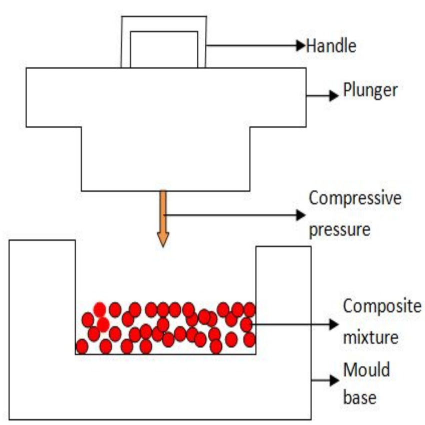

Figure 1: Schematic of the mould development

2.3. Hardness Test

A hardness test was carried out on the developed samples of the composites. The hardness experiment was carried out on "C" scale by setting the ball indenter to a diameter of 1/16″ (Akinyemi *et al*, 2019). The workpiece dimensioned 20.5 mm by 20.5 mm as shown in Figure 2 was placed on the sample holder positioned 60 mm from the conical diamond indenter so as to be properly focused on the screen of the machine with the aid of instrument's optical lens. The test was conducted using Rockwell hardness testing machine shown in Figure 3. An initial force of 100 N was applied to the indenter so as to align with the surface of the workpiece before being increased to a major force of 1500 N for complete indentation effect on the workpiece surface. On removal of the workpiece, the result obtained was read off the screen of Rockwell hardness testing machine. The value of the hardness was determined by applying equation (1) obtained from Akinyemi *et al.*, (2019).

$$HRB = E - e \quad (1)$$

Where HRB=Rockwell hardness number, E= Indenter constant, conical diamond indenter was maintained at 100 units and e = penetration depth occasioned by the application of the major load.

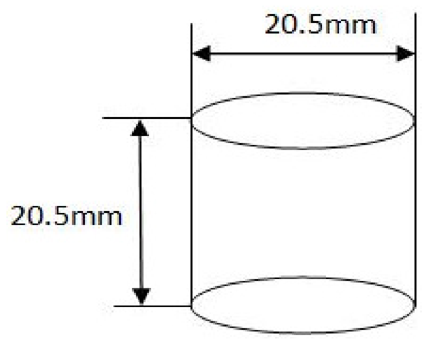

Figure 2: Composite specimen

Figure 3: Rockwell hardness testing machine

A compression test was carried out on the developed composite samples which measured 20.5 mm by 20.5 mm giving a cross sectional area of 422.25 mm^2 as shown in Figure 2. The test was conducted to determine the compession strength of the composite samples. It was conducted on a Universal testing machine. Various sizes of grits were produced and tested to ascertain their efficiencies. The produced emery papers were fixed to existing polishing machine to carry out smoothing experiments on various metallic surfaces. Furthermore, an optimization technique was used to determine the optimal time response between the emery papers produced from the 250 µm and 420 µm sieve sized grains.

2.4. Emery Paper Preparation

The backing paper was firstly, washed with zinc oxide solution in order to input waterproof property on it. The backing paper was introduced into water and washed for about ten minutes. It was removed and dried for about 30 minutes before being put in a rolling machine to get smoothened (Oluwatuyi *et al.*, 2018). The epoxy resin was used as the adhesive to fasten the composite grains to the backing paper. The resin was used to coat the backing paper gently and smoothly on one surface using hand method. The sieved composite grains were sprayed on the adhesive-applied surface of the paper (Oluwatuyi *et al.*, 2018). The bonding enhancement and pressure application of the grains on the paper was done with hand roller.

2.5. Statistical ANOVA and Multiple Linear Regression

Analysis of Variance (ANOVA) is an important statistical technique used to ascertain whether there are significant differences among the means of three or more groups. The Analysis for Variance was used in this study to determine the significance of the developed mathematical model and the various input parameters. The Multiple Linear Regression was used to develop the mathematical model using the conditions applied in the Design of experiment (DOE).

