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Research Article

RECENT ADVANCES IN MECHANICAL BEHAVIOR OF FIBRE REINFORCED SMART BIODEGRADABLE POLYMERS

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ABSTRACT

Fibre-reinforced polymer composites have been developed from the reaction of fumarate resin with natural material Perch fibre. The composite material is fabricated by hand layup technique. The fabricated composite material was tested for its mechanical properties such as Tensile Strength, Flexural Strength and Impact Strength. The composite specimens for the above-mentioned test were prepared as per the ASTM standards. The fibre reinforcement influenced the improvement of mechanical properties of polymers and surface morphology of the polymer was analysed by Scanning Electron Microscope. Moisture absorption and vibration damping with polymers and its effect on mechanical properties can also be studied. Tensile strength, flexural strength and impact strength were observed and compared to each other. Tensile test showed maximum ultimate tensile strength for untreated 80 mm length fibre compared to others. Flexural test showed maximum ultimate flexural strength for untreated 80 mm length fibre compared to others. Impact test showed higher impact energy for treated 40 mm length fibre compared to others.

Keywords: Biodegradable, Eco-friendly, Thermoset, Mechanical, Moisture, Vibration.

1. INTRODUCTION

Natural fibres are recently attracted towards researchers due to their low cost, eco-friendly, low density, good mechanical properties and as a renewable source [1]. Natural fibres offer many technological and environmental benefits to reinforce low density materials with high strength and is favourable as a reinforcement in making lightweight polymers with good mechanical properties [2]. A special benefit of using fibre reinforced polymer is its biodegradability and extremely available from a renewable resource. As fibre contents increases, the mechanical properties such as tensile, impact and flexural strengths of these properties also increases [3]. Different kinds of tests have been performed on the polymer composites and the reports reveal that they have interesting mechanical properties [4]. Due to various chemical treatments on fibres, the hydrophilic behaviour of the fibres was reduced to improve mechanical strength in natural fibre reinforced polymers [5]. Fibre reinforced polymers assist to expand strength and ductility without increase in stiffness [6].

2. EXPERIMENTAL

2.1. Materials

Azadirachta Indica oil (AIO) and Thennamarakudi oil (TKO) were purchased from local market, Formic acid (97%) (Rankem), Hydrogen peroxide (30%) (Rankem) were used in the first step fractionalization. Maleic anhydride (Rankem) morpholine (Rankem) and benzoyl peroxide (Rankem) was used as a radical initiator and N, N- dimethyl aniline (Rankem) was used as accelerator in the curing process. Styrene (Rankem) was used as a vinyl co-monomer.

2.2. Synthesis of plant oil polyol

A 100 g of AIO/TKO was taken in a three necked flask fitted with condenser and thermometer.100 mL of 97% formic acid and 55 mL of 30% hydrogen peroxide was added. Ice water bath was used externally to keep the temperature below 4°C. The reaction mixture was vigorously stirred over 16hr.The resulting emulsion was poured into a separating funnel and extracted with ether. The ether layer was dried over anhydrous sodium sulphate and the resulting product was polyol resin obtained from AIO/ TKO.

2.3. Synthesis of polyesters

The polyol resin was heated in a three necked flask and maleic anhydride was added in 1:2 ratio at 70°C. Morpholine was used as a catalyst. After 2 hours a golden yellow viscous liquid formed it indicates the formation of oligomerised AIO/TKO fumarate resin.

2.4. Synthesis of polyester film from oligomerised AIO/TKO fumarate resin and comonomer styrene

Synthesis of aliphatic polyester was carried out by free radical addition polymerization reaction by using the homopolymer (oligomerised AIO/TKO fumarate resin) and styrene at different

concentration using benzoyl peroxide as catalyst and N,N-dimethyl aniline as accelerator. The viscous liquid is fabricated with different weight ratio of Perch fish fibre and is transferred in to glass mould coated with silicone oil at room temperature. The polyester thin films were synthesized from homopolymer and styrene. Finally, the fibre reinforced polyesters sheets were removed from the mould.

2.5. Characterization of Polymers

Double-beam UV/visible spectrometer is used to verify the characteristic absorption of the polymer composites. Fourier transform infrared (FTIR) spectra of polymers were obtained using Shimadzu FT-IR spectrophotometer using KBr pellet at wavelengths between 4000 cm^{-1} and 400 cm^{-1} at 27°C. SEM analysis was carried out to know about the surface property of the polymer. The mechanical studies of the biopolyesters were determined using dumbbell shaped cut from the specimen according to ASTM D3039 standards.

