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Flexural Strength of Saw dust Reinforced PP-PE Copolymer Nano Composites

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Abstract

Copolymerization of monomers combines their individual properties to facilitate a targeted matrix of optimum properties, which can give solutions to many practical applications. When these copolymers are reinforced with natural particles and nano fillers, the resulted composites give high strength along with special feature of biodegradation. In this study, strong and stiff polypropylene (PP) was combined with ductile and soft polyethylene (PE). This copolymer was reinforced with natural fiber (6 wt.% wood saw dust) to improve biodegradability and 1 wt.% nano clay to improve mechanical properties of the composite. The developed composite samples were characterized by means of flexural tests. Experimental result exhibited that addition of saw dust particle degrades the flexural properties, however, addition of nano clay revives the lost properties to some extent.

Keywords: Copolymers, Wood saw dust, Nano clay, Biodegradation, Flexural properties.

1. Introduction

Polymer nano-composites are considered as new generation materials and the most promising sector in the field of composite industries. These composites combine the use of a nanostructured organic or inorganic clay filler with cellulous saw dust particles as reinforcement materials and a thermoset or thermoplastic matrix. Thermosets such as epoxy, polyester, phenolic, etc cannot be melted repeatedly, however, thermoplastics can be repeatedly melted, which permits saw dust particles to be mixed with the polymer matrix to form the desired composites. Polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC) are widely used thermoplastics for wood plastic composites [1]. Wood–plastic composites (WPCs) are getting a great attention in industrial sectors and academics due to their favourable properties, which include low density, low cost, renewability and recyclability as well as desirable mechanical properties [2]. The fast degradation of composites after usage is also facilitated by the renewable and biodegradation features of saw dust particles. On the other hand, nano science and nanotechnology have opened a new horizon to develop WPCs [3]. Nanotechnology is a very promising area for enhancing the mechanical, physical as well as other properties of WPCs using nano sized fillers. These improvements include high moduli; increased tensile and flexural strength, decrease in water absorbance and increased biodegradability of biodegradable polymers [4]. In this context, nano clay is widely used as filler. A dramatic increase in the interfacial area between fillers and polymer can significantly improve the properties of the polymer [5]. Interestingly, even in a very small concentrations nano clay is capable to improve physical and mechanical properties of the composites [6]. An increased number of polymer-particle and particle-particle interactions relative to traditional fillers are provided by the high specific surface area of nano clay, which is due to its nanometer size and high aspect ratio [7].

The aim of this experimental work was to design an ecofriendly wood saw dust reinforced copolymer nano composites with improved flexural properties, which can be used in many industrial and household applications including light weight, high strength parts, circuit-switch boards, insulation materials, false ceiling, partitions etc.

2. **Materials and Experimental Procedure**

Materials

To accomplish all the experimental works for the preparation of saw dust reinforced copolymer nano composites, following raw materials were used:

- Polypropylene (PP) and polyethylene (PE) granules.
- Saw dust.
- Nano clay.

The most common thermoplastics, polypropylene (PP) and polyethylene (PE) (Fig. 1a and b) were chosen for copolymer matrix materials and they were collected from local market. Saw dust collected from BUET carpentry shop (Fig. 1c) and nano clay was imported from abroad (Fig.1d). Before molding, wood saw dust was dried at 115°C temperature in an oven.

