MECHANICAL AND FLAMMABILITY PROPERTIES OF LOW DENSITY POLYETHYLENE/KOLA NITIDA WOOD FIBRE COMPOSITES

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ABSTRACT

Composite samples of Low Density Polyethylene (LDPE) and Kola Nitida (KN) wood fibres were prepared with fibre loading of 0, 5, 10,15, and 20 wt%. Tensile, hardness, and indentation tests were used to determine the mechanical properties of the composites. Tensile tests results show that yield strength and Young's Modulus of the composites increased with increasing fibre content, after initial decrease. Yield strain followed a rather sinusoidal path, but increased from 0 to 20 wt%. The indentation test results, also show the indentation values increasing with increasing fibre content. Hardness test show that Shore D hardness value decreased with increasing fibre content. The improved mechanical properties of the composites suggest that Kola Nitida has good interaction with LDPE matrix. Flammability tests were used to assess the relative resistance of the composite to combustion. Ignition time, auto-combustion time, and Flame propagation rate tests were used. Flammability test results show that the ignition time, auto-combustion time, and flame propagation rate increased with increasing fibre content. This suggests that improvement in the flame retardancy of LDPE was achieved using Kola Nitida wood fibres.

Keywords: polyethylene, composite, kola nitida, flammability, mechanical

INTRODUCTION

Nowadays, researchers through the development of polymer composites have been able to develop an array of novel materials that could be used as suitable replacements for pure polymers. Wood plastic composites have specifically attracted immense research interest (Stark et al., 2010). Plastics are mostly petroleum-based and are normally non-biodegradable. Wood, on the other hand, is a naturally occurring biodegradable composite (Bledzki et al. 1998), and therefore, when used in plastic composites it could reduce the amount of non-biodegradable plastic resin in the material. This has a positive impact on the environment because it could reduce the menace caused by the presence of 100% non-biodegradable plastics. Although, the presence of woodfibres in the composite does not actually induce biodegradability in the plastic matrix, nevertheless, it reduces the amount of the non-biodegradable fraction in the environment. Although, there are some petroleum-based biodegradable thermoplastics, wood fibres, unlike these do not add to the total amount of CO_2 in the atmosphere during biodegradation. In other words, wood fibres are CO_2 neutral. They also offer various advantages like: low density, high toughness, acceptable specific strength, enhanced energy recovery, recyclability, etc over glass fibres (Chauhan et al. 2000; Debapriya and Basudam 2004; Jacob et al. 2006). Besides, they are relatively abundant in nature, easy to access, process, and use. They are also cheap, thereby using them provides an economical angle on the composite cost.Although natural fibre reinforcements are meant to provide support for the polymer matrix during load-bearing, it has not always been so. In fact, the mechanical properties of some of the composites thus formed have been known to be poor (Oksman et al. 2003; Santos and Pezzin 2003). This has been attributed to fibre-matrix incompatibility (Felix and Gatenholm 2005). Wood fibres are naturally hydrophilic while the matrix is usually hydrophobic. Hydrogen bonding could be formed between the hydroxyl groups of cellulose fibres in the matrix (Woodham 2000). This can cause a partial separation thereby creating fibre concentrated sites within the matrix. This disparity caused by fibreagglomeration inhibits proper fibre/matrix interaction, leading to stress concentration points, and thus early failure. Furthermore, hydrophilicity of the fibres could attract moisture from the atmosphere which during composite compounding could be given off in the presence of heat. This off-gassing could create voids in the composite microstructure resembling a highly densed foam (Stamm 2002). This could also lead to poor mechanical properties of the composite.

