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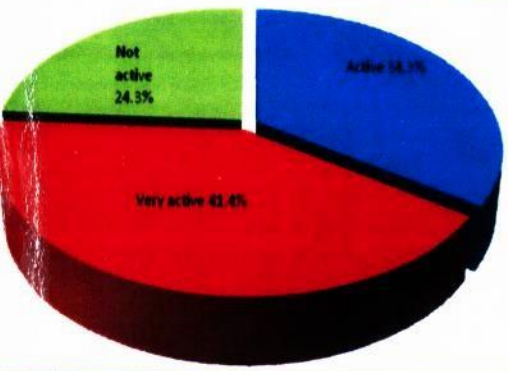

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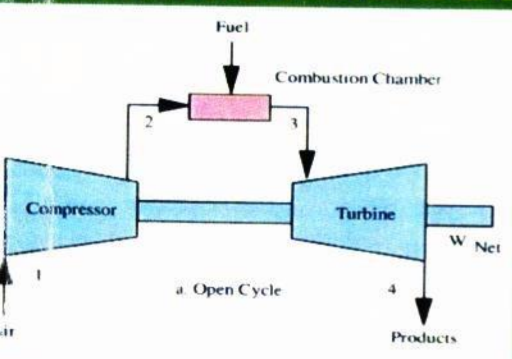

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Modelling Analysis on Properties of Nano Hybrid $CaCO_3$ - Rice Husk Filled Polyester Composite

*Onuegbu, G.C.[1], Obidiegwu M.U[1] and Onyedika, G.O.[2]
[1] Department of Polymer and Textile Engineering, Federal University of Technology, Owerri, Nigeria
[2] Department of Chemistry, Federal University of Technology, Owerri, Nigeria
(*gc. onuegbu@ yahoo.com)

Abstract
Hybridization of rice husk (RH) and calcium carbonate ($CaCO_3$) nano particles filled polyester were prepared at different weight percent of the two fillers of nano particle sizes,11nm by casting. The tensile strength of polyester, rice husk/polyester, calcium carbonate/ polyester and hybrid nano composites were determined. The analysis was carried out using the robust MATLAB modelling environment. Each analysis was carried out within a 95 % confidence bound ($p < 0.05$ Significance) using a custom equation describing each of the system. From the results obtained from the modelling analysis of the tensile strength, the highest tensile strength occurred at S2 (67 % UPR, zero $CaCO_3$ and 100 % rice husk) and the least value occurred at S3 (67 % UPR, 10 % $CaCO_3$ and 90 % rice husk) Moreover, the tensile strength decreased with increase in weight per cent of calcium carbonate despite the increase in weight per cent of rice husk till at 70 % RH.

1.0 Introduction

The most common types of fibre reinforcements used in composite applications are glass, carbon and aramid. Natural fibres have received much attention from material scientists and engineers in the past decades because they are less expensive, lightweight, non-toxic, ease of recyclability and biodegradable (Joshy, 2004). Recent reports indicate that natural fillers can very well be used as reinforcement in polymer composites, replacing to some extent the more expensive and non-renewable synthetic fillers such as talc (Mallick, 2007; Francucci, 2010).

Though natural filler reinforced polymer matrix composites are attractive, they suffer from low strength; lower modulus compared to synthetic filler reinforced composites such as talc filler reinforced plastics (Netravali, 2003). It is shown that the hydrophilic nature of natural fillers adversely affects the hydrophobic matrix (Jawwaid, *et al.*, 2011) resulting in poor strength. These results induced the development of natural and synthetic hybrid nano composites.

Polyester resins are widely used in polymer composites. Due to their good adhesion characteristics they have resulted in remarkable success as matrix materials for filler composites (Alagar et al., 2000). They also have a good balance of physical, mechanical and electrical properties and have a lower degree of cure shrinkage than other thermosetting resins, such as epoxy and vinyl ester resins (Lu, 2012). Other attractive features for composite application are relatively good hot wet strength, chemical resistance, dimensional stability, and ease of processing and low cost (Kalyani & Ashok, 2014).

