

# Flexure and impact properties of glass fiber reinforced nylon 6-polypropylene composites

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**Abstract.** In recent years, polymer composites are rapidly developing and replacing the metals or alloys in numerous engineering applications. These polymer composites are the topic of interests in industrial applications such as automotive and aerospace industries. In the present research study, glass fiber (GF) reinforced nylon 6 (PA6)-polypropylene (PP) composite specimens were prepared successfully using injection molding process. Test specimens of five different compositions such as, 70%PA6+30%PP, 65%PA6+30%PP+5%GF, 60%PA6+30%PP+10%GF, 55%PA6+30%PP+15%GF and 50%PA6+30%PP+20%GF were prepared. In the experiments, flexure and impact tests were carried out. The obtained results revealed that flexure and impact properties of the polymer composites were significantly influenced by the glass fiber content. Results showed that flexural strength is low for pure polymer blend and flexural strength of GF reinforced composite increases gradually with the increase in glass fiber content. Test results also revealed that the impact strength of 70%PA6+30%PP is the highest and 55%PA6+30%PP+15%GF composite shows moderate impact strength. On the other hand, 50%PA6+30%PP+20%GF composite shows low toughness or reduced impact strength.

## 1. Introduction

Polymers and their composites are gaining popularity in numerous engineering applications such as bearing material, gears, cams, wheels, rollers etc. for improved mechanical properties in relation to industrial requirements. The application of high performance polymer blend composites is a suitable alternative to conventional materials due to their high specific strength and stiffness. Polymer blends of different thermoplastics can be prepared and these polymer blends can be reinforced by different fibrous materials to enhance the mechanical properties. During the past decade, a number of research works were carried out to investigate the mechanical and tribological properties of different types of polymer composites [1-8]. The obtained results showed that the properties were significantly influenced by several operating conditions and the type of reinforced material.

Impact behaviour of E-glass fiber reinforced epoxy and polypropylene matrix composites was investigated and the obtained results show that the type of resin is an important parameter for the impact behaviour of the composites [9]. Flexural strength of polymethyl methacrylate (PMMA) resin reinforced with glass, aramid and nylon fibers were evaluated using 3-point bending test with universal testing machine [10]. The experimental data were compared with the flexural strength of pure PMMA resin and the comparison revealed that reinforced specimens showed better flexural strength than the conventional acrylic resin. Moreover, the specimens reinforced with glass fibers exhibited highest flexural strength, followed by the specimens reinforced with aramid and specimens reinforced with nylon showed the lowest flexural strength. Flexural properties of glass fiber reinforced polyamide 6-6 composites were investigated [11]. The obtained results showed that



flexural properties were significantly improved as the fiber content was increased whereas flexural properties were not much improved with the increase in fiber length.

Flexural strengths of epoxy resin based hybrid polymer composites were investigated using 3-point bending test for different thicknesses of the composites [12]. The obtained results revealed that bending strength of the composite was significantly influenced by the thickness of the composite and the grade of the epoxy resin. Mechanical properties of short glass fiber reinforced polyamide 66 and polypropylene (PA66/PP) thermoplastic blend composites were investigated [13]. It was found that flexure and impact strengths of the composites were significantly different as compared to the strengths of the PA66/PP pure polymer blend. Mechanical properties of glass and carbon fibre reinforced polymer composites were investigated at different strain rate conditions [14]. From the experimental data it was concluded that flexural strength of the composite was greatly influenced by the strain rate condition. In addition, experimental data revealed that impact strength of the carbon fiber reinforced polymer composite was much higher than that of glass fiber reinforced polymer composite. For pure nylon polymer, the injection parameters such as pressure, temperature, fill time etc. were theoretically investigated [15]. Mechanical properties of glass and carbon fiber reinforced with polyester resin composites were investigated [16]. The obtained results showed that flexure and impact properties of the composites were significantly influenced depending on the type of composite and percentage reinforcement. Tensile strength and impact strength of glass fiber reinforced nylon were examined and the obtained results revealed that tensile strength and impact strength are greatly influenced by glass fiber content [17].

Within this research, five different types of glass fiber (GF) reinforced nylon 6 (PA6)-polypropylene (PP) composite specimens were prepared successfully using injection molding machine. The effects of glass fiber content on the flexure and impact properties of the composites were investigated.

