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FUZZY ASSESSMENT OF THE IZOD IMPACT ENERGY OF DATE PALM WOOD FIBER RECYCLED LOW DENSITY POLYETHYLENE COMPOSITE

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ABSTRACT
The izod impact energy of recycled low density polyethene composite filled with date palm wood fiber was achieved using a fuzzy logic model. The composite was tested with different percentages of 2 to 30% by weight of filler and with grain sizes of 150µm to 300µm. The izod impact energy experimental results obtained for the 2% filler by weight of the particle sizes were 1.46kj/m, 1.49kj/m, 1.52kj/m, and 1.55kj/m. The model developed predicted values of 1.55kj/m, 1.49kj/m, 1.52kj/m and 1.46kj/m. Comparison of the experimental and predicted results indicate little or no significant variation.. The results show that the coefficient of correlation (R) of all the predictions was above 0.999. This confirms the ability of the model as a substitute for prediction of the izod impact energy of LDPE filled with date palm wood flour.

Key words: Date palm, izod impact energy, Wood fibre, Fuzzy logic, prediction, LDPE.

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Introduction

Fuzzy Logic which was first developed by the mathematician Lotfih A. Zadeh in 1965, deals with imprecision and uncertainty reasoning rather than exact measurement.Fuzzy logic can has three major stages, namely Fuzzification, inference and / or defuzzification. Since Zadeh's 1965 contribution to this field, there has been large volume of literature, covering both academic research and practical implementation in almost every area, from physical to social science. The literature review here focuses on the prediction of the mechanical properties of low density polyethylene (LDPE) filled with date palm fiber. The application is quite diverse. It might be a replacement of classical sets with fuzzy sets, a full-blown implementation of a fuzzy logic system or hybrid model that includes a fuzzy logic model. The objective is to introduce a range of possible applications of fuzzy logic in material properties prediction. The properties of agro-based thermoplastic composites are very process dependent. Yam *et al.* (1990) concluded that the level of fiber attrition depended on the screw configuration and the processing temperature in wood flour/LDPE composite. The tensile strength of pure LDPE was higher than that of the wood fiber-LDPE, irrespective of the level of fiber filling. This was explained to be because of a lack of dispersion, with fibers clumping in bundles, and poor fiber-matrix bonding.

Many industries in Nigeria face the problem of material selection, however inorganic materials have been used as fillers in the polymer industry for production of composites and these materials face some problems like abrasion of the processing equipment, low insulating properties, low specific properties, high density, high cost of production, etc. for these reasons, organic fillers are increasingly being considered in composite production. Hence, date palm wood was used as a filler to develop the polymer composite used in this work. Izod impact energy of materials are very important to determine the quality of the material with respect to its application to engineering as polymer composites are a very important class of engineering materials.

Experiments are expensive and mathematical computation is often difficult but computational method such as fuzzy logic which requires minimal data and experimental observation will be used to predict the material properties.

Review of literature

Traditionally, laboratory trial mixes have been used to determine the mechanical properties of polymer composites, as well as other engineering materials. Experimental determination of the mechanical properties of materials is costly and time-consuming. Finding a portable low-cost way of predicting the strength of polymer composite materials would help in solving the problem (Nwobi-Okoye *et al.,* 2015; Nwaeto and Placid, 2018). One way this could be done is by developing a computational model based on fuzzy logic for predicting the strength of polymer composite materials (Nwobi-Okoye *et al.,* 2015). With mathematical and computational models such as fuzzy logic, a designer can easily find the best combination of constituent materials to balance strength and cost.

The advantages of composite materials over conventional materials stem largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile. They also have good resistance to corrosion, low cost, increased toughness and good resistance to fire (Bledzki & Gassan 1999).

Al-Kaabi *et al*. (2005) investigated the potential of natural fiber extracted from the date palm tree as reinforcement for polyester matrix composites. Their results show that these fibers may yield reasonable properties and could be used for low-cost applications that require low to medium strength.

Mahdavi *et al.* (2010) compared the mechanical properties of composites made from various fibers extracted from date palm and high-density polyethylene. From the literature, it is apparent that percentage composition, particle sizes and type of fillers affect the mechanical properties of composites.

Nwobi-Okoye, *et al.* (2016) used fuzzy logic to evaluate breakdown risk on engineering facilities.

