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MECHANICAL AND FLAMMABILITY PROPERTIES OF LOW DENSITY POLYETHYLENE/ALSTONIA BOONEI WOOD FIBRE COMPOSITES

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ABSTRACT

The mechanical and flame retardancy properties of Low Density Polyethylene (LDPE) reinforced with AlstoniaBoonei (AB) wood fibres were studied. Composite samples of LDPE/AB were prepared with fibre loading of 0,5,10,15, and 20 wt%. Tensile test was used to assess the Young's Modulus, yield strength, and yield strain. Tensile test results show an increase in Young's Modulus and yield strength after an initial decrease, yield strain showed decreases and increases alternatively at different fibre loading. Indentation results show indentation values increasing with increasing fibre loading, while hardness tests reveal a decrease in Shore D hardness value with increasing fibre loading.

Flammability tests reveal that LDPE/AB wood fibre composite had improved flame resistance properties with increasing fibre loading. The ignition and auto-combustion time increased with increasing fibre loading, while flame propagation rate (FPR), decreased with increasing fibre loading

Keywords: Composites, polyethylene, flammability, mechanical properties

INTRODUCTION

As far back as 1500BC, the use of natural fibres for reinforcement have been used (Chawla 1987). The ancient Egyptians used straw as reinforcements in bricks to produce bricks with improved mechanical properties (Smith and Li, 2000). Since the beginning of the 20th century, polymer composites became an increasingly attractive material type. For about three decades, polymer composites were manufactured basically by thermosetting matrices (Hancox 2001). Nevertheless, after moulding, the products are non-reparable, non-recyclable, and cannot be re-shaped, re-formed, or remoulded as the need arises. Thermoplastic polymers have ever since attracted increased attention due to their advantages over thermosets.

At present, there is a widespread concern of non-biodegradable plastics. They are a menace to the environment if they are not recycled, and when incinerated can cause potential harm in the release of CO_2. Wood like other natural fibre sources is readily available, and biodegradable, hence, it can reduce the non-biodegradable fraction in the composites. Of course, this have beneficial consequences on the environment. Although there are other petroleum-based biodegradable polymers that could be used as reinforcements, however, these on degradation would add to the overall CO_2 in the atmosphere.

The specific advantages offered by natural fibres like, low cost, low density, high toughness, acceptable specific strength, enhanced energy recovery, recyclability, etc, (Chauhan et al., 2000; Debapriya 2004; Jacob et al., 2006), prompted the use of various fibres as reinforcements. Sisal, Jute, flax, hemp, henequen, and others have been used to make composites (Fung 2003a; Keller 2003; Garkhail et al. 2000; Herrar-Franco et al. 1997). In jute fibre reinforced HDPE composites, the mechanical properties are enhanced at fibre loading of 10 - 30%, and then starts deteriorating afterwards (Mohanty et al. 2006). Untreated, alkaline, and silane treated flax fibre was used to reinforce HDPE (Anup 2008). It was observed that mechanical properties improved with increasing fibre content, with silane treated flax fibres showing the best mechanical properties. Anupalluded this to be a result of better interfacial adhesion. It has been reported that flax reinforced composites have not significantly increased the tensile strength of composites because of poor adhesion between fibre and matrix (Oksman et al. 2003; Santos and Pezzin 2003). Improved mechanical properties of fibre reinforced composites have been alluded to improved bonding between the fibre and the matrix (Mohanty et al. 2001; Bledzki and Gassan 1999). Though different fibre sources have been used, nevertheless, most native African plants have not been used as reinforcements in polymers. Hence, the mechanical and flammability properties of LDPE and various African plants remain open to research.

Low Density Polyethylene is a very useful thermoplastic material which has found application in almost all industrial and domestic circles. Although, different reinforcing materials have been used to improve the properties of this polymer, natural fibres have remained very useful reinforcements. PE remains useful as composite matrix due to its melting temperature. Thus, natural fibres which degrade at a higher temperature could be used. For polymers with very high melting point, the fibre can experience degradation during compounding. This may adversely affect the mechanical properties of the fibre, and invariably, that of the composite (Van de Velde and Kiekens 2001).Although PE offers this advantage over most thermoplastics, studies on PE composites with a host of fibres still needs to be developed.