3. RESULT AND DISCUSSION

3.1. UV analysis

Figure 1shows the UV spectra of AIO and TKO, hydroxylated triglyceride oils and their resins. They have been investigated (230 nm-800 nm). The AIO and TKO samples showed an electronic absorption band around 262 nm and 270.50 nm, respectively. The hydroxylated resins exhibited a blue shift when compared with the corresponding parent oil which is attributed to the substitution of hydroxyl group at the unsaturated moiety.

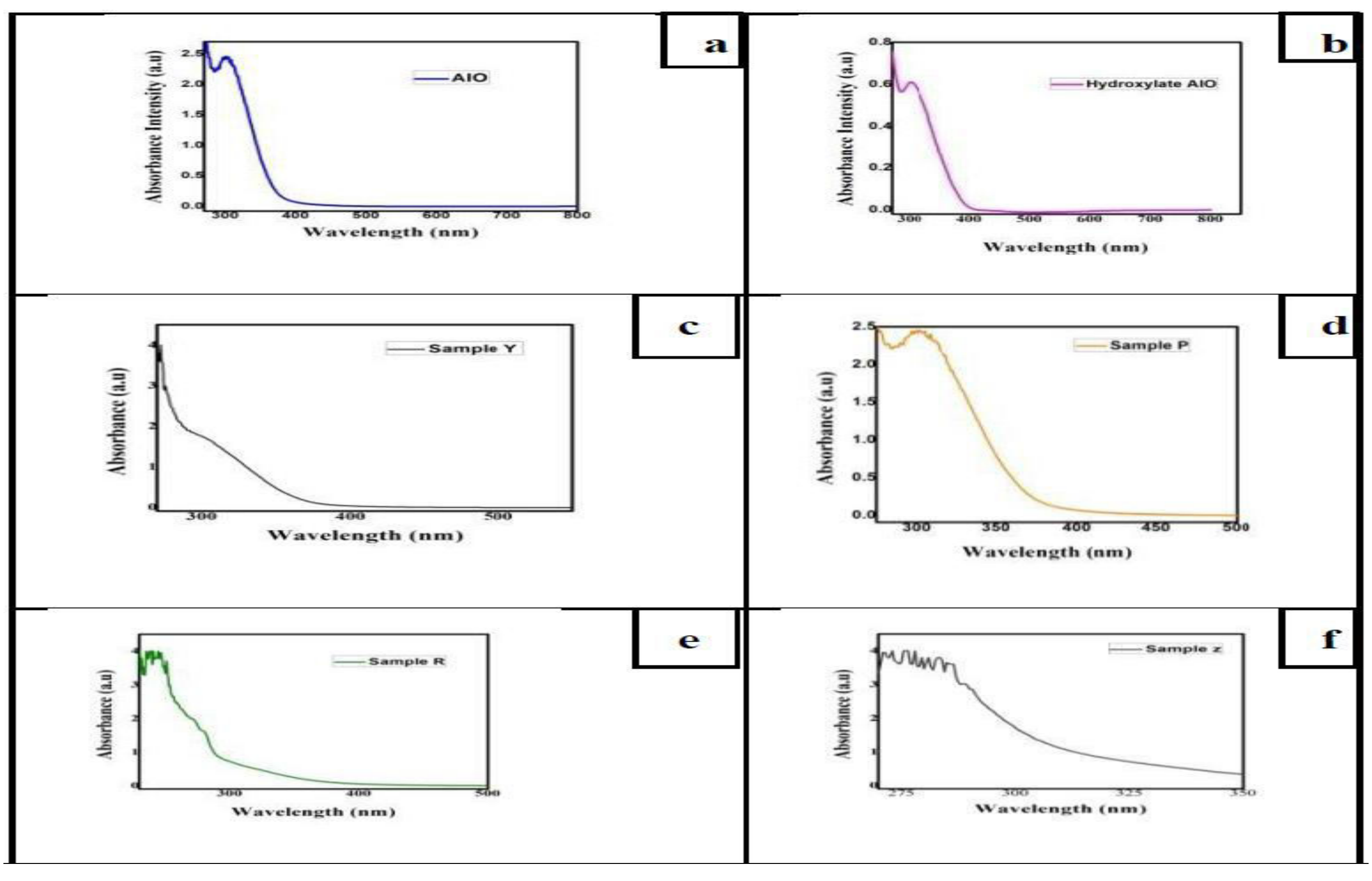


Fig. 1: UV Spectra of a) AIO b) HAIO c) PAIOFRS d) TKO e) HTKO and f) PTKOFRS

3.2. FTIR spectral analysis

Table 1 shows the IR spectra of AIO, TKO, hydroxylated triglyceride oils and their resins. They have been investigated between 500 cm^{-1} to 4000cm^{-1}. In hydroxylated triglyceride oils, FT-IR spectra showed a strong absorption band at 3565.17$cm^{-1}$and 3172.68 cm^{-1}, respectively due to the presence of free -OH group in the molecule. The corresponding peaks are completely reduced in the resins indicates the entire OH group get substituted.

Table 1: FT-IR probable assignments of AIO and TKO

Probable assignment	AIO (cm^{-1})	HAIO($cm^{-1)}$	AIOFRS (cm^{-1})	TKO (cm-1)	HTKO (cm-1)	TKOFRS (cm-1)
- CH_2 Group	2927.74	2927.74	2929.67	2925.81	2926.78	2928.71
-C- O Group in GM	2854.45	2855.45	2855.42	2854.4	2854.45	2855.42
C=O in esters	1745.46	1726.17	1729.06	1746.42	1730.99	1734.85
TerminalCH_3Groups	1209.28	1400.22	1460.01	1196.75	1116.71	1168.78
CarboxylGroupof Acids	1167.82	1178.43	1374.19	1162.03	1145.75	1132.14
-CH-CH-Stretching	1072.35	1076.21	1058.85	1086.81	1073.31	1055.95
CH2-sequences of the aliphatic chains	649	725.18	723.26	753.15	723.26	671.18
-OH Group	3658.71	3565.17	3268.15	3161.11	3172.68	3635.57