In general, the nano substances used are nano tubes, nano particles and they are dispersed into another composite materials during processing. A nano composite is the material consisting of a polymer matrix reinforced with a filler, platelet or particle having one dimension on the nanometer (nm) scale (10^{-9} nm). On the other hand, polymer nano composites represent a class of material alternative to conventionally filled polymers. In this type of materials, nano fillers (having at least one dimension in nanoscale range) are finely dispersed in polymer matrix offering remarkable

improvement in performance properties of the polymer, including high moduli (Sikarwar & Raman *et al.*, 2012), and increased strength (Alexander, et al.,2009).
The aim of this work is to determine the effect of nano filler particle sizes (rice husk and calcium carbonate) and to show how hybridization of the two fillers affect on the tensile strength of polyester composites using MATLAB modelling Analysis.

2.0 Materials and Methods

2.1 Materials

Unsaturated polyester resin and nano particles of calcium carbonate and rice husk were obtained from Micromat Limited , Lagos state, Nigeria. Commercial grade methyl ethyl ketone peroxide, poly (vinyl alcohol), gel coat, cobalt naphthanate solution used were bought from the same company.

2.2 Preparation of Hybrid Nano Composites (Calcium carbonate/Rice husk Filled Polyester)

Unsaturated polyester was mixed with 1 weight per cent of methyl ethyl ketone peroxide, 2 weight per cent of naphthanate for 5 minutes. Different weight per cent of calcium carbonate /rice husk nano particle sizes were hybridized respectively ; 0/100 (S2), 10/90 (S3), 20/80 (S4), 30/70 (S5), 40/60 (S6), 50/50 (S7), 60/40 (S8), 70/30 (S9), 80/20 (S10), 90/10 (S11) and 100/0 (S12). The 0/100 %, 100/0% and hybrid nano fillers were thoroughly mixed with 67 g of unsaturated polyester .They were homogenized and processed by casting to obtain rice husk, calcium carbonate and hybrid nano composites. The Different hybrid nano composites were prepared from the formulations shown in Table 1

Table 1: Formulation of Hybrid RH and $CaCO_3$ Nano Particle Sizes

Formulation	Ingredients, wt.%		
Code	UPR	$CaCO_3$	RH
S1	0	0	0
S2	67	0	100
S3	67	10	90
S4	67	20	80
S5	67	30	70
S6	67	40	60
S7	67	50	50
S8	67	60	40
S9	67	70	30
S10	67	80	20
S11	67	90	10
S12	67	100	0

2.3 Testing

The tensile test was performed according to ASTM D3039-79 standard using Universal Testing machine at a crosshead speed of 0.5 mm/min, length of the test specimen was 125 mm and four specimens for each sample were tested for accuracy. The tensile strength was calculated using the custom equation governing the behaviour of material subjected to tensile force(Navaneethakrishnan, *et.al.*, 2015).

$$P = ke \qquad (1)$$

where P = maximum load applied on test (N) specimen

e = extension (mm), and

k = constant (a measure of strength of material)

3.0 Results and Discussion

The results obtained from unsaturated polyester, hybrid nano composites, calcium and rice husk composites are illustrated in fig. 1 to 12. Figures 1 shows the result obtained from regression modelling of the tensile strength (Mpa) of the unfilled unsaturated polyester (S1). Figure 2 shows the result obtained from regression modelling of the tensile strength of 100 % calcium carbonate filled polyester (S2). Fig. 3 shows the result obtained from regression modelling of the tensile strength of 10 % rice husk and 90 % calcium carbonate (S3). Fig. 4 shows the result obtained from regression modelling of the tensile strength of 20 % nano rice husk and 80 % nano calcium carbonate (S4). The result obtained from regression modelling of the tensile strength of 30 % nano rice husk and 70 % of nano calcium carbonate (S5) is shown in Fig. 5. Fig. 6 to 11 show the results obtained from regression modelling of the tensile strengths of 40 % nano rice husk and 60 % of nano calcium carbonate (S6), 50 % nano rice husk and 50% calcium carbonate (S7), 60 % nano rice husk and 40 % nano calcium carbonate (S8), 70 % nano rice husk and 30% calcium carbonate (S9), 80 % nano rice husk and 20% nano calcium carbonate (S10), 90 % nano rice husk and 10 % calcium carbonate (S11) and 100 % nano rice husk (S12).