Polyethylene is a highly useful plastic and have been used extensively in composite manufacture (Raj and Beshay 2004; Herrera-Franco and Aguilar-Vega 2000). Nevertheless, like most thermoplastics, the lack of goodfibre/matrix compatibility has hindered improved mechanical properties of polyethylene/wood fibre composites. As a result, different methods have been used to increase fibre-matrix compatibility. Rozman and Gent (2003), have reported to have used coupling agents to have increased the compatibility of rubber woodfibres and high density polyethylene. 3-aminopropyltriethoxysilane coupling agent reduced the tensile modulus, but increased the elongation at break for both fibre-and-powder filled polyethylene composites. Saphiea and Good (2000), used dicumyl benzoyl-peroxides as initiators to directly graft polyethylene unto cellulose fibres to increase adhesion between fibre and matrix. The composite thus formed showed improved mechanical properties. By using additives such as ionomer modified polyethylene, maleic anhydride modified polypropylene, and two low molecular weight polyprotylenes on wood fibres/high density polyethylene, Childress and Selke (2003), were able to assess the tensile properties of the composites. Mechanical properties of the composites improved with increasing concentration of additives. Maleic anhydride modified polypropylene produced better mechanical properties in comparison to other reinforcing fibres studied by the investigators.

However, these treatments are relatively expensive and do not significantly increase the mechanical properties relative to the given treatment, time, andcomplex procedures. Additionally, they do not generally affect the flame retardancy of the polymer which is becoming an important criterion for various domestic and industrial application of polyethylene. Besides, some of these chemical additives like other flame retardants could release toxic gases into the atmosphere during combustion of the polymer.

During combustion, polymers initially experience preheating. Consequently, they lose their structural integrity and decompose releasing combustible hydrocarbons into the atmosphere. At the appropriate temperature, these hydrocarbons ignite and combustion takes place. Since the combustion of polymers follow a particular pattern of: preheating, decomposing, ignition, and combustion, flame retardants have been developed to break the cycle (Cullis and Hirschler 1981). This could be done either in the solid phase - smothering the fire by forming a char over the polymer, or gaseous phase - releasing non-combustible gases into the atmosphere that would react with flame propagating radicals (Nelson 1995). Assessing the degree of flame retardancy is therefore a function of the relative delay of the polymer sample to either the ignite and combust on its own without continuous supply of flame from the flame source, or the rate of the spread of fire over the sample(Stark et al. 2010; Gerad et al. 2010).

This research work focuses on the effect of Kola Nitida, a plant denizen in WestAfrica with a very high annual production rate, on the mechanical and flame retardancy properties of Low Density Polyethylene.

MATERIALS AND METHOD

Materials

Low Density Polyethylene was gotten from CEEPLAST Industry Ltd., Adaelu Street, Osissioma Industrial Layout, Aba, Abia State, Nigeria.
Cola nut stem bark was obtained from cola nitida plant, from a local farm in AhiazuMbaise, Imo State, Nigeria.
Kola Nitida stem bark samples were dried in a 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.

CompositePreparation

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 (wt %)*
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 were determined by the Indentation Test Machine. A pressure of 10MN/m^2 was used to monitor the depth of penetration. Results were obtained from the penetrometer. The indentation value 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 represent 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.

Auto-CombustingTime

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.

FlamePropagationRate

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 sampleend (i.e., 3 cm) and the flame propagation time.

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

RESULTS AND DISCUSSION

Tensile properties of LDPE/KN composite can be deduced from the stress/strain graph (Fig 3.1). Test results show that yield strength (see Fig 3.2) increased with increasing fibre loading after showing an initial decrease at 5 wt%. Young's Modulus (see Fig 3.3) showed a steady increase from 10 – 20 wt%, after decreasing from 0 – 10 wt%. Yield strain values as seen from Fig 3.4 followed a rather sinusoidal path from 0 – 20 wt%. Improved tensile properties of composites is a function of efficient stress transfer from fibre to matrix brought about by good interaction between fibre and matrix. This could therefore mean that a good interfacial interaction exist between Kola Nitida and Low Density Polyethylene.