Due to the wide range of polymer application, its flammability characteristic has attracted considerable attention. The combustion of polymers follow a cyclic pattern of preheating, decomposition, ignition, and combustion. In the presence of a flame source, the polymer becomes preheated. It then loses structural integrity and decomposes releasing combustible hydrocarbon gases into the atmosphere. The gases at the appropriate temperature ignite, and then combustion takes place releasing heat. The heat continues the cycle: preheating, decomposing, igniting, and finally combusting the polymer. Since the whole process is time dependent, the flammability properties of the polymer can therefore be expressed as a function of time. The use of wood in polymer composites has shown promising flame retardancy properties of the composite. The presence of wood in a polymer composite can reduce the flammability property of the polymer because the amount of available hydrocarbon is reduced. Nevertheless, flammability properties of wood polymer composites have received limited attention in the literature (Stark et al. 2010).

In Africa, AlstoniaBoonei, remains a useful medicinal plant. Due to its use in the treatment of malaria, it is very abundant. The rise of different anti-malarial drug has shifted its relevance and use in the society. Though much research have been made on its medicinal effect, however, its use as reinforcements in polymers have not been researched as such. This research work focuses on the effect AlstoniaBoonei (AB), would have on both the mechanical and flame retardancy properties of Low Density Polyethylene (LDPE).

MATERIALS AND METHODS

Materials

Low Density Polyethylene was gotten from CEEPLAST Industry Ltd., Adaelu Street, Osissioma Industrial Layout, Aba, Abia State, Nigeria. AlstoniaBoonei was obtained from a local farm in AhiazuMbaise, Imo State, Nigeria. The stem bark samples were dried for three weeks, and then pulverized into powder form. The powdered fibres were then sieved with 0.3mm mesh size at the Corrosion Control Laboratory, Federal University of Technology Owerri, Imo State, Nigeria.

Composite Preparation

Composite samples were prepared with LDPE/wood fibres using formulations of varying fibre contents from 0 – 20 wt%. Powdered samples of LDPE and AB at varying weight contents were fed into an injection moulding machine to produce compounded composite samples. The injection moulding was done by the injection moulding machine in the Department of Polymer and Textile Engineering, Federal University of Technology, Owerri, Imo State, Nigeria was used. Sample formulations are given in Table 3.1.

Table 3.1 Sample Formulation

Samples	Kola nut (Stem bark wt.%)	LDPE (wt. %)
LDPE		100
KN1	5	95
KN2	10	90
KN3	15	85
KN4	20	80
Samples	**Alstonia Boonei (stem bark wt.%)**	**LDPE**
AB1	5	95
AB2	10	90
AB3	15	85
AB4	20	80

TensileTesting

Tensile Testing of the composite samples were carried out at Socotherm Nigeria Ltd, Oneh, Rivers State, Nigeria. The Tensile tests were carried out using the Matest Machine in accordance with ASTM D638-95 specification.

IndentationTest

The indentation test of the composite samples was determined by the Indentation Test Machine. The indentation values obtained represent the mean value of three specimens.

Hardness Test

Hardness test on the composite samples was carried out in accordance to ASTM 2240 specification. The Shore D hardness value obtained represents the mean of three specimens.

Flammability Tests

The following flammability tests were carried out in the Laboratory of the Department of Polymer and Textile Engineering, Federal University of Technology Owerri, Imo State, Nigeria.

Ignition time

Composite samples were held by a retort stand over the heat source at a constant distance. The ignition time was recorded as the time between the initial supply of flame from the heat source and the appearance of flame on the sample. The values obtained represent the mean value of three samples analysed.

Auto-combusting time

Samples were held by a retort stand at a constant distance over a heat source. The auto-combusting time was recorded as the time that elapsed between an initial supply of flame and self-sustaining combustion of composite samples. The values obtained represent the mean value of three samples analysed.

