Determination And Analysis of Mechanical Properties of Cast Resin From Mango (*Mangifera Indica*) Kernel Oil

A. S. Sadiq[#1,] A. A. Bello[*2] and M. A. Bawa[#3]

[#1, 2 & 3] *Department of Mechanical and Production Engineering, Abubakar Tafawa Balewa University, Bauchi, Nigeria.*

Abstract

The work presents report on determination and analysis of some mechanical properties of cast resin from mango kernel oil (MKO). The bioresin from MKO extracted was produced via epoxidation and acrylation chemical reactions in the previous work. This section of the work is centered on determination and analysis of tensile, compression and impact strengths of cast resin from MKO and compared with cast polyester resin (synthetic resin) for analysis. All the test specimens were produced by cast polymer molding method (hand layup method) where methyl ethyl Ketone peroxide (MEKP) catalyst and cobalt amine hardener were added to each of the resins and mixed thoroughly without reinforcements before pouring the content into the wooden moulds made for the purpose. The tensile, compressive and impact strengths of the cast MKO resin determined were, 177.00N/m^2. 101.01N/m^2 and 29.57J/m^2 respectively while that of the cast polyester resin were 209.11N/m^2, 131.68N/m^2 and 41.82J/m^2 respectively. The results showed that bioresin from mango kernel oil has appreciable mechanical properties close to that of polyester resin and thus can serve as alternative resin to the petrochemical one at lower stresses. However, the overall results gave an insight into the areas of applications and to some extent the limits of mechanical forces that the cast resins can withstand when used without reinforcement. This will help to sharpen the selection decision process where choices are available and the need arises.

Keywords*: MKO resin, Polyester resin, Hand layup, Tensile strength, Compressive strength, Impact strength.*

I. INTRODUCTION

The demand for light weight materials with unusual combinations of properties that cannot or easily be met by the conventional materials such as metals and their alloys necessitated the concerted researches for alternative materials some decades back. One of these materials that have not gained full ground in many developing countries is fibre reinforced polymer (FRP) material commonly called composite material, [1].

Composite material is one of the emerging materials widely used nowadays in the fields of Air, Land and Sea transportation among others for production of materials that have high strength to light weight ratio coupled with corrosion resistance, [2].

Composite material generally consists of two major constituents, reinforcement (fibre) and matrix (commonly called resin). Resin, as defined by [2] and [3] separately, is a viscous and transparent liquid either from organic or inorganic source that will transform (cured and hardened) into solid when treated with suitable catalyst, accelerator with or without heat. Those from inorganic sources (petrochemicals) are commonly called synthetic resins while those from organic sources (such as plant or animal) are called bioresin or renewable resins.

Resin (polymer matrix) constitutes a significant volume fraction (above 50%) of any fibre reinforced composite material that requires proper impregnation of the reinforcement. Despite the fact that the reinforcement (fibre) carries the bulk of the load that the composite is subjected to, it is hardly possible to use the reinforcement alone as a single component in any load bearing structure without the resin (matrix) while the resin in some cases may be used alone in a low load bearing components. This indicates the importance of resin in composite system, [4].

There are different types of resins (bioresins and synthetic resins), however according to [2] any type of resin has several functions; it is a binder that holds the reinforcement (fibre) in place, it transfers external loads to the reinforcement and redistributes the load to surrounding fibers when an individual fiber fractures and laterally supports the fibers to prevent buckling in compression among others and also protect reinforcement from adverse environmental effects.

Considering the problems associated with linear and total use of synthetic (petrochemical) resins for composite manufacturing activities coupled with increasing global demand for composite materials, concerted efforts were made by researchers across the globe to source for alternative materials that are renewable and sustainable for fibre reinforced composite resins. Going by [5], Mango seed kernel oil is one of the renewable sources of oils that is affordable and sustainable and can be processed via epoxidation and acrylation chemical reactions into composite resin. Resin from mango kernel oil had been produced by [6] in the previous work. This is a continuation of the research work for alternative and sustainable bioresin and is centered on determining and analyzing some mechanical properties (tensile, compressive and impact strengths) of the bioresin. The outcome of the work will give an insight into the possible areas of applications and to some extent the limits of those mechanical forces the cast resins can withstand without reinforcement. This will help to sharpen the selection decision when the need arises in that context.