Indentation test results (Fig 3.5) show a linear increase in indentation values with increasing fibre content. Hardness test results are presented in Fig 3.6. The hardness value decreased with increasing fibre content. This decreases has been reported by other researchers when dealing with natural fibre based composites. Anap (2008) reported that with increasing flax fibre content, hardness value of High density polyethylene/flax fibre composites and polypropylene/flax fibre composites decreased. Khairaih and Khairhul (2006), also reported decreasing hardness values with increasing fibre content when they worked on polyurethane and empty fruit bunch blend composites. They alluded the decrease to the inability of the matrix to encapsulate the fibre strands. The overall improved mechanical properties of LDPE/KN composites suggest good compatibility of KN wood fibres and LDPE matrix.

Flammability properties of LDPE/KN composites were evaluated using various flame resistance tests. Flammability test results reported in Fig 3.7 – Fig 3.9, show improved flame resistance of LDPE/KN composites with increasing fibre loading.

Ignition time reflects the relative tendency of a material undergoing combustion to ignite within a period of time. The increase in ignition time indicates that the material resisted ignition. This is a measure of flame retardancy. Ignition time (see Fig 3.7) increased by over 600% from 0 – 20 wt%.

Auto-combustion time is also an important parameter in assessing the flame retardancy of a combusting material. It reflects the self-extinguishing property of the material. A material undergoing combustion usually becomes able to sustain combustion even when an external source of flame is removed. The relative readiness of the material to attain the level of auto-combustion can be viewed as a function of time. The longer the time, the higher the self-extinguishing character of thecombusting material. The test results presented in Fig 3.8 show that auto-combustion time increased 1000% from 0 – 20 wt%.

The relative readiness of the composite to combust suggests that the time required for combustion of composite material would be less, hence, FRP value would be high. Flame retardancy therefore is an inverse function of the FRP value. The lower the FRP the higher the flame resistance property. Flame Propagation Rate (see Fig 3.9), reduced by over 200% from 0 – 20 wt%. The increase in ignition time and auto-combustion time with increasing KN wood fibre content suggests that the presence of KN wood fibres in LDPE/KN wood composites produced anti-combustion gases, thereby reducing the amount of combustible hydrocarbons released. These gases could also react with flame propagating radicals thereby limiting the amount of heat released during this combustion. This could make it difficult for the composite to decompose, release combustible hydrocarbons into the atmosphere, combust, and attain auto-combustion status.

Flame Propagation Rate (FPR) which is a measure of the rate of decomposition of the material during combustion decreased. Since decomposition of combusting material increases thespread of flame, the relative resistance to flame spread indicates that the material resisted decomposition and therefore combustion. This suggests that the presence of Kola Nitida wood fibres increased the structural integrity of the composite.

CONCLUSION

Kola Nitida wood fibres were used to reinforce Low Density Polyethylene. Improved mechanical and flame retardancy properties were obtained. LDPE/KN wood fibre composite showed improved tensile properties. Yield strength, yield strain, and Young's Modulus increased from 0 – 20 wt%. Indentation results also show values increasing with increasing fibre loading while hardness values decreased with increasing fibre loading.

Flammability retardancy tests show that flame resistance of LDPE/KN composites was increased by the presence of Kola Nitida wood fibres. Ignition time and auto-combustion time increased by over 600% and 1000% respectively from 0 – 20 wt%, while the Flame Propagation Rate (FRP), decreased by over 200% from 0 – 20 wt%.

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FIG 3.1 GRAPH OF STRESS VS STRAIN FOR LDPE/KN COMPOSITES AT DIFFERENT FIBRE CONTENT