Flame propagation rate

The rate of spread of fire was recorded as the flame propagation rate. Composite samples were held by a retort stand at a constant distance over a heat source. Test samples were marked X, a distance 3 cm from the end just above the flame source. The Flame Propagation Time (FPT) was recorded as the time between an initial supply of flame and the combustion of the X mark. Flame Propagation Rate (FPR) is the ratio of the distance from the sample end (i.e., 3 cm) and the flame propagation time. The values obtained represent the mean value of three samples analysed.

$$FPR = \frac{X}{FPT} \qquad 2.1$$

RESULTS AND DISCUSSION

From the tensile test results presented in Fig 3.1, it is evident that tensile properties increased with increasing fibre content from 0-20 wt%. Fig 3.2 and Fig 3.4 show that the path taken by Young's Modulus and yield strength values showed a rather progressive increase after initial decrease. This is consistent with the results of other investigators who inferred that the low values of yield strength and Young's Modulus at low fibre loading indicates that the fibres tend to act as flaws instead of reinforcements (Beshay and Hoe 2000, Onyeagoro 2009). At higher values, the reinforcing character of the fibres becomes apparent. Although yield strain values increased from 0 – 20 wt%, it increased and decreased from 10 – 20 wt%. Improved tensile properties of thermoplastic/wood fibre composites have been alluded to proper fibre/matrix interaction (Felix and Gatenholm 2005). This increase in tensile properties could therefore mean improved fibre/matrix adhesion.

Fig 3.5 shows the reaction of the composite to indentation tests. Indentation values increased with increasing fibre content. The increasing indentation value, (i.e., depth) with increasing fibre loading could be as a result of the fibre/matrix adhesion. Since indentation values suggest the depth of impact the material could withstand before deformation, this could mean that the load sharing between matrix and fibre help reduce the load on the matrix, consequently increasing the indentation value. Hardness values which show the behaviour of the material under immediate impact and not gradual loading decreased with increasing fibre content. Decrease in Shore hardness value with increasing fibre content has also been reported by Khairaih and Khairhul (2006), when working on polyurethane and empty fruit bunch blend composites. They alluded the decrease to the inability of the matrix to encapsulate the fibre strands, even though good interfacial bonds might exist between fibre and matrix. Anap (2008), also reported decrease in

Shore hardness value with increasing fibre loading when High density polyethylene was reinforced with flax fibres.

Flammability test results are presented in Fig 3.7 – Fig 3.9. Test results show that the flammability of the composite increased with increasing fibre loading. Ignition tests show that the composites experienced increase in ignition time with increasing fibre content. Since ignition depends on the availability of combustible gaseous hydrocarbon, it can be inferred that the delay in ignition time with increasing fibre loading means that the presence of wood fibres decreased the release of combustible gases. *Auto-combustion* time also increased with increasing fibre loading. *Auto-combustion* which is the point at which the material is able to continue burning without an external flame source is dependent on the amount of heat released during the combustion cycle. A limited quantity of heat released would not be able to preheat, decompose, ignite or combust the material. The delay in *auto-combustion* could therefore mean that the presence of AlstoniaBoonei wood fibres reduced the heat release during combustion either by releasing anti-combustible gases that reacted and stabilized flame propagating radicals, or, the presence of ash in the wood fibres smothered burgeoning flame. Flame Propagation Rate (FPR) test result (Fig 3.9), FRP reveal the relative resistance of the composite to decompose and consume. The more readily the material consumes the higher the FRP value. The decreasing value of FRP with increasing fibre loading suggests that the presence of AB wood fibres in LDPE improved the relative structural integrity of the material in the face of heat.

CONCLUSION

Reinforcing LDPE with AB wood fibres improves both mechanical and flammability properties of the composite. Tensile properties – yield strength, Young's Modulus and yield strain increased from 0 – 20 wt%. Indentation tests show increasing indentation value with increasing fibre loading. However, the value of hardness decreased with increasing fibre content. The general improvement in the mechanical properties of the composite could mean proper compatibility of AB wood fibres and LDPE matrix.