II. MATERIALS AND METHODS

A. MATERIALS

The materials used for the work include:
Bioresin from MKO, Polyester resin, Catalyst (methyl ethyl Ketone peroxide, Accelerator (cobalt amine). Digital weighing machine, Measuring cylinder, Rollers and brush, Wooden moulds, Steel rule, Hacksaw, Hand files, Small plastic containers, wooden mallet, Tensile testing machine, Compression testing machine and Impact testing machine

B. METHOD

a) PRODUCTION OF SPECIMENS

All the specimens were produced by cast polymer molding method (i.e. hand layup technique) where methyl ethyl Ketone peroxide (MEKP) catalyst and cobalt amine hardener were added to each of the resins and mixed thoroughly without reinforcements before pouring the content into the wooden moulds made for the purpose. The ratio of catalyst, hardener and resin mixture depends on how quickly one wants the resin to harden. In this work the ratio was 1:2:75 (catalyst, hardener, resin) in ml. The moulded specimens were sun dried for five day to cure and harden fully Detail of hand layup technique of producing composites or cast resin is found in [2].

b) PREPARATION OF SPECIMENS

Prior to testing, the demoulded specimens were cut and finished to the dimensions suitable for each test.

Tensile tests: 80mm length by 30mm breadth by 10mm thick. Three pieces for bioresin and three pieces for polyester resin. The bioresin tensile specimens were labeled TB_1, TB_2 and TB_3 while those of polyester resin were TP_1, TP_2 and TP_3

Compression tests: 50mm height by 30mm breadth by 10mm thick. Three pieces for bioresin and three pieces for polyester resin. The bioresin specimens were labeled CB_1, CB_2 and CB_3 while the polyester's were CP_1, CP_2 and CP_3

Impact tests: 50mm length by 30mm breadth by 10mm thick with vee notch at the centre of the length. Three pieces for bioresin and three pieces for polyester resin. The bioresin specimens were labeled IB_1, IB_2 and IB_3 while the polyester specimens were labeled IP_1, IP_2 and IP_3. The specimen's original parameters in terms of dimensions and surface areas are shown in table 1 while plates 1 and 2 show some samples of the specimens for both resins.

Plate 1: Some sample of cast polyester resin specimens

Plate 2: Some samples of cast MKO resin specimens

Table 1. Specimen parameters prior to tests

S/No.	Specimen	Dimension (mm)	Area (m^2)
Tensile tests			
1	TB_1	80 x 30 x 10	3×10^{-4}
2	TB_2	80 x 30 x 10	3×10^{-4}
3	TB_3	80 x 30 x 10	3×10^{-4}
4	TP_1	80 x 30 x 10	3×10^{-4}
5	TP_2	80 x 30 x 10	3×10^{-4}
6	TP_3	80 x 30 x 10	3×10^{-4}
Compression tests			
1	CB_1	50 x 30 x 10	3×10^{-4}
2	CB_2	50 x 30 x 10	3×10^{-4}
3	CB_3	50 x 30 x 10	3×10^{-4}
4	CP_1	50 x 30 x 10	3×10^{-4}
5	CP_2	50 x 30 x 10	3×10^{-4}
6	CP_3	50 x 30 x 10	3×10^{-4}
Impact tests			
1	IB_1	50 x 30 x 10	3×10^{-4}
2	IB_2	50 x 30 x 10	3×10^{-4}
3	IB_3	50 x 30 x 10	3×10^{-4}
4	IP_1	50 x 30 x 10	3×10^{-4}
5	IP_2	50 x 30 x 10	3×10^{-4}
6	IP_3	50 x 30 x 10	3×10^{-4}

c) TESTING OF SPECIMENS

All the tensile and compression specimens were tested on universal testing machine (i.e.100KN capacity) in line with ASTM standard described by [7]. The tensile force was gradually applied until failure occurred while the same procedure was adopted for compression tests. In each case the maximum applied (breaking) force was read from the digital load meter of the machine. The tensile strength was calculated using the formula explained in [7].