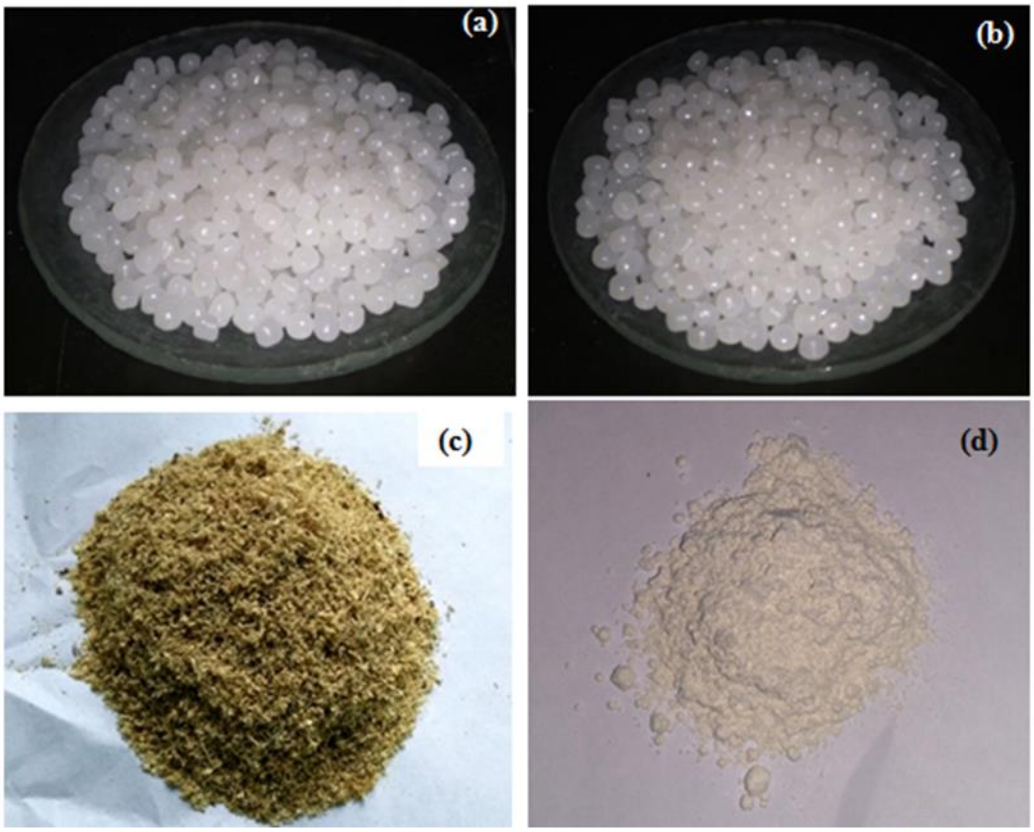

Fig. 1. (a) Polypropylene (PP) granules, (b) polyethylene (PE) granules, (c) oven dried sawdust of random wood and (d) nano clay.

Blending

In order to get optimum level of PE in PP, their five different proportions as 90PP-10PE, 80PP-20PE, 70PP-30PE, 60PP-40PE and 50PP-50PE were selected. Thus five different types of copolymer blends were prepared along with pure PP and PE, which are presented in Table 1. In the second section, copolymer blend with the optimum tensile properties from Table 1 had been chosen for the fabrication of the copolymer nano composites, which included subsequent addition of saw dust and nano clay into it.

Table 1. Composition of copolymer blends

Sample No.	Sample Composition
1	100PP
2	90PP-10PE
3	80PP-20PE
4	70PP-30PE
5	60PP-40PE
6	50PP-50PE
7	100PE

Flexural tests of seven different groups of samples were carried out. From these test results, it has been revealed that the copolymer blend with 90PP-10PE results better combination of flexural properties. So, this blend of copolymer was chosen for making composites for further works. For doing this, mixing sawdust and nano clay into it the copolymer was done. The final sample compositions for composites are shown in Table 2.

Table 2. Composition of composite blend

Sample No.	Sample Composition
8	85PP-8PE-7Saw dust
9	85PP-8PE-6Saw dust-1Nano clay

For all cases, hot compression molding was done using closed die method. A typical cast sheet of saw dust reinforced nano composite is shown in Fig. 2.

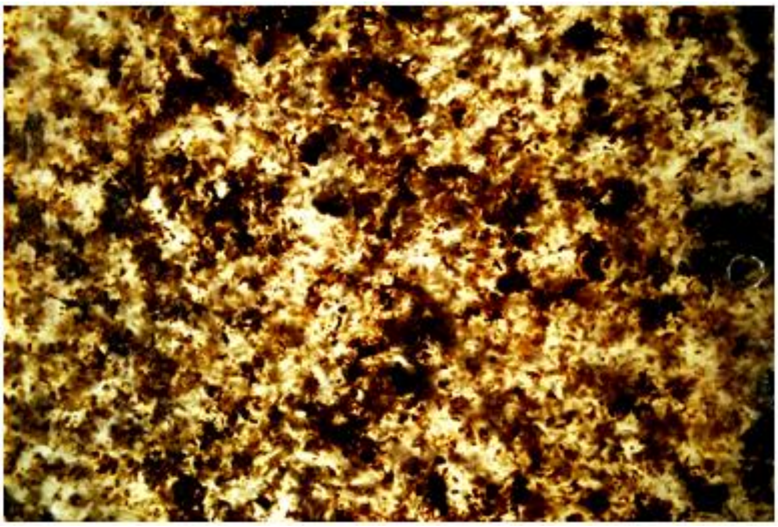

Fig. 2. Sawdust reinforced copolymer nano composite sheet after hot compression process.