3. RESULTS AND DISCUSSION

3.1. Hardness

The hardness result recorded for the developed composite is shown in Figures 4 and 5. The experimental observation as reported in Figures 4 and 5, show that the hardness value increases with an increase in the quantity of polyester resin. A 4% polyester resin yielded 9 HRB while that of 12% produced 12 HRB for grit size of 250 µm. Conversely, a decrease in the quantity of periwinkle grains yielded a decrease in the hardness of the composite as evident in the Figure 4 where 90% periwinkle grain yielded 9 HRB and the 70% produced 12 HRB for the 250 µm grit size and almost a similar result found for the 420 µm grit sizes. The trend was graphically displayed in Figure 5 showed that hardness of the composite increases with an increase in the quantity of the polyester resin and decreases with an increase in the quantity of the periwinkle grains as shown in Figure 4. This obtained result was noticed to be similar to that obtained in Obot *et al.* (2017) and Saad *et al.* (2021). Also, it was noticed that the hardness values of the grain samples formed from the 250 µm were higher than that of the 420 µm sieve size.

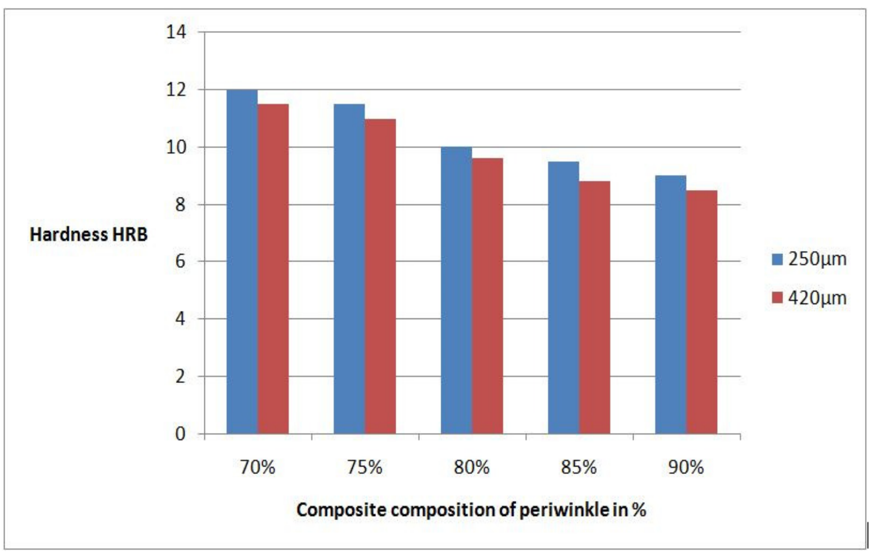

Figure 4: A plot of hardness against periwinkle composition

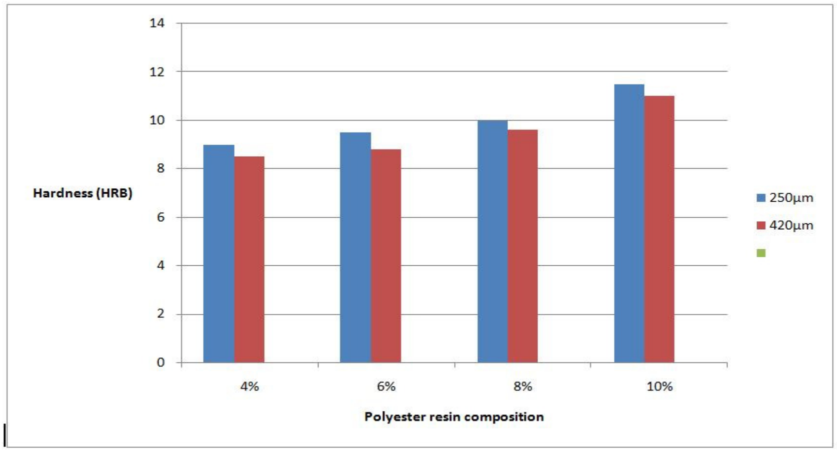

Figure 5: A plot of hardness against polyester resin composition

3.2. Characterization of the Periwinkle Shell Grains

The periwinkle shell grains characterized using the ultra modern XRF characterization machine reveals that the shell is made up of 92 % calcium oxide as shown in Table 2. The presence of calcium oxide could be the reason for the hardness of the shell (Nagajothi and Elavenil, 2018).

Table 2: Constituents of the periwinkle shell

Constituent	CaO	Fe_2O_3	SO_3	SiO_2	TiO	MnO_2	Cr_2O_3
Composition	92	1.48	1.90	1.92	0.64	1.31	0.75

3.3. Performance Analysis of the Developed Emery Paper

The developed emery paper from the two sieve sizes of 250 µm and 420 µm were applied in a metal polishing operation in Metallographical laboratory. An experimental design platform used for the polishing operation was created by the Design Expert software. A 2×2 Design of Experiment (DOE) platform of the Full Factorial model was applied. The experimental design platform is shown in Table 3 (Dagwa and Ibhadode, 2006).

