A Preliminary Mechanical Characterization of Polyurethane Filled with Lignocellulosic Material

Malachy SUMAILA, Benjamin Iyenagbe UGHEOKE*, Levi TIMON, Theophilus OLOYEDE

Mechanical Engineering Department, Federal University of Technology, Yola, Nigeria
sumalachy@yahoo.com, *ugheokeb@gmail.com

Abstract

A preliminary study of the mechanical properties (tensile strength, compression strength and impact energy) of groundnut husk powder filled polyurethane composite was carried out and reported in this paper. Filler content was varied between 2 and 10 weigh percent of matrix. It was observed that the tensile strength increased marginally with increase in filler content, while the impact strength decreased with increased filler loading. These effects are attributable to the poor interfacial interactions between fibre and matrix. More work is therefore suggested to optimise the composite production and improve the interfacial interaction of the fibre and matrix for possible use as shoe soles.

Keywords

Polyurethane matrix, Groundnut husk, Tensile strength, Impact strength

Introduction

Present day technology requires materials with unusual combination of properties that cannot be met by the conventional classes of materials- metals, ceramics and polymers. As a result engineers are compelled to search for alternative materials to meet the complex service requirements for today's applications. Amongst the desired material properties requirement are: low density, strong, abrasion and impact resistant and are not easily corroded [1]. These material property combination and ranges have been met and are yet being extended by the development of composite materials.

Composite materials are materials having two or more distinct phases such that a better combination of properties is achieved [1,2]. The constituents must be chemically and physically dissimilar and separated by a distinct interface. The composite consists of a matrix, which is continuous and surrounds the filler, which provides the reinforcement such that the resulting composite property is a function of the properties of both the matrix and filler.

The matrix materials commonly used are metals, ceramics and polymer. Depending on the type of matrix used, composites have been roughly grouped [3] into: metal-matrix-composites (MMC's), ceramics-matrix-composites (CMC's), intermetallic-matrix-composites (IMC's), carbon-matrix-composites (CCC's) and polymer-matrix-composites (PMC's). However, polymers are the most widely used matrix materials because of their low specific gravity, chemical stability and ease of fabrication [4]. Polymers have also been viewed as a viable substitute for other engineering materials with a strong and formidable end product when processed [5]. Thus, composites with polymers as matrices have found wide applications in automobile, construction and aerospace industries.

Polymers are non-biodegradable and now that consumers are becoming more health and safety conscious, attention is being turned to end products that are not only safe for use, but also environmentally friendly [6]. For this reason, instead of mineral and synthetic fibres, which are often used and are non-biodegradable, bio-fibres have been used differently to reinforce polymers [7, 8, 9] in order to introduce environmental friendliness into the end Ligno-cellulosic fibres such as rice husk, groundnut husk, rice straws etc, come handy in choosing a biodegradable fibre either as a filler or reinforcement in polymer matrices, due to their rather very low cost, ease with which they are obtained (especially in tropical Africa, where they are indiscriminately dumped), low weight and low thermal conductivity. These characteristics would vibrantly lend credence to the use of the afore mentioned ligno-cellulosic fibre as possible fillers in the manufacture of shoe soles from polymeric composites. This act would reduce overall cost of the end products.

Literature is replete [9, 10, 11] with the use of wood fibre, glass, rice husk, rice straw, etc, in the filling and reinforcement of various polymer matrices, thus yielding composites

Issue 9, July-December 2006
p. 159-166

with better dimensional stability, improved mechanical properties, better thermal response among others. What the authors have not known from available literature is the use of groundnut husk powder as filler in any polymer matrix composite formulation. In this work therefore, it was intended to develop a composite material with polyurethane as the matrix and groundnut husk powder as the filler. The work also investigated the basic mechanical properties (pertinent to shoe soles manufacture) of the developed composite.

Materials Collection and Preparation

3kg of the filler material (groundnut husk) was obtained locally from the farmer and was ground in a hammer mill (Series 200) and sieved through 415μm BS sieve. 2, 4, 6, 8 and 10g of the sieved sample were measured out and labelled A, B, C, D and E respectively. These were stored in an airtight bag and kept in a dessicator in the laboratory. Concord Foam and Allied Chemical Industries, Yola supplied 1kg of polyurethane (the matrix) in liquid form. Five 100g of the matrix was measured out and each blended with the previously prepared filler samples A-E using a mixer running at 120 rpm until a homogenous mixture was obtained. The mixtures were then separately poured into a prepared mould and allowed to cure for 6hrs.