Flammability property tests: ignition time, auto-combustion time, and Flame Propagation Rate, show improved flame retardancy of LDPE/AB composite with increasing fibre loading.

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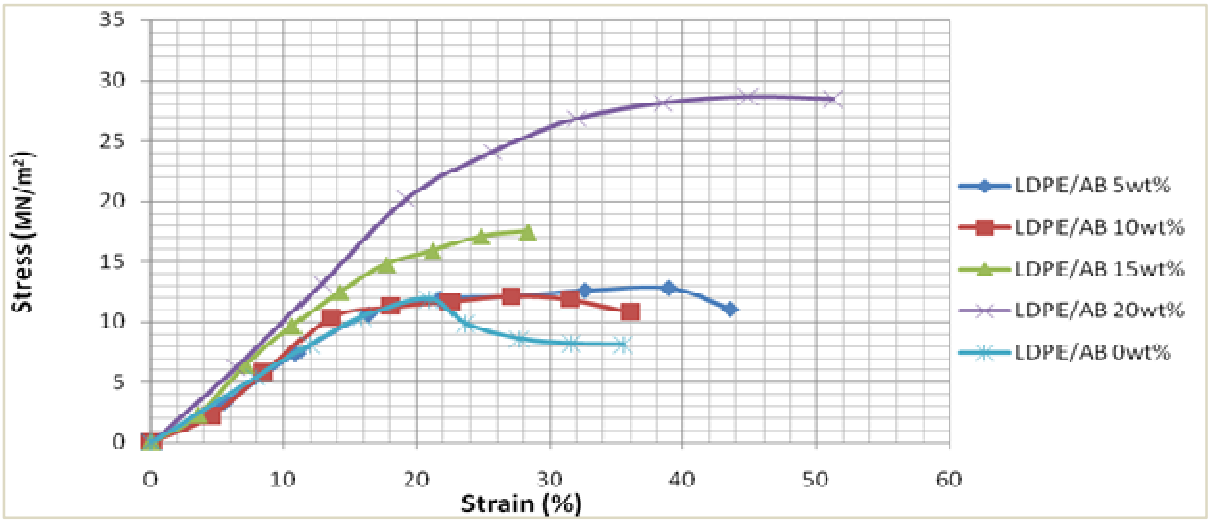

Fig 3.1 Graph of Stress vs. Strain for LDPE/AB Composites at Different Fibre Content