Therefore, in this work, low-density polyethylene from containers used to package table water was gathered, recycled and combined with date palm wood fibre flour to produce a composite material. The izod impact energy of the material was determined experimentally for various percentage weight compositions of date palm wood fibre ranging from 2% to 30% and for particle sizes of 150μm to 300μm. The experimentally determined izod impact energy of the composite at various percentage compositions of the date palm wood fibre and at various particle sizes were later used to develop a fuzzy logic model. This fuzzy logic model was then used to predict the izod impact energy of the composite at various percentage compositions of the date palm wood fibre with dissimilar particle sizes.

Materials and method

The materials used include date palm wood fiber, sieves, low density polyethylene, water, single screw extruder, and izod impact tester.

The date palm wood was obtained from Bauchi State: The fibers obtained from the above mentioned state were separated from the meshes manually and washed with clean water and detergent to remove the contaminants, dirt and dust. The extracted fibers were cut into small sizes, sun-dried, crushed, ground and sieved using a mechanical sieve of sizes150μm to 300μm, and stored in a polyethylene bag.

Collection and preparation of recycled low-density polyethylene: The recycled low-density polyethylene (LDPE) plastic container was obtained from the refuse bin. The plastic was washed with a clean water to remove the dirt, dust and sun-dried. The (LDPE) materials were cut to small sizes to enable the crushing machine to accept them.

Preparation of the composite

The date palm wood flour constitutes the filler for the composite. The LDPE was filled with different percentages of date palm wood flour ranging from 2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18%, 20%, 22%, 24%, 26%, 28% and 30%. The particle sizes of 150μm to 300μm were used to examine the size effect of date palm wood flour as filler on the properties of LDPE, respectively. These particle sizes were examined to find the one which gives the best properties for LDPE composite.

The polyethylene and filler were mixed with different percentage compositions of the flour. The mixing of the recycled LDPE and date palm wood flour was done using a single screw extruder manufactured by DongyangFuqiang Electrical Industry Co., Ltd, China. Since the melting point of LDPE is 115°C, the temperature of the screw extruder was set at 130°C to 140°C during the compounding process to ensure that a melt flow index of at least 9.0 g/10 min was achieved for successful mixing. Each of the mixtures was injection-molded using an injection molding machine. The composites produced were allowed to cool at room temperature.

Results and Discussion

Membership functions for the date palm fiber composite mechanical properties

After experimentally determining the izod impact energy of the date palm fiber composite and using MATLAB software, fifteen input variables describing the percentage of the filler content were developed. The input terms/variables are: IN1, IN2, 1N3, IN4, IN5, IN6, IN7, IN8, IN9, IN10, IN11, IN12, IN13, IN14, and IN15. The membership functions for the input variables were developed as illustrated in Figure 1

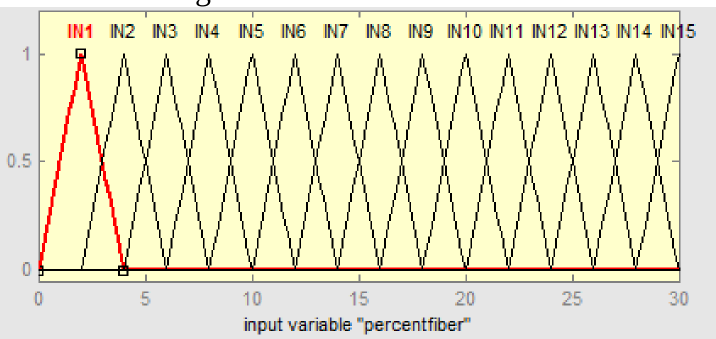
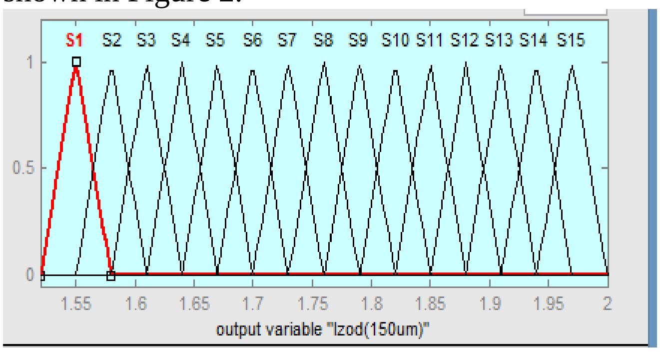
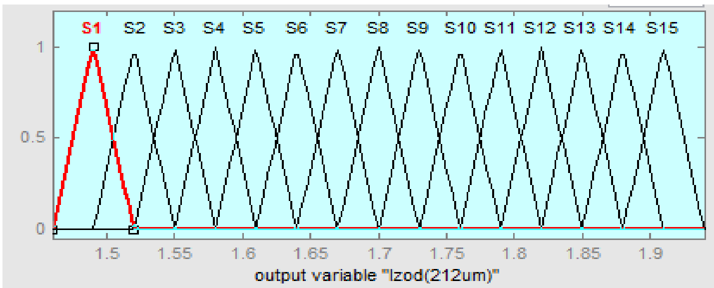
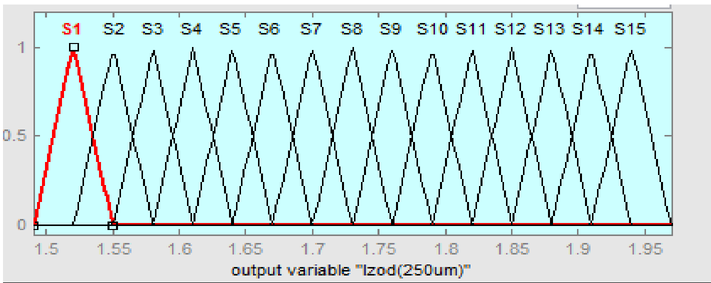