## 2. Experimental

Using injection molding process, dog bone shaped specimens of five different compositions such as 70%PA6+30%PP, 65%PA6+30%PP+5%GF, 60%PA6+30%PP+10%GF, 55%PA6+30%PP+15%GF and 50%PA6+30%PP+20%GF were prepared according to ASTM D638 standard. During injection process, suitable process parameters were selected in producing successful specimens. During processing of the molded specimens, the temperature was controlled according to the type of specimen of different compositions in order to fabricate defect free specimens. Flexural tests of glass fiber reinforced nylon 6-polypropylene composites were carried out to investigate the important mechanical properties such as, flexural modulus, flexural yield strength, flexural strength and flexural strain. Three point flexural tests of the composite specimens were carried out using universal test machine Instron (model:3369, maximum load capacity: 50KN) and followed ASTM D790 standard. All the flexure tests were carried out under cross-head speed of 2 mm/min. Impact tests of the composite specimens were carried out to determine the energy absorbed in fracturing the specimens. Impact tests were carried out by using Instron CEAST 9050 Impact Pendulum-Izod Impact (Unnotched) according to ASTM D4812 standard for different types of polymer composites. For impact tests, the hammer energy of 11J was used and 4 N.m torque was applied during the test.

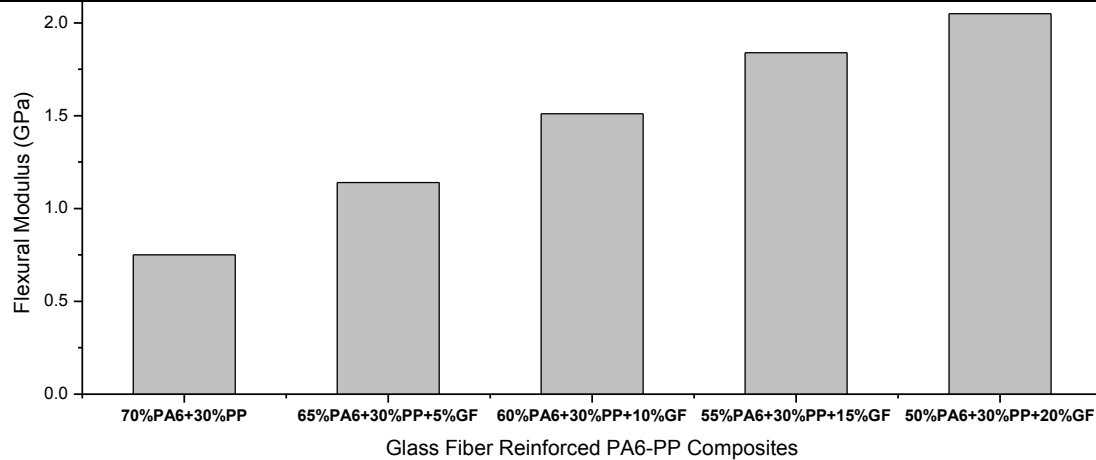
## 3. Results and Discussion

The flexural modulus of different compositions of glass fiber reinforced PA6-PP composites is shown in figure 1. Flexural modulus is a measure of the stiffness of the glass fiber reinforced PA6-PP composites. The experiments were performed under a cross-head speed of 2mm/min. The data generated by flexure stress-strain curves during the test is shown in Table 1. From figure 1 below, 70%PA6+30%PP neat polymer blend shows a low flexural modulus of 0.75 GPa. The 65%PA6+30%PP+5%GF composite shows an increased modulus of 1.14 GPa which is 52% higher in comparison with neat polymer blend. The 60%PA6+30%PP+10%GF composite reveals an increased modulus of 1.51 GPa which is about 101% higher than that of neat polymer blend. The flexural modulus of 55%PA6+30%PP+15%GF composite was recorded 1.84 GPa which is about 145% higher in comparison with neat PA6-PP blend. Finally, 50%PA6+30%PP+20%GF composite shows a further increased flexure modulus of 2.05 GPa which is nearly 173% higher in comparison with neat PA6-PP.

This proves that the composite shows higher resistance to deformation due to increased glass fiber content, hence in turn increases the stiffness of the PA6-PP-GF composite under flexure loading.