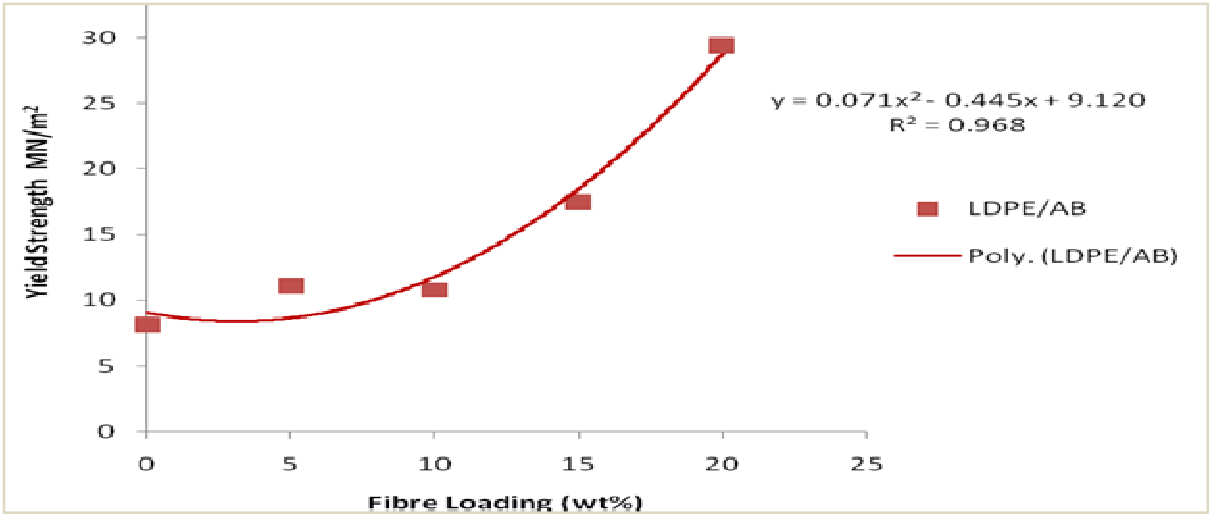

Fig 3.2 Graph of Yield Strength vs. Fibre Loading of LDPE/AB Composite

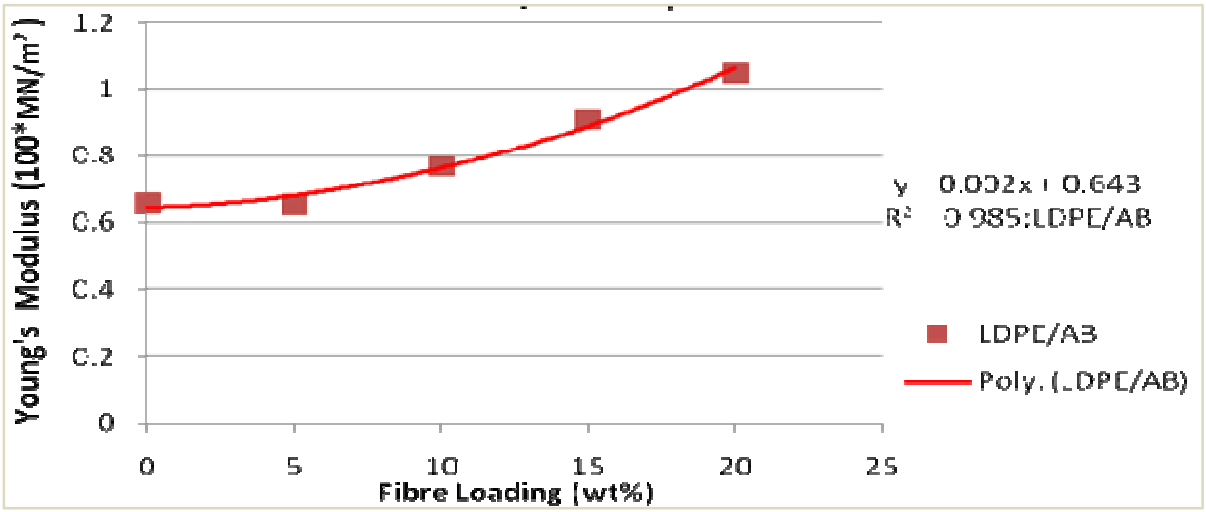

Fig 3.3 Graph of Young's Modulus vs. Fibre Loading of LDPE/AB Composite