Figure 1: Input variables for the filler content

Similarly, fifteen output variables namely: S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, and S15 were created for each grain size ranging from 150µm, 212µm,250µm and 300µm to rate the predicted variables. Membership functions for the twelve output terms were developed as shown in Figure 2.







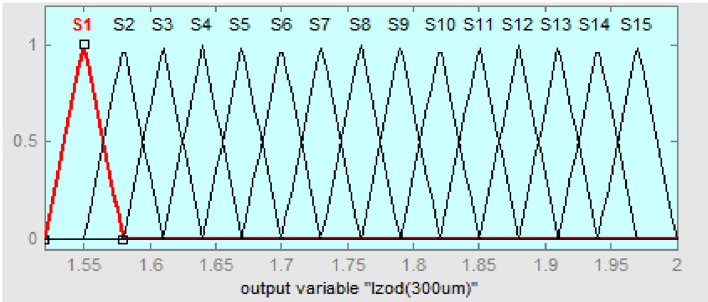
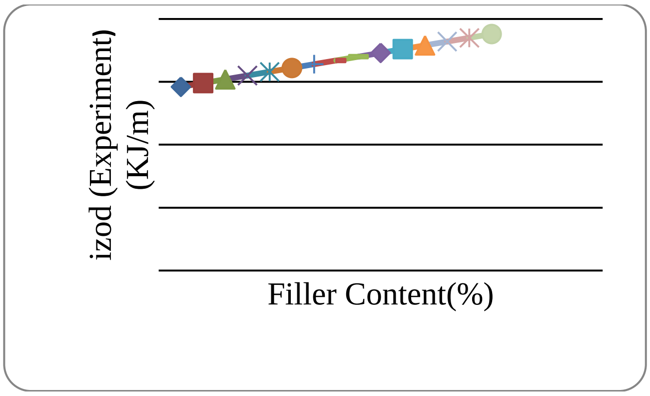
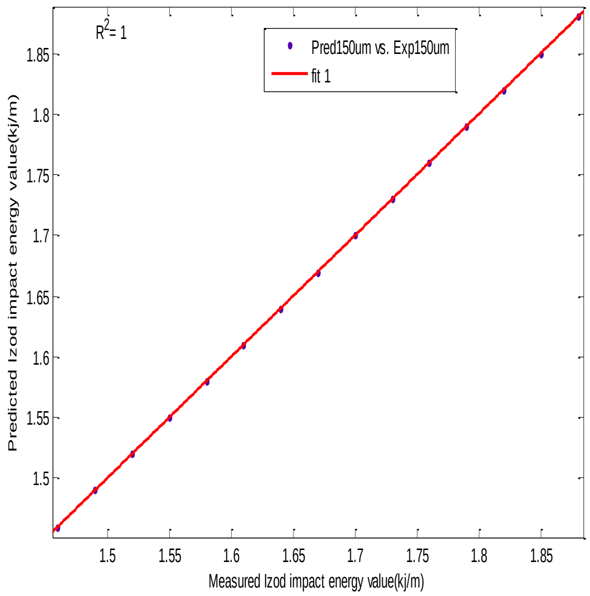


Figure 2: Membership functions for izod impact energy for 150µm, 212µm, 250µm and 300µm mean grain sizes.