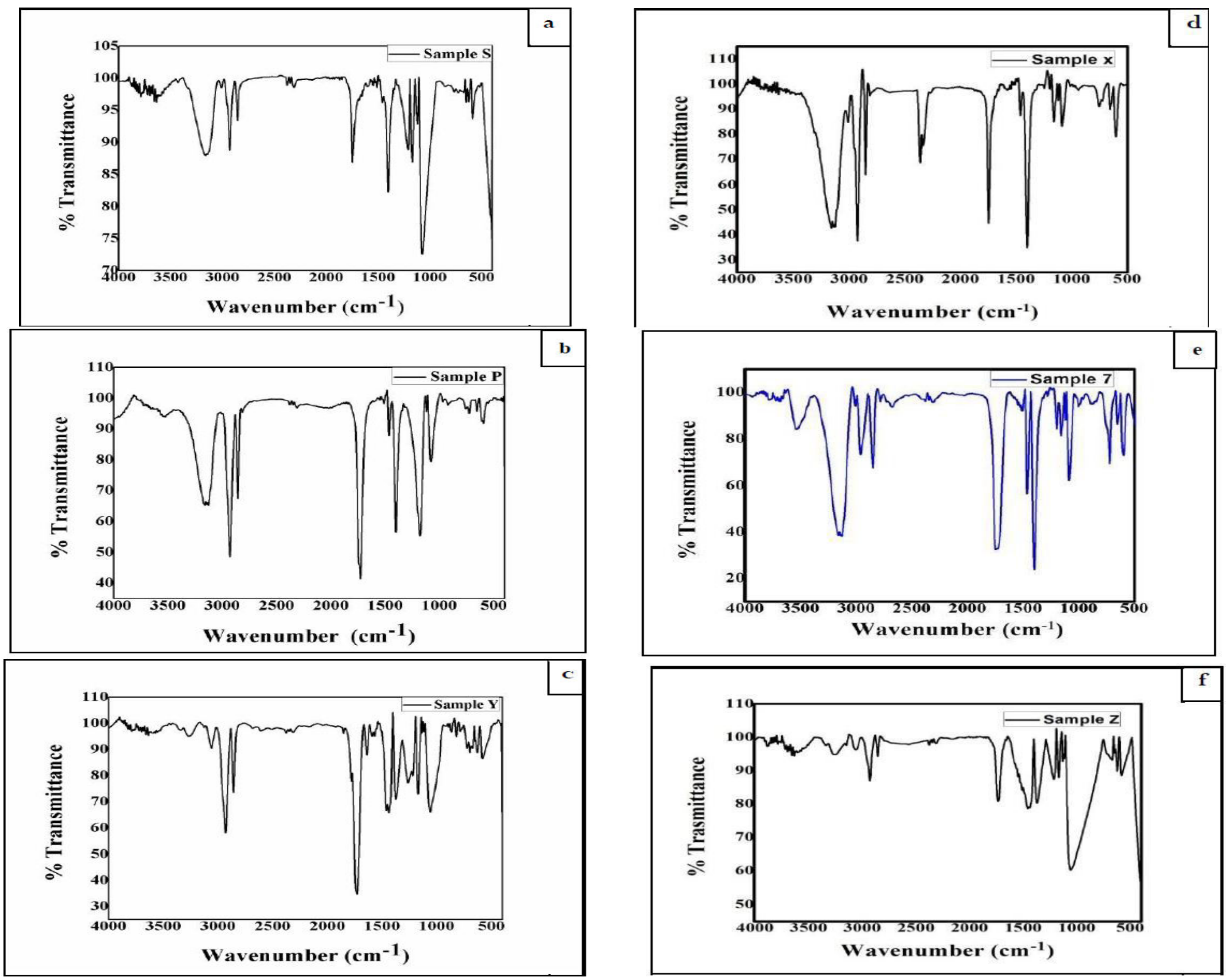


Fig. 2: IR spectrum of a) AIO b)HAIO c)PAIOFRS d)TKO e)HTKO and f)PTKOFRS

3.3. XRD Pattern

XRD patterns explain the crystallographic structure of polymers. AIO and TKO polymers have broad peaks indicate that they are semi crystalline in nature.

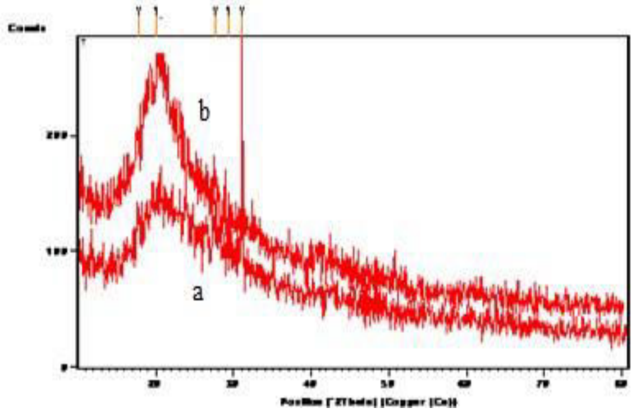


Fig. 3: XRD Patterns of a) AIO polymer b) TKO polymer

3.4. SEM analysis

Scanning electron micrograph provides the information about surface morphology of polymers. Figure 4 and 5 represent the SEM images of untreated and treated AIO and TKO polymers. They have symmetric chain