$$\text{Tensile strength} = \frac{Breaking\ \ force}{Origin\,al\ area\ \ of\ \ specimen}$$

or

$$\sigma = \frac{F}{A} \qquad \ldots\ldots (1)$$

Where,

σ = Tensile Stress

F = Force at failure

A = Original cross sectional area of specimen

$$\text{The compressive strength} = \frac{Crus\,hing\ \ force}{Original\ \ area\ \ of\ \ specimen}$$

or

$$\sigma = \frac{F}{A} \qquad \ldots\ldots.. (2)$$

Where,

σ = Compressive Stress

F = Crushing force

A = Original cross sectional area of specimen

The impact tests were conducted on Charpy impact testing machine. The impact strength of the specimens was calculated in line with ASTM standard obtained from [7].

$$\text{Impact strength} = \frac{Energy\ \ absorbed}{Original\ \ area\ \ of\ \ specimen}$$

or

$$\sigma = \frac{WR\ (\cos\beta - \cos\alpha)}{A}$$

……(3)

Where,

σ = Impact Stress

WR (cosβ - cosα) = Energy absorbed or required to rupture specimen

W = weight of the Charpy impact testing pendulum

R = Length of pendulum or pendulum arm

A = Original cross sectional area of specimen

β = angle of rise

α = angle of fall

III. RESULTS, DISCUSSIONS AND CONCLUSIONS

A. RESULTS

The results of the mechanical tests are shown in tables 2, 3 and 4 while figures 1, 2 and 3 show the variations of the mechanical strengths of the cast MKO and the polyester resins respectively.

Table 2 . Tensile tests results

Tensile			
Specimen	Breaking Tensile force (N)	Tensile strength (N/m^2)	Average tensile strength (N/m^2)
TB_1	53.50	178.33	177.00
TB_2	52.70	175.67	
TB_3	53.10	177.00	
TP_1	59.70	199.00	209.11
TP_2	64.90	216.33	
TP_3	63.60	212.00	

Table 3. Compression tests results

Compression			
Specimen	Breaking Tensile force (N)	Compressive strength (N/m^2)	Average tensile strength (N/m^2)
CB_1	31.43	104.77	101.01
CB_2	29.16	97.20	
CB_3	30.32	101.67	
CP_1	39.67	132.21	131.68
CP_2	39.45	131.50	
CP_3	39.40	131.33	

Table 4. Impact tests results

Impact			
Specimen	Breaking Tensile force (N)	Impact strength (N/m^2)	Average tensile strength (N/m^2)
IB_1	8.70	29.00	29.57
IB_2	9.00	30.00	
IB_3	8.90	29.67	
IP_1	12.80	42.67	41.82
IP_2	11.54	38.47	
IP_3	13.30	44.33	