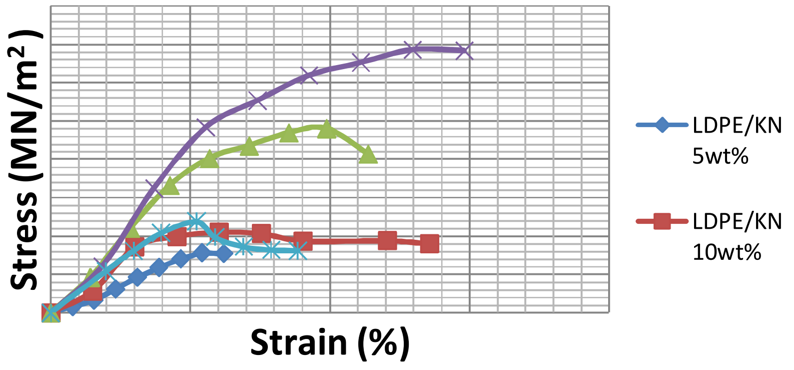


Fig 3.2 Graph of Yield StrengthVs Fibre Loading of LDPE/KN Composite

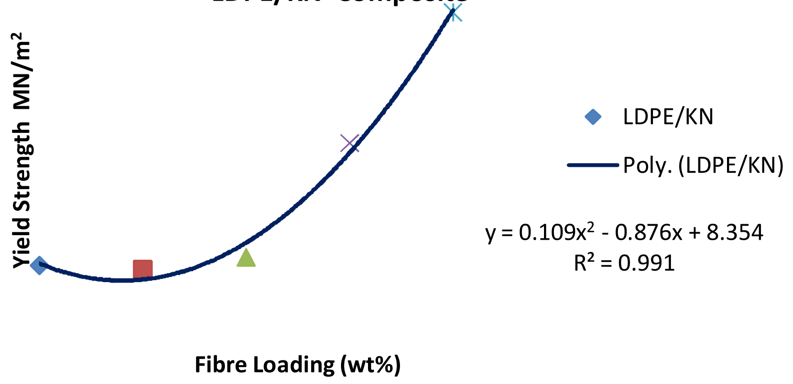
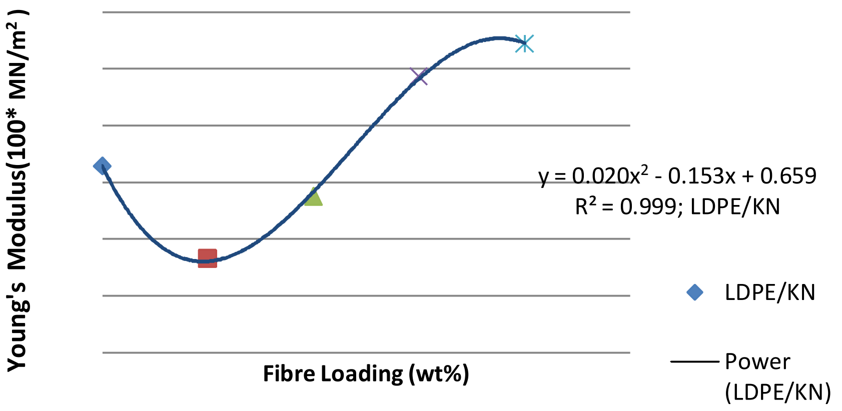