units in parallel and have a good network pattern. The SEM images show the adhesion between the fibres and matrix.

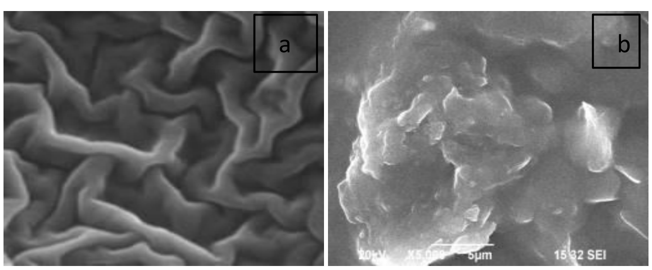


Fig. 4: SEM images of a) untreated AIO b) treated AIO

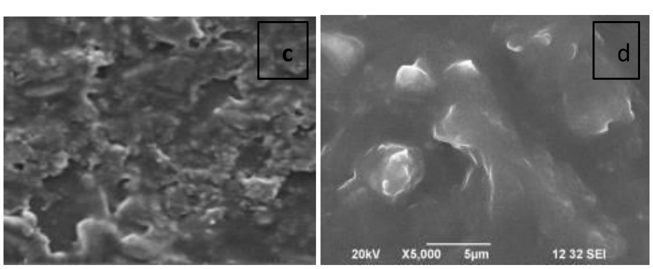


Fig. 5: SEM images of a) untreated TKO b) treated TKO

The above images are of sample with composition of 30 %Perch Fish Fibres and 70% Resin. Figure 4 shows image of surface without any fracture. There are some voids seen in image which are caused because of manually stirred resin mixture and it also may be caused because of random orientation of fibres.