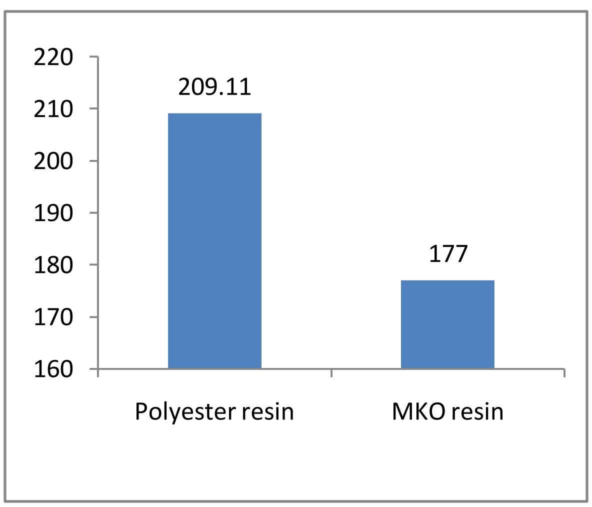

Figure 1: Variation of Tensile strengths of the cast Polyester and MKO resins

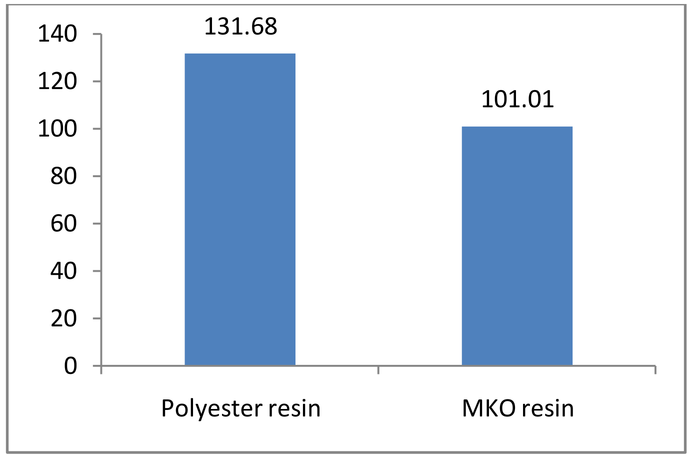

Figure 2: Variation of Compressive strengths of the cast Polyester and MKO resins

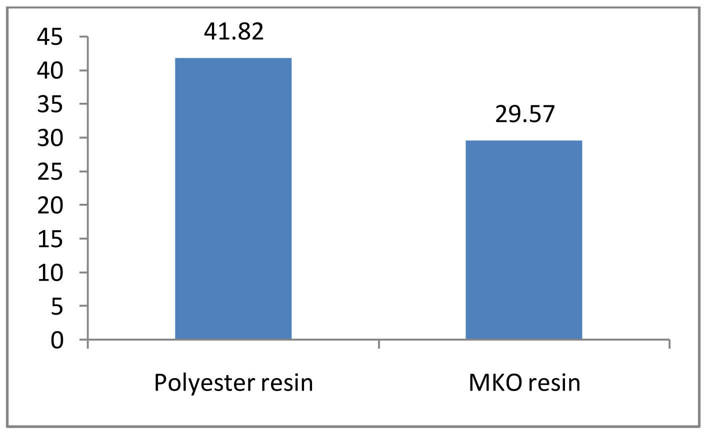

Figure 3: Variations of the impact strengths of the cast Polyester and MKO resins

B. DISCUSSION OF RESULTS

Assessment on the suitability of resin constituent of fibre reinforced composite material requires casting of neat matrix or production of composite laminates consisting of the two constituents (matrix and reinforcement) and subjecting them to suitable mechanical tests prior to usage. The types of tests conducted are inclined towards intended applications. However, the mechanical tests of interest in this work are tensile, compression and impact respectively. The results of these tests as shown in tables 2, 3 and 4 will enables one to have knowledge of the tensile, compressive and impact strengths of the cast resins and to a large extent reveal many other mechanical properties associated with them. In addition, the tests results will also give an insight into the behaviours of the material (resin) when in service and thus helps to sharpening the designer's decisions on selections and usage when the need arises.