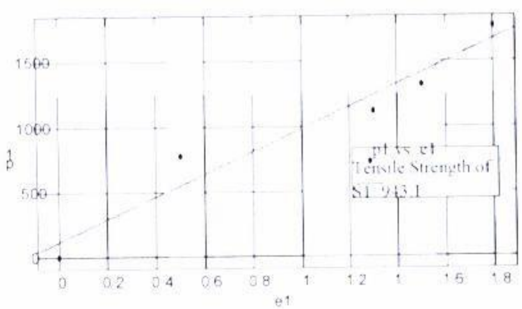

Figure 1: Regression modeling of tensile strength of unfilled unsaturated polyester (S1)

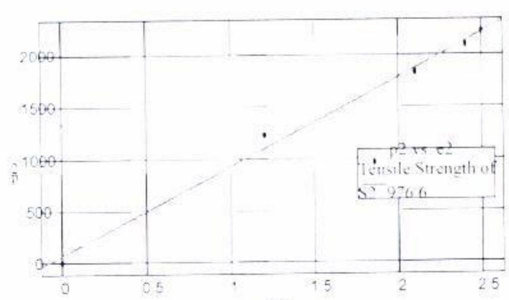

Figure 2: Regression Modelling of tensile strength of 100 % $CaCO_3$ filled polyester (S2)

improvement in performance properties of the polymer, including high moduli (Sikarwar & Raman *et al.*, 2012), and increased strength (Alexander, et al.,2009).
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S6	67	40	60
S7	67	50	50
S8	67	60	40
S9	67	70	30
S10	67	80	20
S11	67	90	10
S12	67	100	0

2.3 Testing

The tensile test was performed according to ASTM D3039-79 standard using Universal Testing machine at a crosshead speed of 0.5 mm/min. length of the test specimen was 125 mm and four specimens for each sample were tested for accuracy. The tensile strength was calculated using the custom equation governing the behaviour of material subjected to tensile force(Navaneethakrishnan, *et al.*, 2015).

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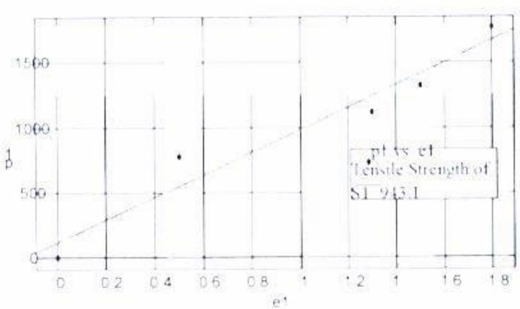

Figure 1: Regression modeling of tensile strength of unfilled unsaturated polyester (S1)

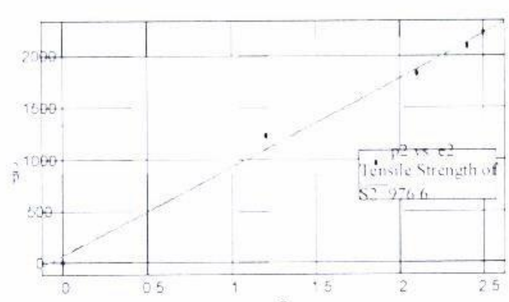

Figure 2: Regression Modelling of tensile strength of 100 % $CaCO_3$ filled polyester (S2)

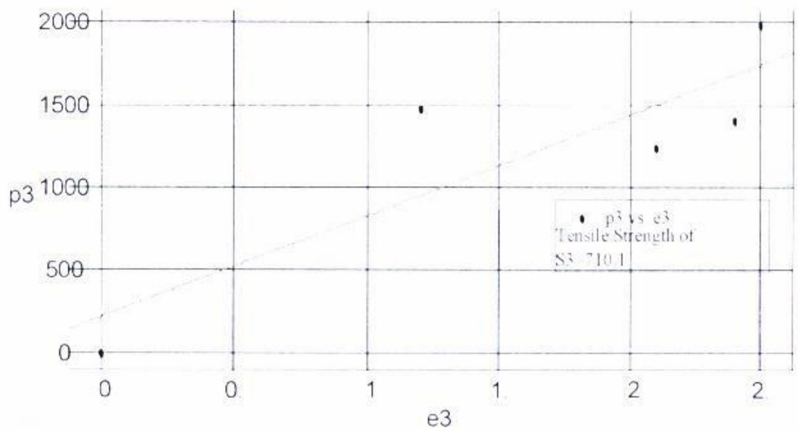

Fig. 3: Regression modelling of tensile strength of 10% nano rice husk and 90% nano $CaCO_3$ (S3)