SEM images prove that the polymer composite has strong bonding between resin and fibres and it also shows that the fibres are completely immersed within resin.Scanning electron microscopy (SEM) study revealed excellent interfacial bonding between the fibre and the resin matrix of AIO/fish fibrereinforced fumarated hybrid composite that evince the improvement in the tensile and flexural properties of the material. Moreover, when compared to other composites, AIO/ Perch fish fibre and TKO/ Perch fish fibre composite absorbs more energy during impact loading that makes the material a good competitor in automotive and textile sectors.

3.5. Mechanicalproperty

The mechanical properties of the polymers prepared were shown in Table2. To evaluate the tensile properties of the TKO and AIO polymers, tensile tests were conducted according to ASTM D3039 to measure the force required to break the polymer composites.

Table 2: Mechanical properties of the polymers

Polymer sample	Tensile strength (Map)	%of Elongation	Flexural strength (Mpa)	lexural Strain (%)
TKO	28.9	16.4	26.43	7
TKO1	30.5	16.08	25.2	7.2
TKO2	31.3	14.18	27.5	6.7
TKO3	32.5	18.94	26.6	7.1
AIO	4.9	20.57	34	7.9
AIO1	6.6	18.4	32.5	8.2
AIO2	6.9	23.9	33.2	8.5
AIO3	10.39	19.4	36.3	7

A standard specimen is subjected to gradually increasing uniaxial tensile load until it fractures. Tensile strength of developed TKO and AIO polymers were found to be 28.9 Mpa and 4.9Mpa. Fig.6 shows the comparison of AIO and TKO polymers of a) Tensile and Flexural strength b) Elongation and Flexural strength c) Impact strength. Among the polymers, tensile strength is high in TKO polymer due to higher cross link density and flexural strength is high in AIO polymer [8]. From the graph, elongation and flexural strain is greater in AIO polymer and impact strength of TKO polymer is greater than AIO polymer. Figure 7 shows that the tensile and impact strength of various fibre ratio of TKO and AIO polymer. From the graph, tensile and impact strength is greater in TKO polymer and flexural strength is greater in AIO polymer.

3.6. Moisture Absorption of Polymers

Fig. 8 shows the curves of percentage of water absorption as a function of time in sea water, distilled water and drinking water. To measure the strength or quality of the polymer, the water absorption tests were performed according to ASTM D570 on a universal test machine. From the graph, water absorption increases with absorption time [9]. Due to the high cellulose content, the percentage of weight of the fibre in the polymer increased as the moisture absorption was decreased. Moisture absorption of fibre reinforced TKO and AIO polymers causes the swelling of fibre as a result of the formation of micro cracks at fibre-matrix space. Due to the damages of the fibre, interfacial bonding and the strength is decreased, which in turn caused degradation of polymers.

3.7. Vibration damping with Polymers

Dampers based on polymers have many applications due to their low cost, light weight and flexibility. The damping factor was determined by using free vibration method as per ASTM standard (D 790). The damping factors were calculated by taking the values of successive peak from the vibration response graph. From the graph, damping factor increases with frequency [10]. Fibre reinforced TKO and AIO polymers exhibit greater vibration damping because fibres are stiff and the fibre-matrix interface increases the damping properties and energy dissipation.