In this work each of the tests focus on the strength of the material. Going by [8], strength is a mechanical property of material that confirms its ability to withstand applied force without failing. Depending on the way the force is applied, it could be tensile, compression or impact forces respectively or even more. According to [8], a material has tensile strength if it can withstand either pulling or stretching forces imposed on it. In this work the tensile strength of cast MKO resin is 177. 00N/m^2. This simply means that one square meter area of the cast resin can withstand the force of 177N. This also implies that the more the size of the area, the higher value of the tensile strength and vice versa. Each of the two materials failed in tension by shearing into two without noticeable change in length. This implies that the materials are brittle and hard.

Comparing the cast MKO resin value with that of cast polyester, 209.11N/m^2 as shown in figure 1, it means that cast polyester resin is 15.3% higher than the cast MKO resin. This is due to the differences in the chemical compositions of the materials, degree of unsaturation of the resins which give additional advantage to functionalize it when catalyst and accelerator are added to form solid body and the variations in the cast defects such as blow holes caused by trapped air. Going by [7], the mechanical strength of polymers increases with the degree of crystalinity and molecular weight. Polyester resin tends to have higher crystal structure and more compact and higher molecular weight than MKO. These facts tend to prove themselves by the differences in the densities of the resins, polyester resin (1.5g/cm^3) and MKO resin (1.2g/cm^3). The densities are functions of the molecular weights and the chemical make up the resins.

Going by [8], a material that has to support static load from above it or withstand compressive load imposed on it has to have good compression strength. Comparing the compression strengths of the two materials as shown in figure 2, it implies that cast polyester resin is 23.3% higher than the cast MKO resin. The reason for the disparity is unconnected with the differences in the chemical composition and the level of unsaturation of the two materials.
During the compression tests, the MKO specimen's flows out some of the undried resin liquid from the interior part of it that cracked open before failure. This means the core of the specimens takes much longer time to dry than polyester resin specimens.

Going by [8], a material that has to withstand shock or suddenly applied force imposed on it has to have enough impact strength. As shown in figure 3, the impact strength of cast polyester resin is 29.3% higher than that of cast MKO resin. This simply means that the cast polyester resin is tougher than the MKO resin. The reason is not far from the reasons mention above and of course some cast defeats like brow holes associated with the production of specimens. All the specimens failed by scattering into to pieces. This confirms the brittle and hard nature of the cast resins.

C. CONCLUSIONS

The following conclusions are made based on the outcome of the study:
(i). The tensile, compressive and impact strengths of the cast MKO resin determined were, 177.00N/m^2. 101.01N/m^2 and 29.57J/m^2 respectively while that of the cast polyester resin were 209.11N/m^2, 131.68N/m^2 and 41.82J/m^2 respectively

(ii) Comparism of the results showed that cast polyester resin is 15.3%, 23.3% and 29.3% higher in tensile, compressive and impact strengths respectively than the cast MKO resin.

(iii) The overall results revealed that resin produced from MKO (bioresin) has appreciable mechanical properties close to the polyester (synthetic) resin and can serve as alternative resin at lower stress applications when the need arises.

REFERENCES

[1] Sadiq A. S. , A. A. Bello and A. Tokan (2016). Shift towards using renewable oil for resin production for fibre reinforced composite materials in Nigeria. Proceeding of the 29th AGM & International Conference of the Nigerian Institution for Mechanical Engineers (NIMechE) hosted by the Nigerian Institution for Mechanical Engineers, Uyo in Akwa Ibom state, Nigeria. 18th – 21st October, 2016. PP.1-18

[2] Astron, B.T. (1997). Manufacturing of polymer composites 1st Edition, London: Chapman and Hall, U.K

[3] Strong A.B. (1999). Fundamentals of composites manufacturing: materials, method and Applications 1st Edition, SME Publishing Ltd. Dearbarn, MI U.S.A

[4] Jianmin Chang, Yong Cui and Wenliang Wang (2016). Fabrication of Glass Fiber Reinforced Composites based on Bio-Oil Phenol Formaldehyde Resin. www.mdpi.com/journal/materials