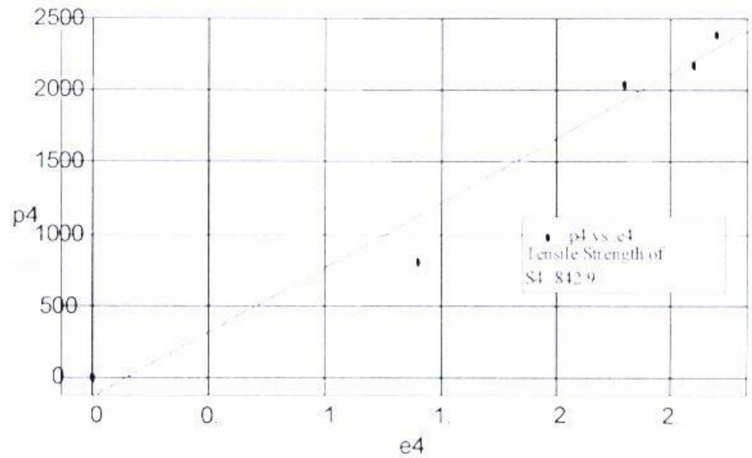

Fig. 4: Regression modelling of tensile strength of 20% nano rice husk and 80% nano $CaCO_3$ (S4)

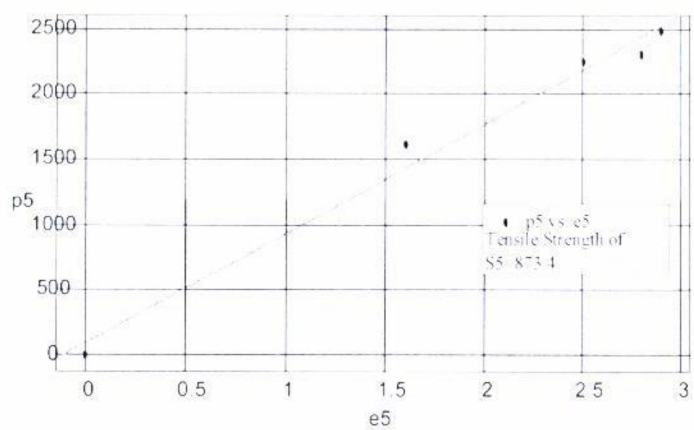

Fig. 5: Regression modelling of tensile strength of 30% nano rice husk and 70% nano $CaCO_3$ (S5)

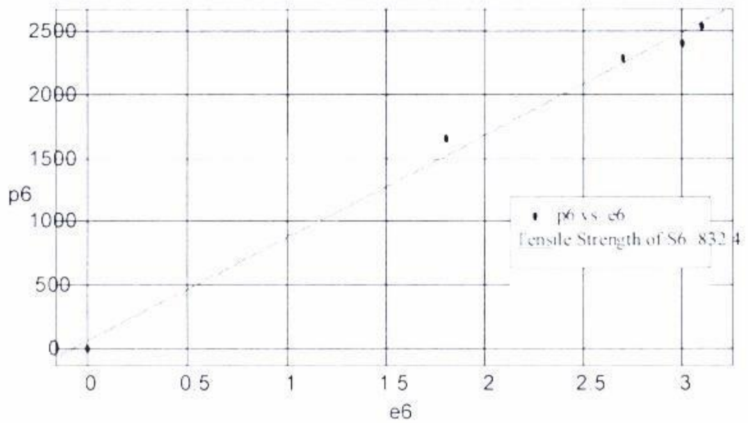

Fig. 6: Regression modelling of tensile strength of 40% nano rice husk and 60% nano $CaCO_3$ (S6)