Table 3: Experimental design platform for the metal polishing operation using emery papers

Run	Feed rate (A) (mm/rev)	Polishing speed (B) (m/min)	Time utilized by emery paper 420 µm sieved size (Ti) (mins)	Time utilized by emery paper 250 µm sieved size,Tn (mins)
1	0.25	15	7.10	5.8
2	0.50	30	6.95	5.65
3	0.50	15	6.70	5.55
4	0.25	30	7.12	5.85

A 500 mm by 500 mm steel plate was subjected to a polishing action using the developed emery papers of the 250 µm and 420 µm sieve sized grains. It was noticed used that the time used for the polishing process by the 250 µm was shorter than that of the 420 µm sieved grain. The input parameters used for the machine operation are Feed rate in mm/rev, A and polishing speed in m/min, B. The ANOVA result for the emery papers for the 420 µm and 250 µm sieve sizes are shown in Tables 4 and 5 respectively.

Table 4: ANOVA result for the Emery paper prepared with the 420 µm sieve sized composite grains

Source	Sum of Squares	DF	Mean square	F-value	P-value
Model	0.0477	2	0.0477	14.91	0.1802
A- Feed rate	0.0441	1	0.0441	27.56	0.0119
B-Polishing speed	0.0036	1	0.0036	2.25	0.3743
Residual	0.0016	1	0.0016		
Cor total	0.0493	3			

The statistical R^2 and adjusted R^2 were determined to be 0.9675 and 0.9026 respectively. The coefficient of determination shows that the developed model is adequate for a significance level of 0.05 (Montgomery and Runger, 2003). The predicted R^2 was determined to be 0.4807. The mathematical model developed is given in Equation (2).

$$T_i = 7.23 - 0.84A - 0.004B \quad (2)$$

Where Ti= Time response for emery paper for the 420µm sieve size, A= Feed rate and B = Polishing speed of machine

The adequacy of the model was buttressed more by the development of a model graph of the predicted values against the actual values. It showed that the residual points were close to the ideal diagonal line. This also connotes even distribution of the points, thus promoting model adequacy as shown in Figure 6.