Fig 3.3 Graph of Young's Modulus Vs Fibre Loading of LDPE/KN Composite



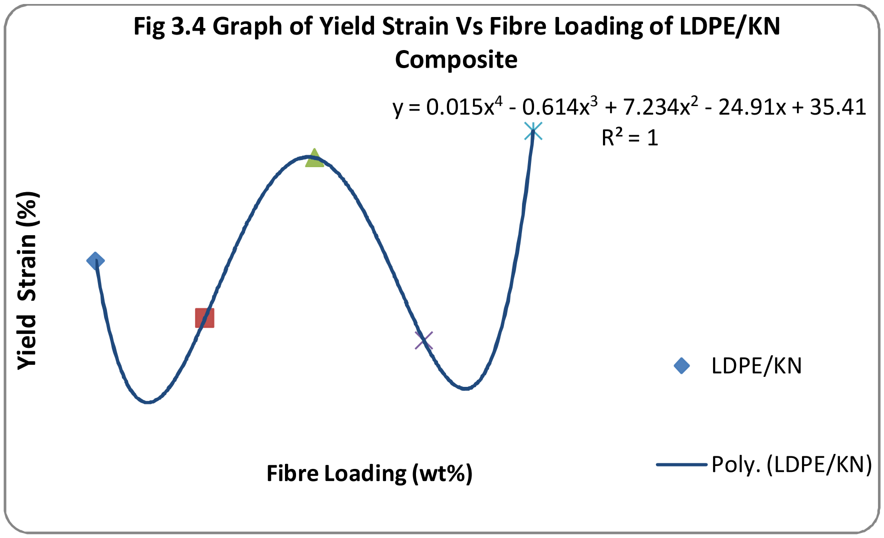


Fig 3.4 Graph of Yield Strain Vs Fibre Loading of LDPE/KN Composite

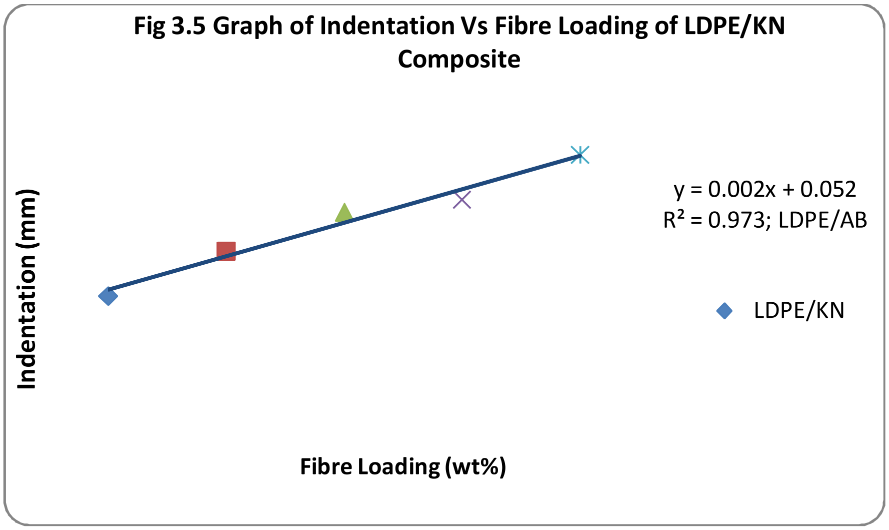


Fig 3.5 Graph of Indentation Vs Fibre Loading of LDPE/KN Composite

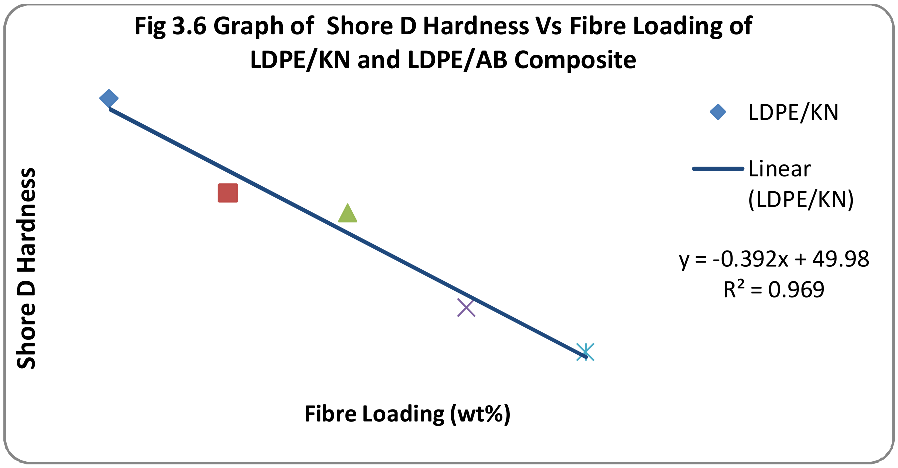


Fig 3.6 Graph of Shore D Hardness Vs Fibre Loading of LDPE/KN and LDPE/AB Composite