Experimental Procedure

Tensile test

From the samples A to E, a sample was prepared for the tensile test with cross sectional area of 150m^2 and gauge length of 50mm in accordance with ASTM. D638 procedure. A universal testing machine (Tinius Olsen Model 290) equipped with 300KN capacity was used for the test at room temperature. The result of the tensile test is presented in table 1.

Table 1. Tests result of Mechanical properties

S/No.	Sample	Filler content (weight %)	Tensile strength (N/mm^2)	Impact energy (J)	Compression strength (N/mm^2)
1	A	2	0.075	12.00	6.90
2	B	4	0.077	11.20	13.50
3	C	6	0.084	10.00	10.60
4	D	8	0.091	6.00	6.60
5	E	10	0.095	4.80	10.56

Impact Strength test

An unnotched specimen with dimensions 20 mm·40 mm was produced for the charpy test carried out on an impact tester (Avery Dension 6705U) in accordance with BS 131:172 with an average impact velocity of 4.7m/s at room temperature. The impact test was carried out in the five samples A to E and the result presented in Table 1.

Compression strength test

A square specimen $2025mm^2$ and 175mm in length was prepared from each of the five samples and subjected to a gradually applied compression load in the universal testing machine until yielding was observed and recorded as shown in Table 1.

Results and Discussions

The results obtained from the mechanical tests carried out are presented in the Table 1 below and the graphs of the mechanical properties relationship with the filler content (weights %) are shown in Figures 1-3.

From the results of the experiments presented in table 1 and figures 1-3, the tensile strength test shows a steady increase in tensile strength with increase in filler content, indicating a 68% increase in tensile strength with 2-weight % of filler addition. However, the results show a decrease in percentage increase in tensile strength to 53% improvement in tensile strength when compared with the unfilled polyurethane with tensile strength of $51N/mm^2$ [4]. This is at variance with trend available in literature [9, 12], which have showed a decrease in tensile strength with increase in filler content.