Prediction of the effect of filler content on the izod notched impact energy. Figures 2 shows the effect of filler content on the izod notched impact energy of date palm wood flour/LDPE composite at 150µm, 212µm, 250µm and 300µmparticle sizes and initial LDPE of 1.1 kJ/m. As shown in the figures, increase in the filler content increased the izod notched impact energy.



(a)

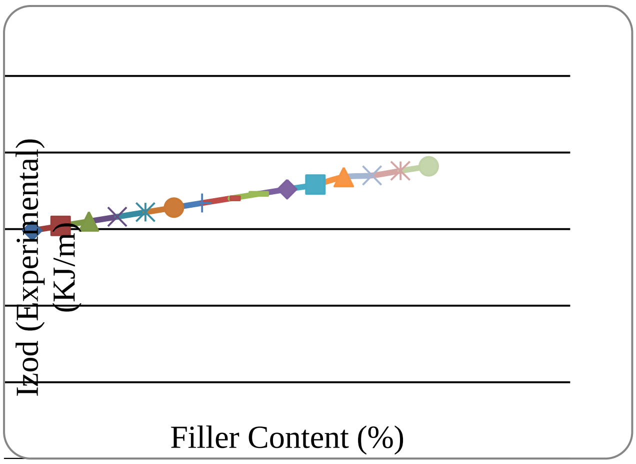


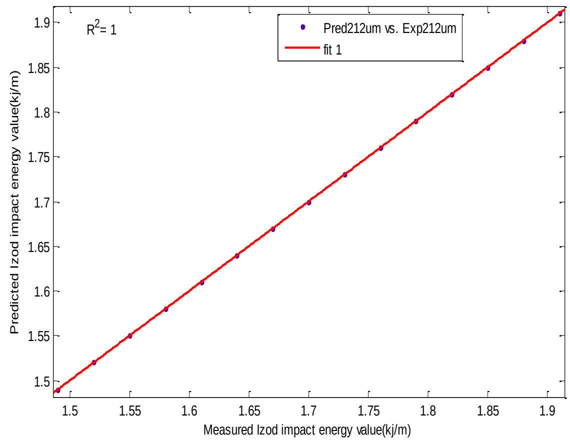
(b)

Figure 3: izod impact energy (experimental and predicted results at 150µm)

Izod notched impact energy (experimental results and FLM predictions) at 150µm and initial LDPE energy of 1.1 kJ/m. (a) Variation of Izod impact energy with filler content. (b) Prediction of Izod impact energy (experimental vs FLM predictions). Figures 3a and 3b show the fuzzy logic model predictions of the Izod notched impact energy of date palm wood fibre/LDPE composite for grain sizes of 150µm. As the figures show, there is very good agreement with the fuzzy logic model predictions and experimental results.

(a)

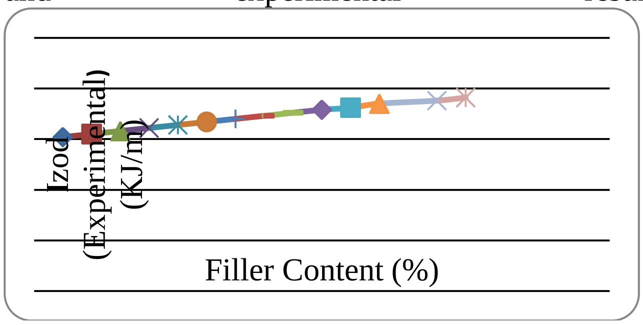




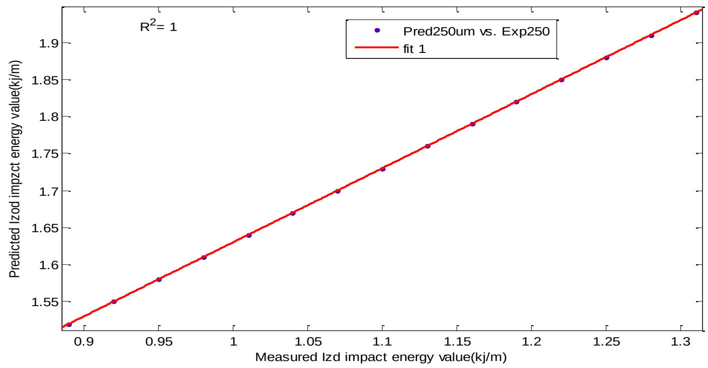
(b)

Figure 4: izod impact energy (experimental and predicted results at 212µm)

Figures 4a and 4b show the fuzzy logic model predictions of the of izod impact energy date palm wood fibre/LDPE composite for grain sizes of 212µm. As the figures show, there is very good agreement with the fuzzy logic model predictions and experimental results.