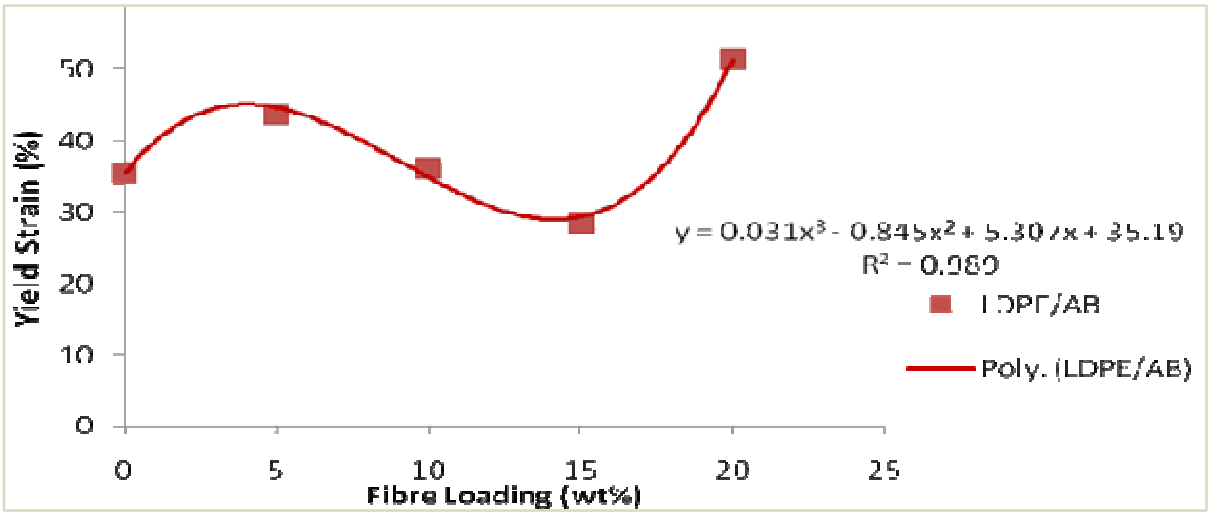

Fig 3.4 Graph of Yield Strain vs. Fibre Loading of LDPE/AB Composite

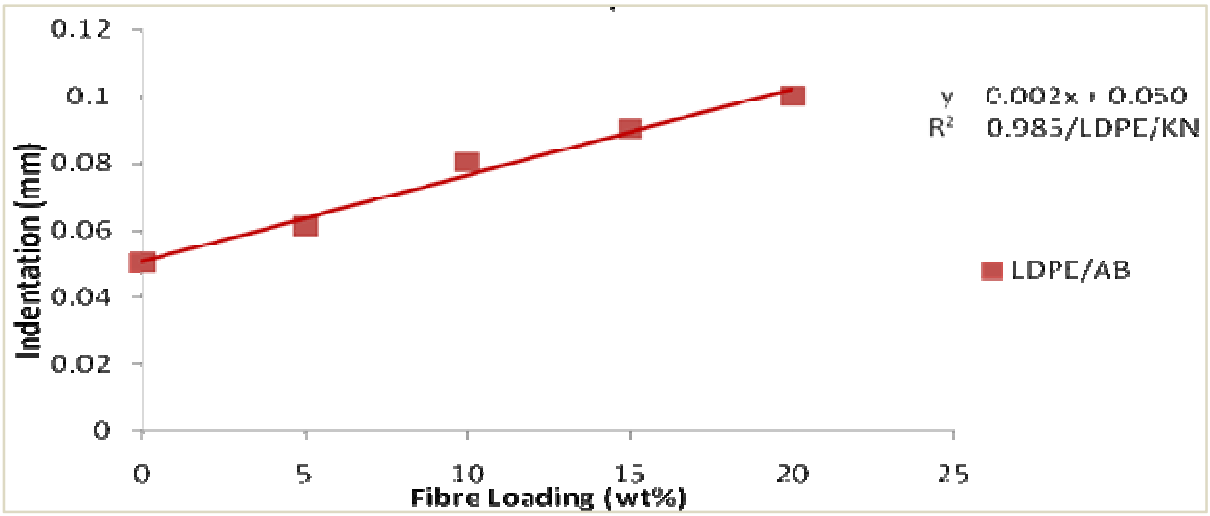

Fig 3.5 Graph of Indentation vs. Fibre Loading of LDPE/AB Composite