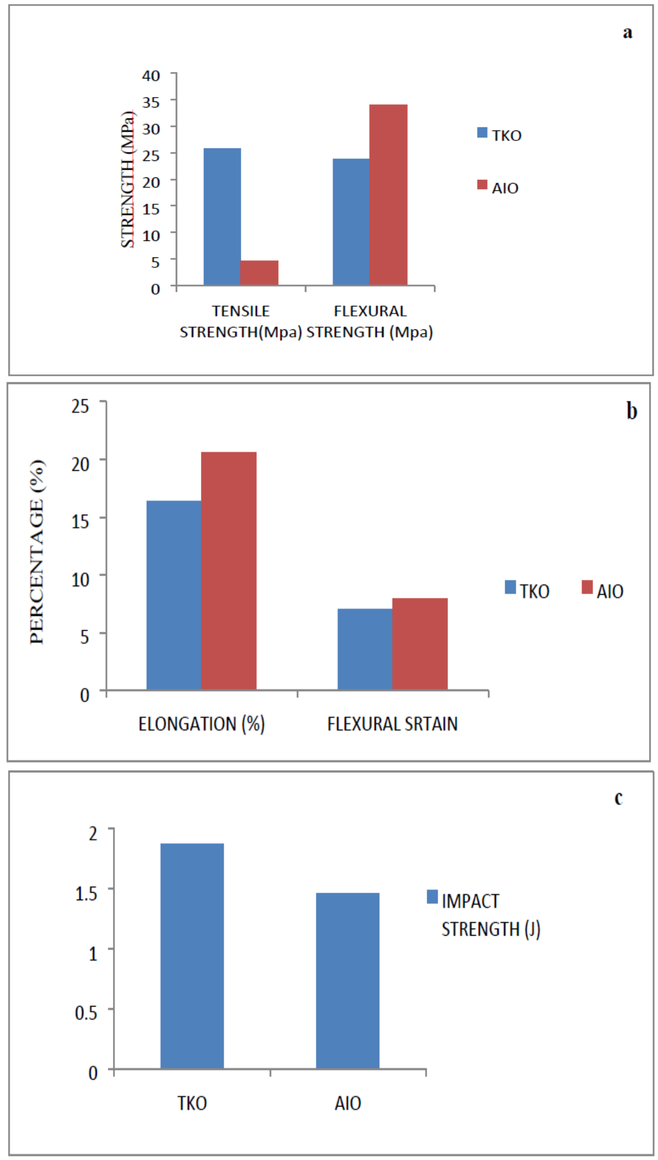
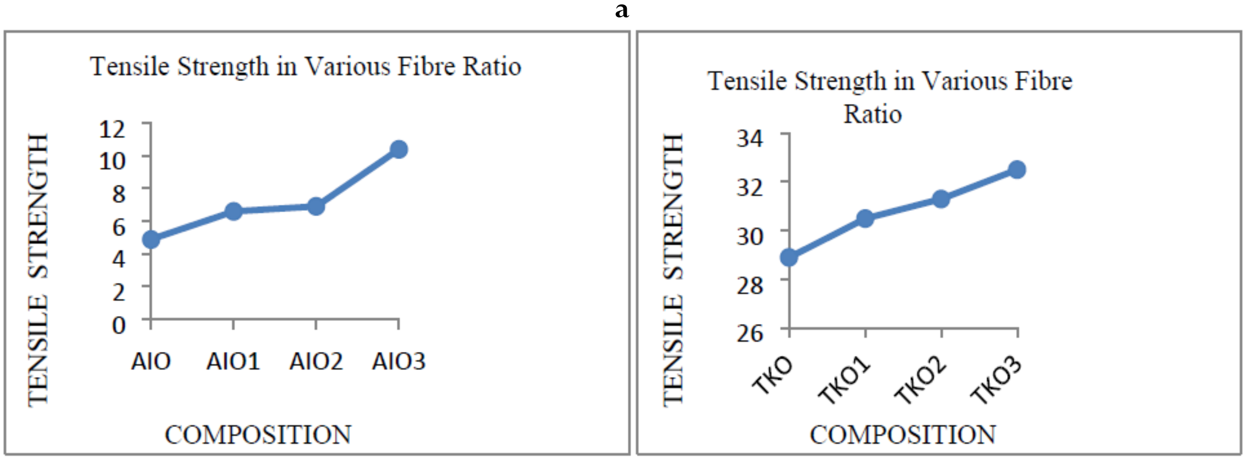


Fig. 6: Comparison of TKO and AIO polymers of a) Tensile and Flexural strength b) Elongation and Flexural strength c) Impact strength