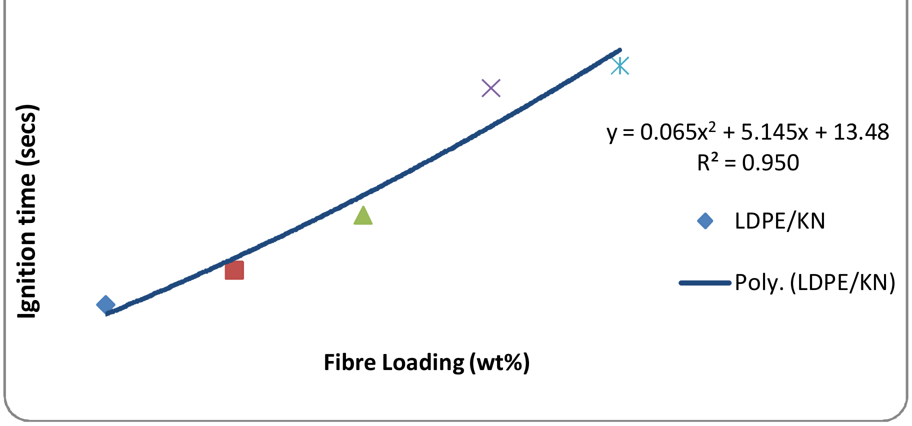


Fig 3.7 Graph of Ignition time Vs Fibre Loading of LDPE/KN and LDPE/AB Composite

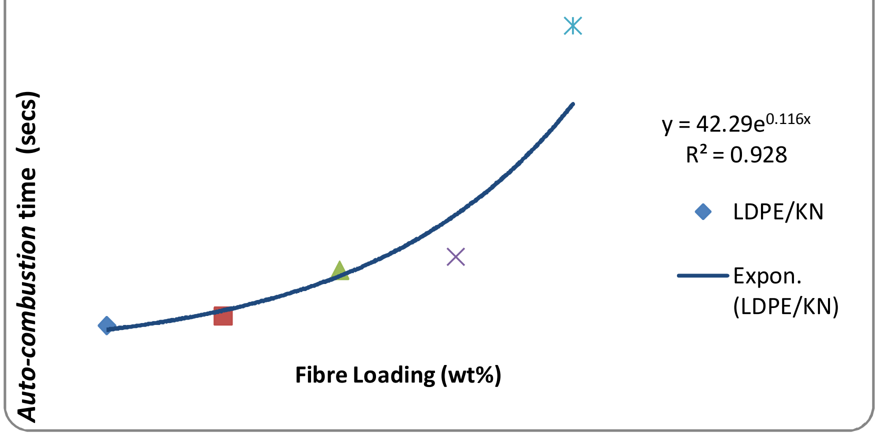


Fig 3.8 Graph of *Auto-combustion* time Vs Fibre Loading of LDPE/KN Composite

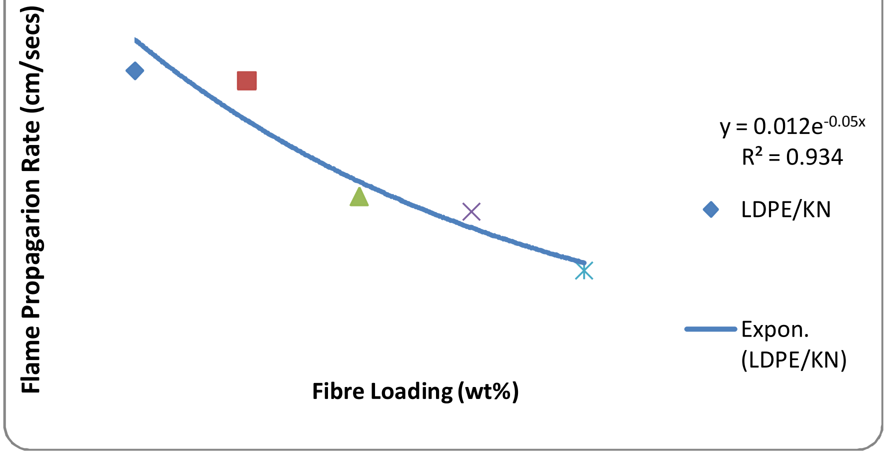


Fig 3.9 Graph of Flame Propagation Rate Vs Fibre Loading of LDPE/KN Composite