[5] Sadiq A. S., A. A. Bello, A. Tokan and S. Abdulsalam (2018). Production and analysis of epoxidized oil from Rosigold mango (Mangifera indica) kernel oil for bioresin synthesis. Journal of the Nigerian Institution of Mechanical Engineers. Vol.8 No. 2 pp 58 – 69

[6] Sadiq A. S., A. A. Bello, A. Tokan and S. Abdulsalam (2018). Production and Analysis of bioresin from Mango (Mangifera Indica) Kernel Oil. International Journal of Modern Research in Engineering and Technology (IJMRET) Volume 3 Issue 12. PP. 5 - 16

[7] Kakani, S. L. and Amit Kakani. (2004). Material science 1st Edition, new age international publisher, New Delhi, India

[8] Ryder,G.H.(1969). Strength of Materials, London and Basing Stroke: Macmillan

Appendix

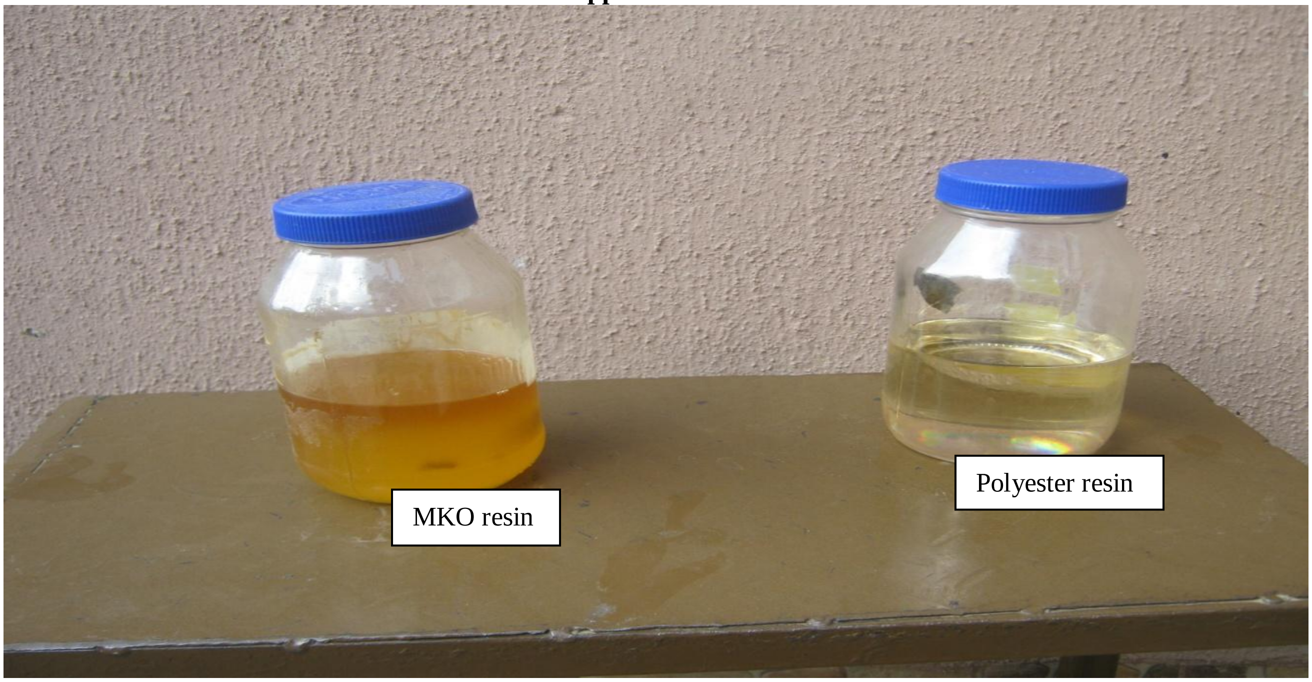

Plate 3: Samples of MKO and Polyester resins used.

Plate 4: Production of specimens from both MKO and Polyester resins in progress