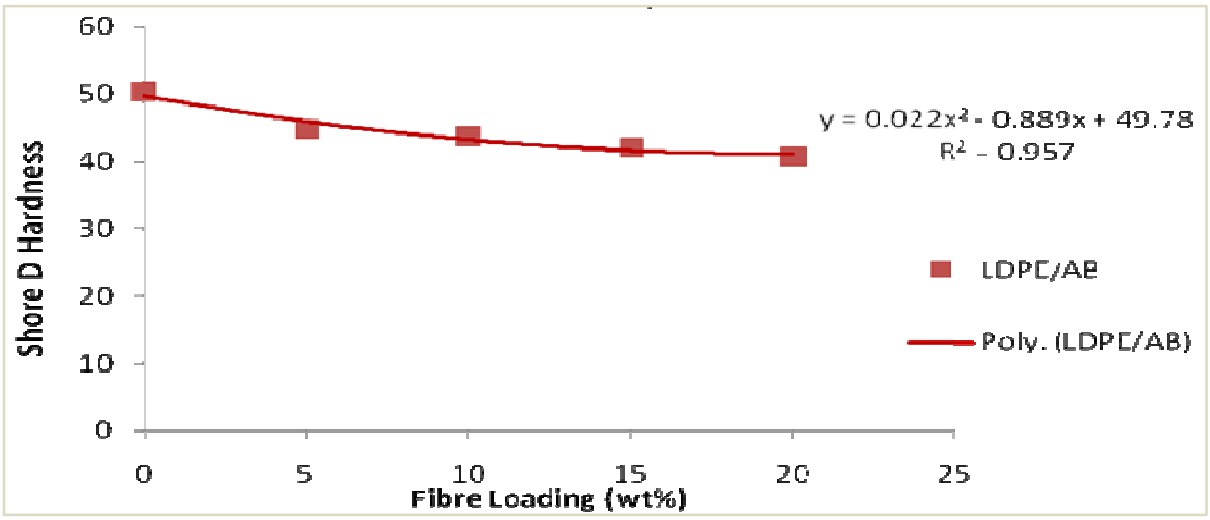

Fig 3.6 Graph of Shore D Hardness vs. Fibre Loading of LDPE/AB Composites

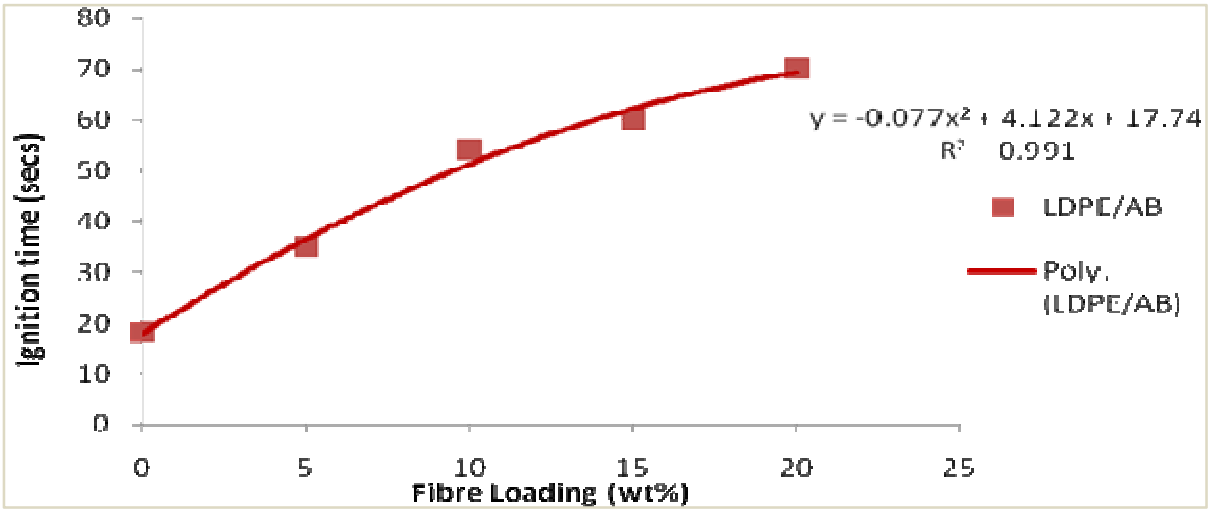

Fig 3.7 Graph of Ignition time vs. Fibre Loading of LDPE/KN and LDPE/AB Composite