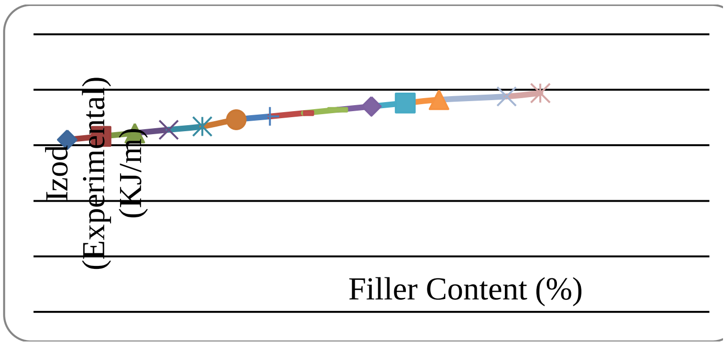
(a)



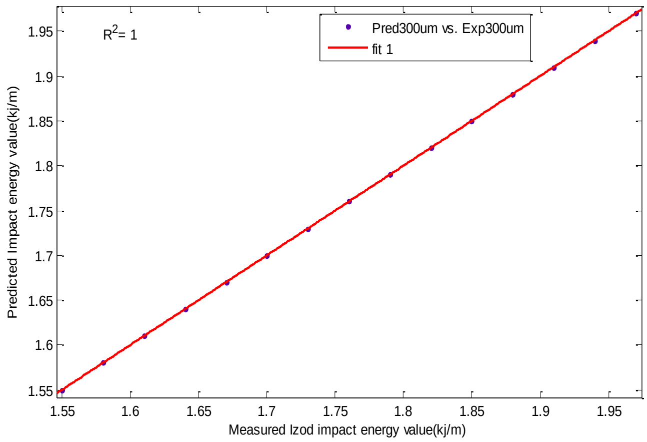
(b)

Figure 5: izod impact energy (experimental and predicted results at 250µm)

Izod impact energy (experimental results and fuzzy logic model predictions) at 250µm and initial LDPE of 1.1kj/m (a) Variation of izod impact energy with filler content. (b) Prediction of izod impact energy (experimental vs FLM predictions).



(a)



(b)

Figure 6: izod impact energy (experimental and predicted results at 300µm)

Izod impact energy(experimental results and fuzzy logic model predictions) at 250µm and initial LDPE of 1.1kj/m. (a) Variation of izod impact energy with filler content. (b) Prediction of izod impact energy (experimental vs FLM predictions).

Figure 3a – 6a shows that there is increase in izod impact energy with increase in filler content due to more energy required to propagate the crack. By comparing the result of previous studies mentioned in this paper, it was observed that the izod impact energy of polymer composite materials depends on the percentage of the filler content. Figures 3b - 6b shows the fuzzy logic model predictions of the izod impact energy of date palm wood fibre/LDPE composite for grain sizes of 150µm 212µm, 250µm and 300µm. As the figures show, there is strong agreement with the fuzzy logic model predictions and experimental results with the correlation coefficients greater than 0.9967.

The FLM prediction summary for izod impact energy: As shown in the table 1, the correlation coefficient is 1. Hence, the FLM predictions are very good.

Table 1: Izod impact energy prediction error summary

Grain size (µm)	Correlation coefficient	Mean squared error (MSE)
150	1	8.709e-017
212	1	6.34e-016
250	1	1.848e-016
300	1	4.77e-016

Conclusion

Following the results of the analysis, it is concluded that izod impact energy increased with increase in filler content. From the fuzzy logic predictions, the behaviour of izod impact energy is remarkably related to the experimental results.The predicted and experimental results are in good agreement. Hence fuzzy logicmodel could be used to predict izod impact energy of date palm wood fiber recycled low density polyethylene composite.

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