a



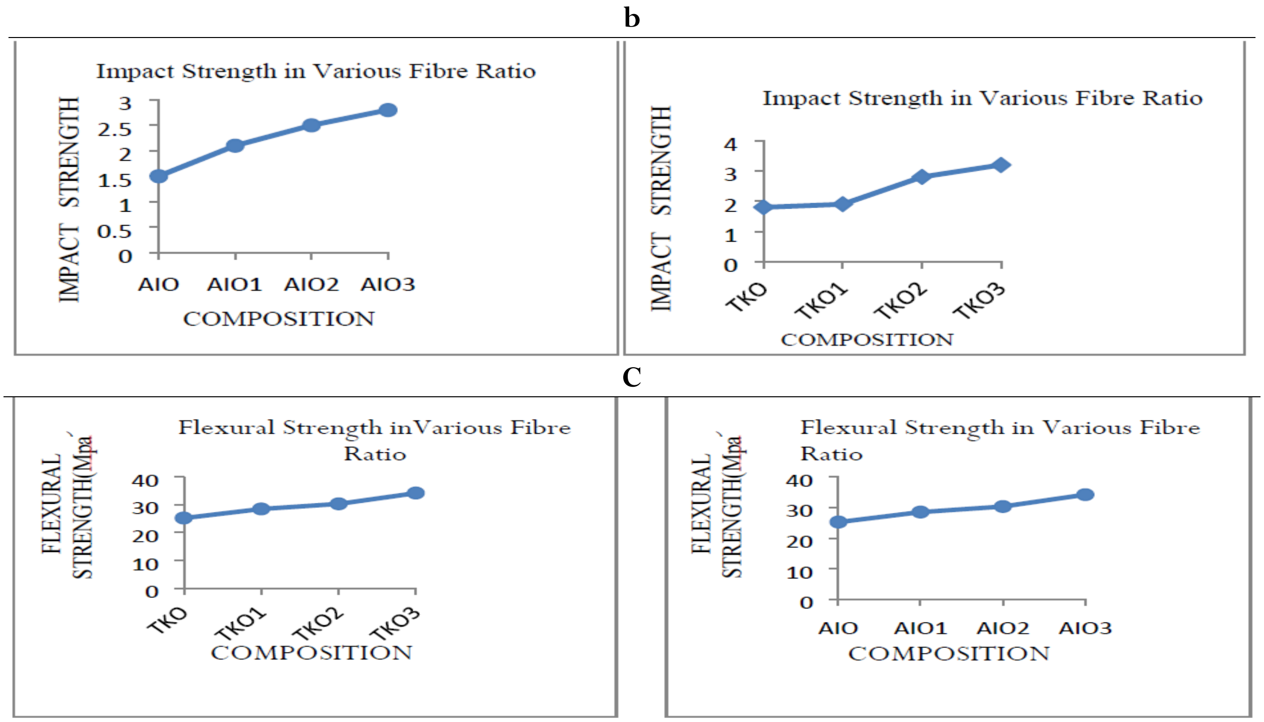


Fig. 7: Various fibre ratio of AIO and TKO polymers of a) Tensile b) Impact c) Flexural strength