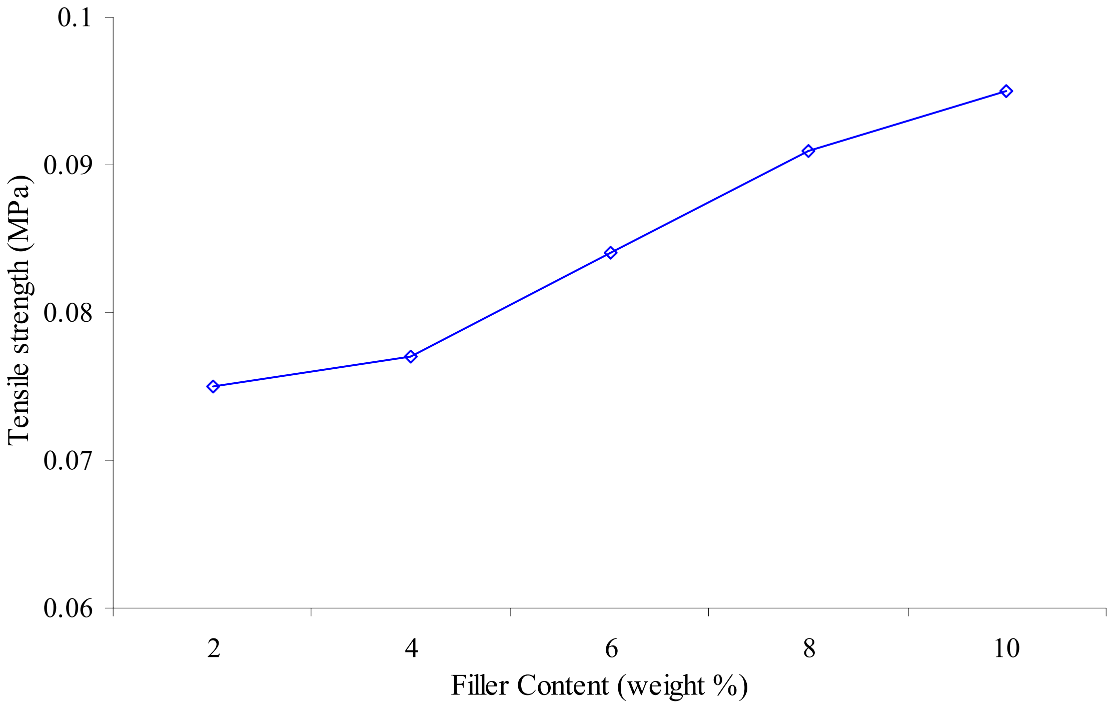

Figure 1. Variation of tensile strength with filler loading

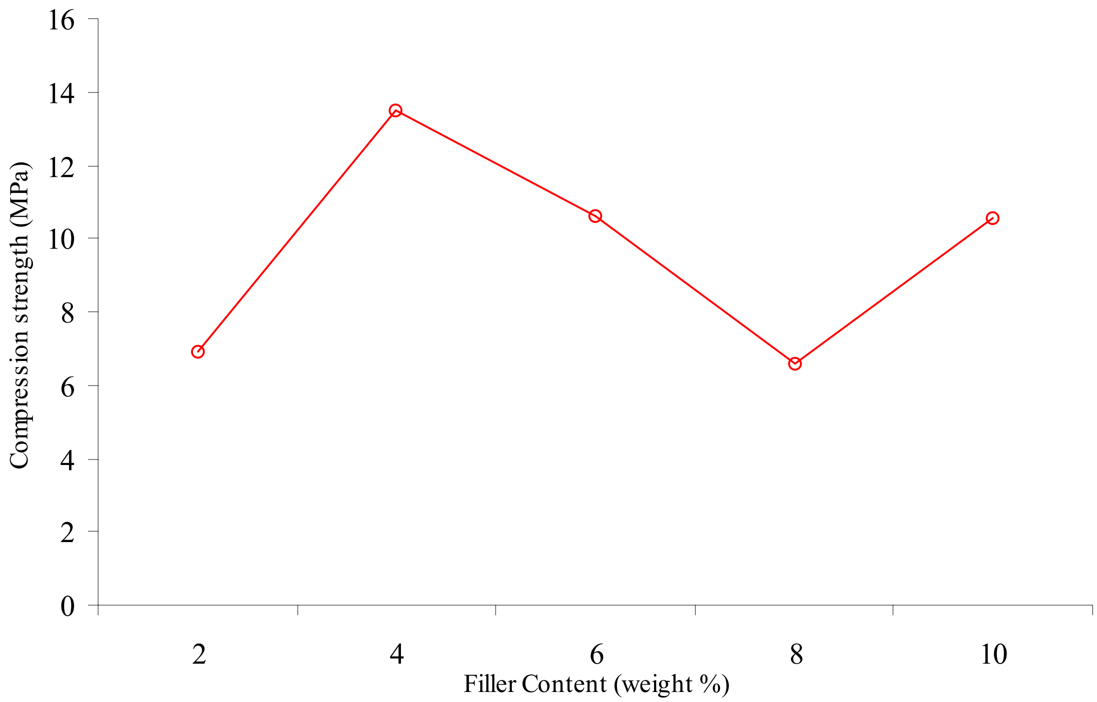

Figure 2. Compression strength versus filler content

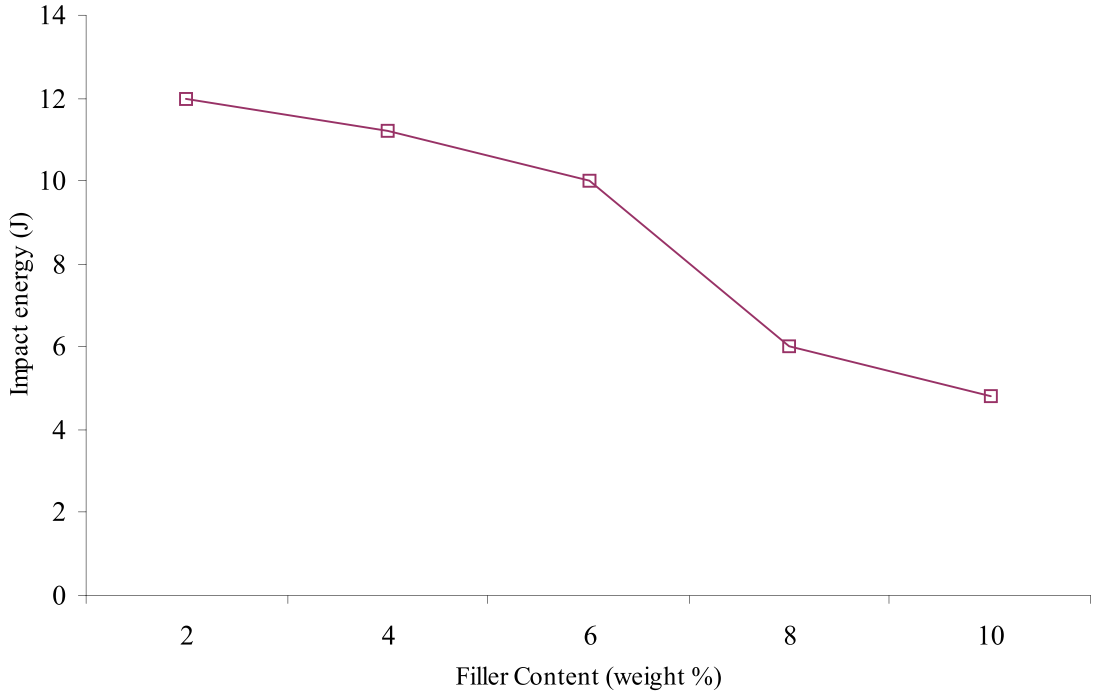

Figure 3. Variation of impact energy with filler content

The trend observed in this work may be attributed to the fact that the filler used may have occupied the spongy polyurethane matrix, creating some reinforcing effect and this possibly may have been responsible for the increase in tensile strength witnessed. It is however, possible that at some point of further increment in the filler content, a decrease in the tensile strength may be witnessed. This behaviour displayed by the composite suggests that the formulation is suitable for applications subjected to tensile load at this low filler loading. However, the response of the formulation indicates a steady decrease in impact energy with increase filler content. This may be attributed to the weak interfacial interaction between the filler and matrix material. From the results obtained (Figure 2), sample D consisting of 10% filler content gave the highest compression strength while sample B the lowest. Figure 3 on the other hand showed a decrease in impact energy to 4.8 J with 10 % filler addition. This could also be attributed to poor interfacial bond between the matrix and the filler material.

Conclusions

Sample D has the highest tensile strength of 0.095N/mm^2 and lowest impact strength of 4.8 J. However, sample B gave the best combination of impact energy and compression strength. This could be used as material for shoe sole production.

This being a preliminary study, it is suggested that further work be done on filler-matrix interphase optimisation in order to obtain a composite with best mechanical performance. Work needs also to be done on the water absorption character of the composite as well as in making it resistant to fungal attack.

References