Flexural test

Flexural test measures the applied stress required to bend sample specimen just before it yields. From each type of the casting sample of Table 1 and 2, at least three specimens were tested. The specimens were tested in Universal Testing Machine of model INSTRON 3369 at a cross-head speed of 6 mm/min. Fig. 3 shows typical samples used for flexural tests.

Fig.3. Composite specimens prepared for flexural tests.

3. Results and Discussion

After flexural test, flexural strengths (MPa) and flexural modulus (GPa) were calculated, which have been presented in Table 3. From Table 3, it is clear that 100PP possesses higher bending strength as well as flexural modulus than 100PE. Addition of 10 wt.% PE in PP deteriorates flexural properties to some extent.

Table 3. Flexural data for pure polymers, copolymers and composites

Sample Composition	Specimen No.	Flexural Strength (MPa)	Average Flexural Strength (MPa)	Flexural Modulus (GPa)	Average Flexural Modulus (GPa)
100PP	1	50.99	48.50	1.445	1.43
	2	52.90		1.460	
	3	41.57		1.387	
100PE	1	13.06	11.82	0.500	0.50
	2	11.23		0.507	
	3	11.18		0.457	
90PP-10PE	1	43.62	43.98	1.492	1.38
	2	45.90		1.377	
	3	42.42		1.287	
85PP-8PE-7Saw dust	1	28.15	26.06	1.601	1.62
	2	28.22		1.585	
	3	21.82		1.671	
85PP-8PE-6Saw dust-1Nano clay	1	57.35	57.73	1.878	1.86
	2	58.73		1.957	
	3	57.10		1.745	

When 7% saw dust was added in the selected copolymer, the flexural strength decreased but flexural modulus had been found to increase significantly. Nano clay helped the saw dust composites in regaining its lost bending strength and modulus to a great extent, Table 3. The regaining of the flexural strength is also very clear from the flexural stress-strain diagrams of the composites, Figs. 4 and 5.

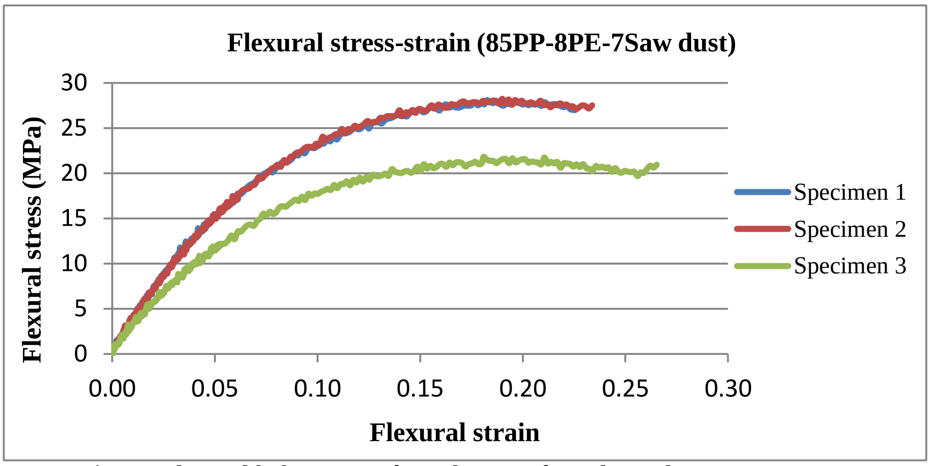

Fig. 4. Flexural behaviour of sawdust reinforced copolymer composites.