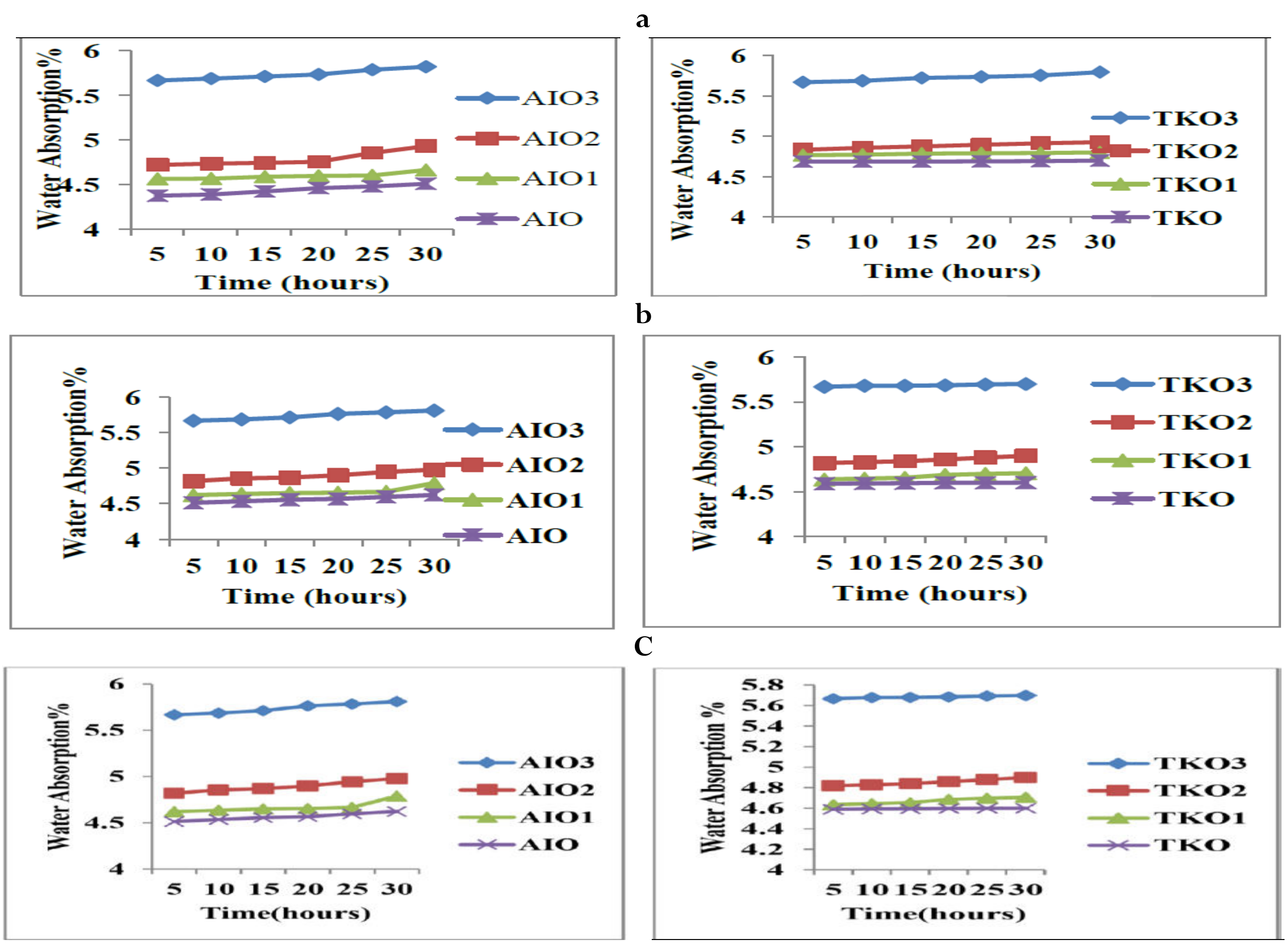


Fig. 8: Water Absorption curves of AIO and TKO polymers in a) sea water b) distilled water c) drinking water

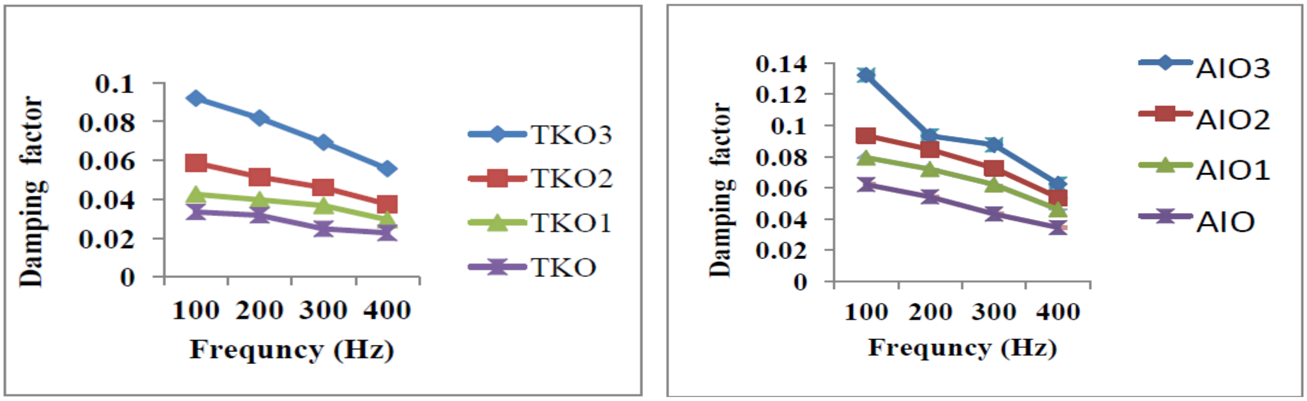


Fig. 9: Damping curves of a) AIO polymer b) TKO polymer

4. CONCLUSION

We have successfully synthesized fibre reinforced polymers. Mechanical characterization of newly synthesised polymers was studied. AIO based polymeric material was more flexible compared to TKO based bio material. TKO based polymer has more stiffness than AIO based polymer. Tensile strength and impact strength is high in fibre reinforced polymers of TKO and flexural strength, elongation and flexural strain is high in fibre reinforced polymers of AIO moisture absorption increases; the degradation of TKO and AIO polymers will also increase. They exhibit greater vibration damping. The newly prepared polymer is biodegradable.

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