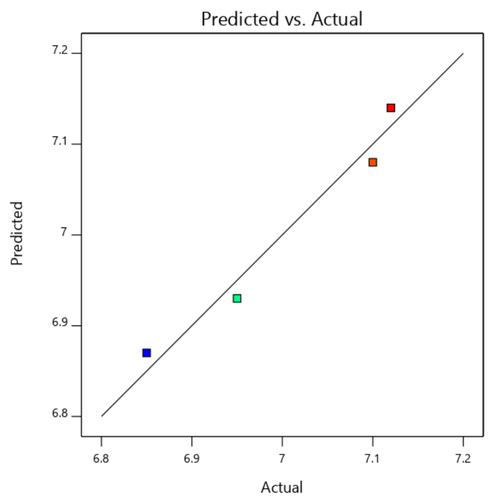

Figure 6: Predicted values against actual values for 420µm sieve size

Table 5: ANOVA result for the Emery paper prepared with the 250 µm sieve sized composite grains

Source	Sum of Squares	df	Mean square	F-value	P-value
Model	0.0562	2	0.0281	45.00	0.0187
A-Feed rate	0.0506	1	0.0506	81.00	0.0490
B-Polishing speed	0.0056	1	0.0056	9.00	0.0248
Residual	0.0006	1	0.0006		
Cor total	0.0569	3			

The developed model was adjudged adequate from the obtained statistical R^2 and adjusted R^2 values determined to be 0.9890 and 0.9671 respectively. The predicted R^2 was determined to be 0.82429. It is evident that the input parameters and the response are significant as obtained in the p-values which are noticeably less than 0.05 used as significance level (Montgomery and Runger, 2003) .This shows that the emery paper developed with the 250 µm sieve size is better in machine operation than the 420 µm model. This lends credence to the work of Saad *et al.*, (2021) which preferred the 250 µm sieve size grains. The statistical mathematical model developed is given in Equation (3).

$$T_n = 5.934 - 0.900A + 0.005B \quad (3)$$

Where T_n= Time response for emery paper from the 250µm sieve size

The predicted and actual values of the time response used by emery paper for the 250 µm sieve size were found to be very close as shown in Figure 7. The residual points were found to be very close to the diagonal line and devoid of any visible outliers. This confirms that the statistical models are adequate as there exist no visible outliers.

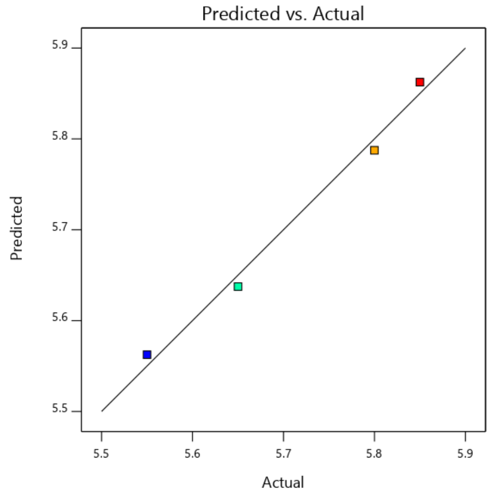

Figure 7: Predicted values against actual values for 250 µm sieve size

4. CONCLUSION

This research technically portrays the application of agricultural produce in achieving a feat in the world of manufacturing. An investigation into the use of composite in developing emery paper has been successfully conducted. The composite was prepared with periwinkle shell grains, silicon dioxide and polyester resin as the binder. The composite sample grits were produced with 250 µm and 420 µm sieve sizes. The specimens produced using compression mould were subjected to characterization and hardness tests. The periwinkle shells grains were found to be made up of 92 % calcium oxide (CaO). The hardness of the composite grains was observed to increase with an increase of the binder's weight composition as noticed in the 4% and 12 % polyester resin which yielded hardness of 9 HRB and 12 HRB respectively. In comparison, the 250 µm sieved sized grains were noticed to have slightly higher value of hardness than the 420 µm sieve sized grains. The developed sample grits subjected to a polishing machine operation showed that the 250 µm sieve size grains emery paper polished faster than the 420 µm sieve sized grain. The ANOVA result conducted showed that the developed model for the time response of the emery paper usage was adequate for a p-value and R^2 (adj) value of 0.0187 and 0.9671 respectively. The probability plot developed, showed that the residual points are close to the diagonal distribution line.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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