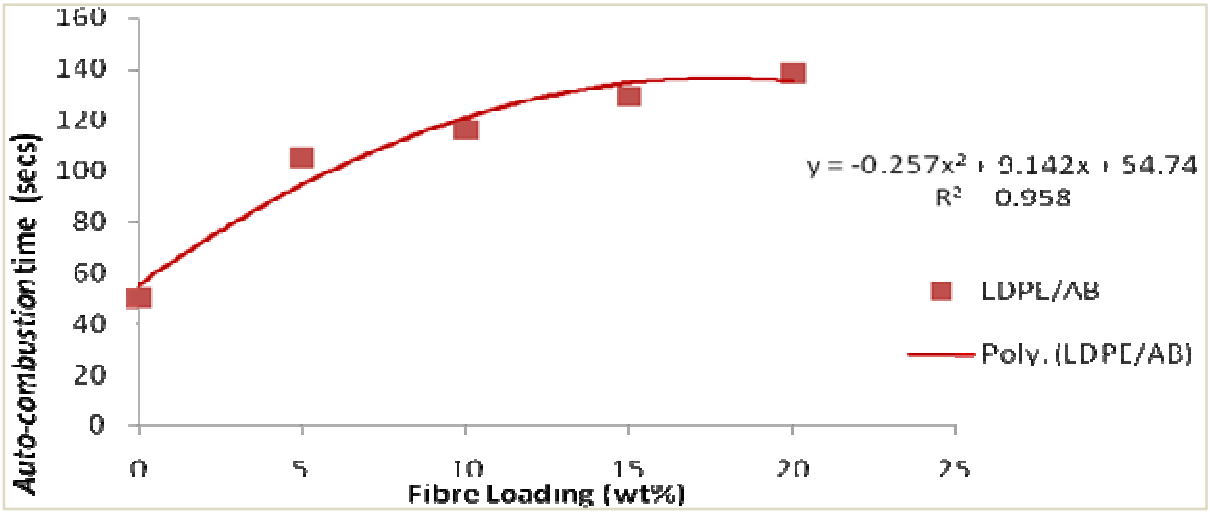

Fig 3.8 Graph of Auto-combustion time vs. Fibre Loading of LDPE/AB Composite

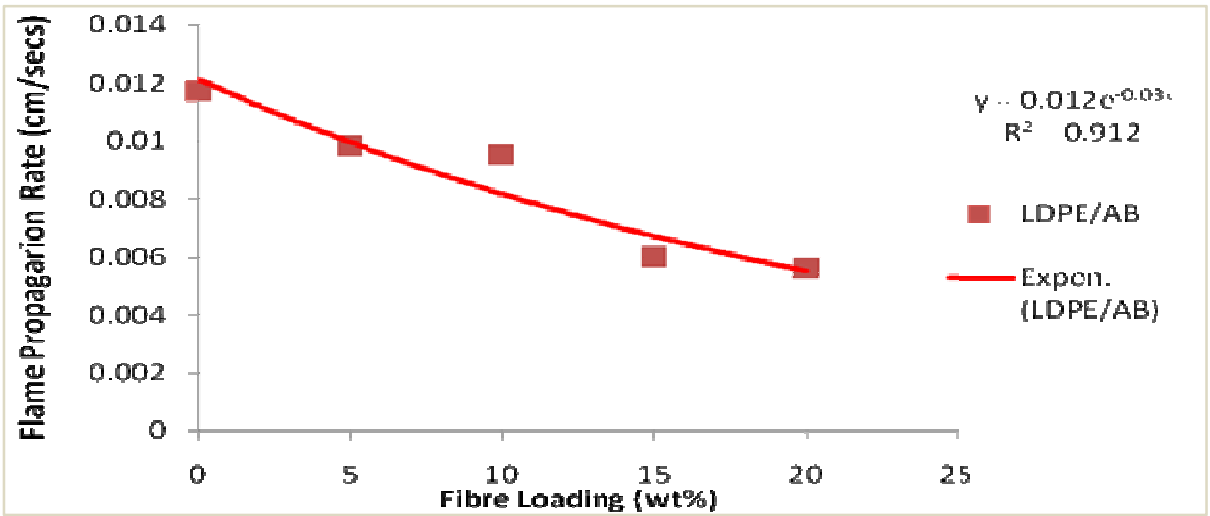

Fig 3.9 Graph of Flame Propagation Rate vs. Fibre Loading of LDPE/AB Composite