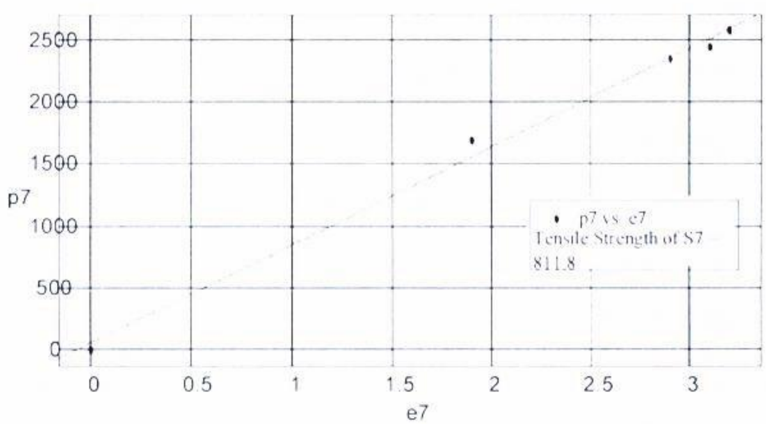

Fig. 7: Regression modelling of tensile strength of 50% nano rice husk and 50% nano $CaCO_3$ (S7)

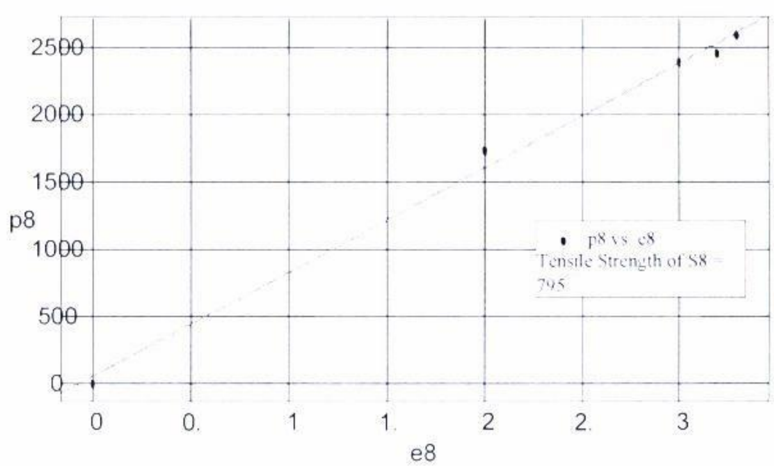

Fig. 8: Regression modelling of tensile strength of 60% nano rice husk and 40% nano $CaCO_3$ (S8)

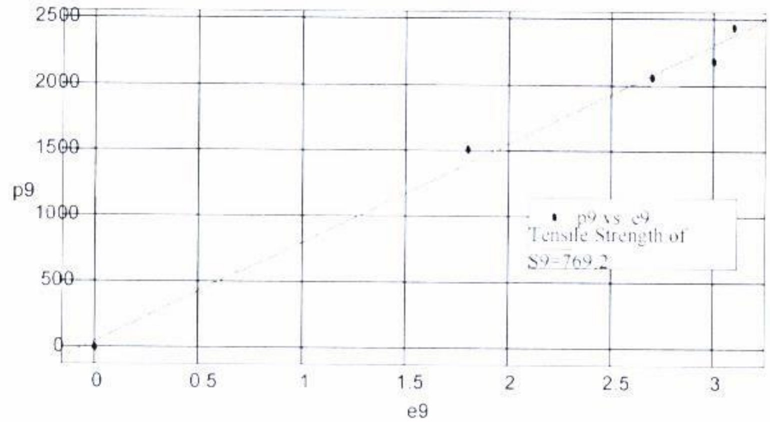

Fig. 9: Regression modelling of tensile strength of 70% nano rice husk and 30% nano $CaCO_3$ (S9)

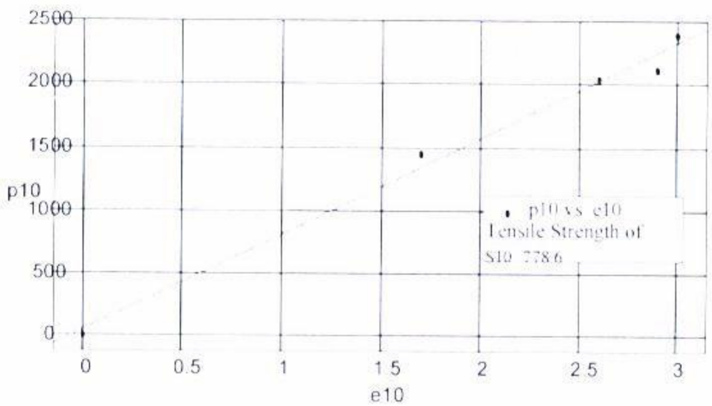

Fig. 10: Regression modelling of tensile strength of 80% nano rice husk and 20% nano $CaCO_3$ (S10)