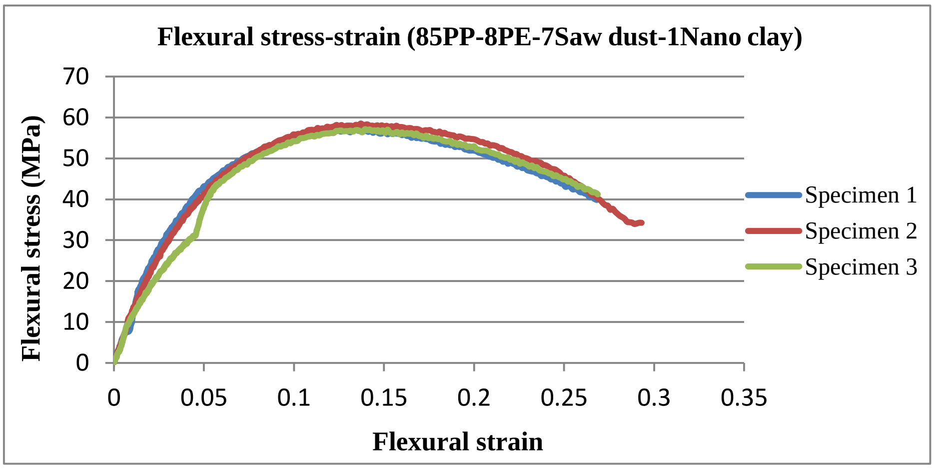

Fig. 5. Flexural behaviour after nano clay addition into sawdust reinforced copolymer composites.

From Table 3, it is evident that addition of sawdust into the copolymer blend (90PP-10PE) of optimum flexural properties degrades its flexural strength value from 43.98 to 26.06 MPa but increases flexural modulus value from 1.38 GPa to 1.62 GPa. It has been mentioned that the flexural properties of composites are mainly influenced by filler fraction and the interfacial adhesion between particles and matrix. Larger saw dust particles have smaller surface area, which results in poor bonding of the filler and the matrix [8]. Crack formation was easier between sawdust particle/copolymer matrix interfaces as the specimens were loaded. Once crack is formed inside the composite, there is no powerful barrier to arrest the propagating crack. As a result, the composites become very unstable under loading condition and fails very easily. This has been mentioned as one of the most dominating reasons to decrease the flexural strength of saw dust reinforced polymer composites [9]. Besides, sawdust as a particulate filler showed higher flexural modulus in copolymer composites. The flexural modulus in composites is mainly a function of the modulus of individual components [10]. The reason might be that the flexural modulus of saw dust is considerably higher than PP and PE copolymer matrix. The main advantageous feature of wood sawdust is, as a natural particulate filler, it plays a vital role as the reinforcing element due to its low cost, low density, renewable resources, biodegradability and ecofriendly nature. As it is incorporated into PP:PE copolymer matrix, its hygroscopic nature enhances biodegradation of the fabricated composites after usage.

In case of nano clay addition into sawdust reinforced composites blend, Table 3 shows that the flexural strength and modulus values were enhanced respectively to 26.06 to 57.73 MPa and 1.62 to 1.86 GPa. Only 1% nano clay picked up the flexural strength of the designed composite material by 121.53%.

Generally, the filler particles tie polymer chain bundles together by filling interstitial voids, thereby restricting molecular movement or slippage on application of force [11-15]. At the same time, the filler particles assist in distributing any induced stress more equitably [12]. However, it is very important to note that the overall internal changes are favoured if the reinforcement particles are fine enough. Therefore, with finer size of filler clay particles, flexural properties gradually increased. Moreover, it is very difficult to avoid micron size void and gas bubble in the open air casting of polymeric materials. Addition of nano clay plays very positive roles in overcoming such unfavourable situation. Nano clay can enter into the micro voids, shrinkage or crack and decreases their stress concentration effects [6,11-13]. This reduction in stress concentration sensitivity in one side increases the flexural strength.

4. Conclusion

In this research work, copolymer of PP and PE was designed for a good combination of flexural properties. This copolymer was then used to develop biodegradable composites by adding natural fiber (wood saw dust) and nano clay. After detail experimental works, following final remarks are made from this work:

- Addition of PE into PP:PE copolymer blend gradually degrades its flexural properties. In this regards, 90PP-10PE provides a good combination of flexural strength and flexural modulus.
- Addition of wood saw dust into the designed copolymer matrix by 7 wt.% causes a very drastic decrease in flexural strength but a significant increase in flexural modulus.
- Addition of nano clay by 1 wt.% into the saw dust reinforced copolymer blend helped in regaining the lost flexural strength by 29.5% and elongation by 241% of the composite materials.

5. References

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