[1] Callister W. D., *Material Scarce and Engineering, an Introduction*, 4th Ed., John Wiley and Sons Inc., New York, 1997.

[2] Agarwal B. D, Broutman L. J., *Analyses and performance of fiber composite*, 2nd Edition, John Wiley and Sons Inc., N.Y., 1990.

[3] Raizana M. T., *Cellulose fibre reinforced thermoplastic composites: processing and product characteristic*, MSc Thesis, department of forest products, Virginia Polytechnic Institute and State University, Virginia, USA, 1998.

[4] Dyson R. W., *Engineering Polymer*, Chapman and Hall, N.Y., 1990.

[5] Fredonia Group Inc., *Composite Technology*, 2001, p. 7 – 15.

[6] Kim S., Lee Y.-K., Kim H.-J., Lee H. H., *Physico-mechanical properties of particleboards bonded with pine and wattle tannin-based adhesives*, Journal of Adhesion Science and Technology, 2003, vol. 17, no. 14. p. 1863-1875.

[7] Rajeev K., Krishnan M., Narayan R., *Biofiber-reinforced polypropylene* composites, Polymer Eng. Sci., 1997, vol. 37, no. 2, p.476-483.

[8] Oladipo A. B., Wichman I. S., Beck J. V., *Experiment investigation of the thermal properties of wood fiber/thermoplastic composites*, Journal of Composite Materials, 1999, vol. 33, no. 5, p. 480-495.

[9] Yang H.-S., Kim H.- J., Son J., Park H.-J., Lee B.-J., Hwang T.-S., *Rice Husk Flour Filled Polypropylene Composite: Mechanical And Morphological Study*, Composites Structures, 2004, vol. 63, p. 305 – 312.

[10] Kristiina O., Clemons C., *Mechanical properties and morphology of impact modified polypropylene-wood flour composites*, Journal of Applied Polymer Sci., 1998, vol. 67, p. 1503-1513.

[11] Johnson D. A., Johnson D. A., Urich J. L., Rowell R. M., Jacobson R., Caufield D. F. *Weathering Characteristics of Fiber-Polymer Composites*, The Fifth International Conference on Woodfiber-Plastic Composites, Madison, Wisconsin, USA, 2003.

[12] Premalal H. G. B., Ismail H., Azahari B., *Tensile properties of rice husk powder filled polypropylene composite*, Postgraduate research papers, Universiti Sains Malaysia, 2002.