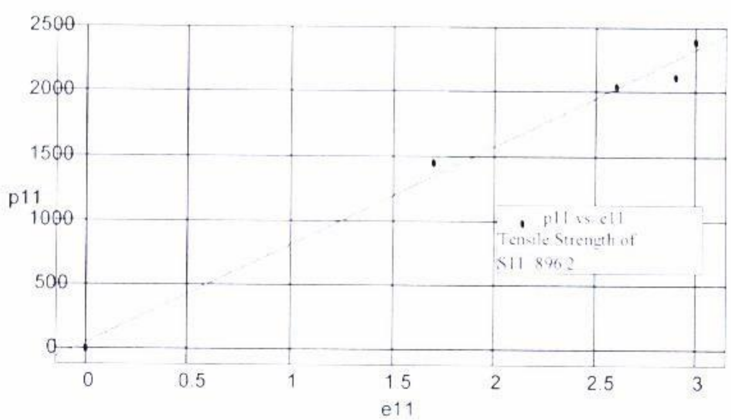

Fig. 11: Regression modelling of tensile strength of 90% nano rice husk and 10% nano $CaCO_3$ (S11)

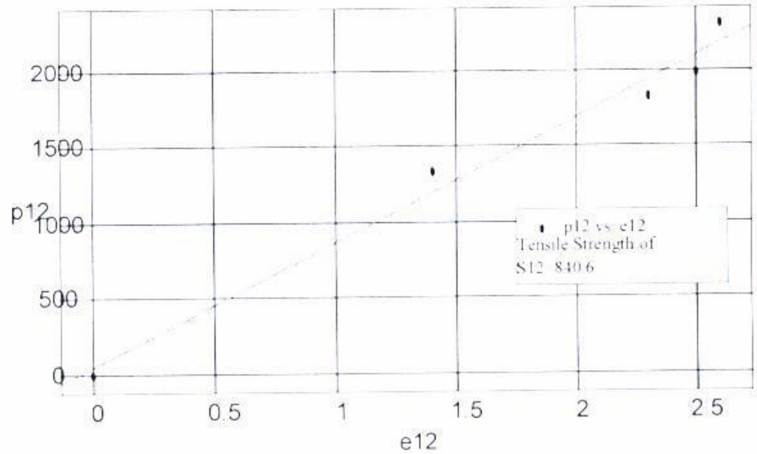

Fig. 12: Regression modelling of tensile strength of 100% nano rice husk (S12)

Table 4.1: Modelled Tensile Strengths Nano Hybrid Polyester Composite

Formulation Code	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Tensile Strength (mpa)		976.6	710.1	842.9	873.4	832.4	811.8	795	769.2	778.6	896.2	840.6

From the results obtained, the modelling analysis of the tensile strength and the order on the increase in tensile strength is as follows: S2 > S1 > S11 > S5 > S4 > S12 > S6 > S7 > S8 > S10 > S9 > S3. The highest tensile strength occurred at 100 % calcium carbonate, the tensile strength is 976.6 Mpa . This is due to high density of calcium carbonate which is an attribute of mineral fillers and its main contribution to the composite is strength as confirmed by Sampson *et al.* (2013). S1 has the second highest value (943.1 Mpa). This is due to high crosslink density of polyester structure. It is in agreement with Osman et al. (2012) and Devallo *et al* (2010). The least value of the tensile strength occurred at 10 % rice husk and 90 % calcium carbonate (S3). At 80 % rice husk 20 % calcium carbonate, the tensile is low despite the increase in weight per cent of the rice husk . This is attributes to lack of adhesion between organic filler (rice husk) and polyester (S10) and it is in agreement with the findings of Clemons (2002).Figures 3 to 6 show increased in tensile strength with increase in weight per cent of calcium carbonate and decrease in weigth of rice husk.

Conclusion

Maximum tensile strength was obtained when 100 % calcium carbonate was incorporated into the polyester. However, the hybridization of nano rice husk and nano calcium carbonate on the composites shows ductile behaviour. Hybridization of the nano fillers can be used where moderate strength is needed. In addition, hybridization of rice husk and calcium carbonate nano particles would greatly reduce the cost of production of the nano composites.

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