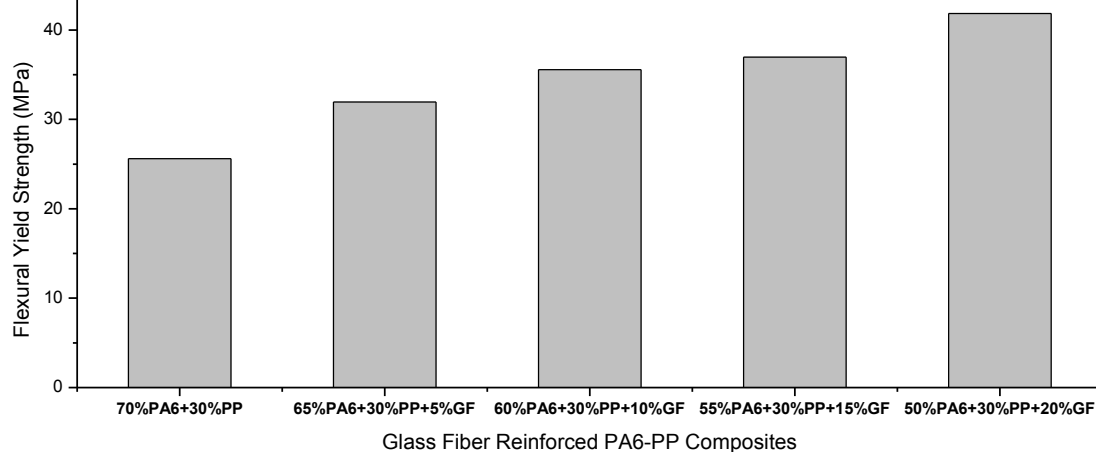
**Table 1.** Flexure test results of polymer blend composites.

Strain rate: 2 mm/min				
Specimen composition	Flexural modulus [GPa]	Flexural yield strength [MPa]	Flexural strength [MPa]	Flexural strain [%]
70%PA6+30%PP	0.75	25.62	26.07	7.20
65%PA6+30%PP+5%GF	1.14	31.95	32.17	5.81
60%PA6+30%PP+10%GF	1.51	35.58	36.11	4.38
55%PA6+30%PP+15%GF	1.84	36.96	37.24	3.50
50%PA6+30%PP+20%GF	2.05	41.84	42.61	3.53



**Figure 1.** The flexural modulus of different compositions of glass fiber reinforced nylon 6-polypropylene composites.

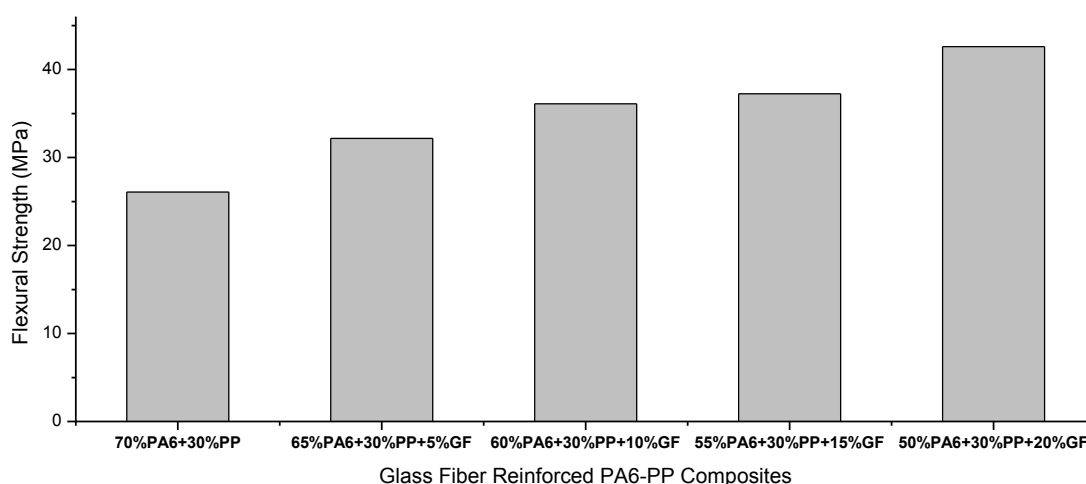
The flexural yield strength (offset 0.2%) of glass fiber reinforced nylon 6-polypropylene composite is shown in figure 2. The obtained results revealed that the plastic deformation of 70%PA6+30%PP pure polymer blend started at low stress level of 25.62 MPa. Yielding of 65%PA6+30%PP+5%GF composite started at higher stress level of 31.95 MPa which is about 25% higher than PA6-PP blend. The 60%PA6+30%PP+10%GF composite showed increased yield stress level of 35.58 MPa which is almost 39% higher than the neat blend. For further increase of glass fiber



**Figure 2.** The flexural yield strength (MPa) of different compositions of glass fiber reinforced nylon 6-polypropylene composites.

content to 15%, the flexural yield strength of the composite slightly increases to 36.96 MPa which is 44% higher than that of neat blend. Finally, 50%PA6+30%PP+20%GF composite showed an improved value of flexural yield strength of 41.84 MPa which is nearly 63% higher than the neat blend. It is apparent that the plastic behavior of the blend composite started at higher stress level with the increase in glass fiber content.

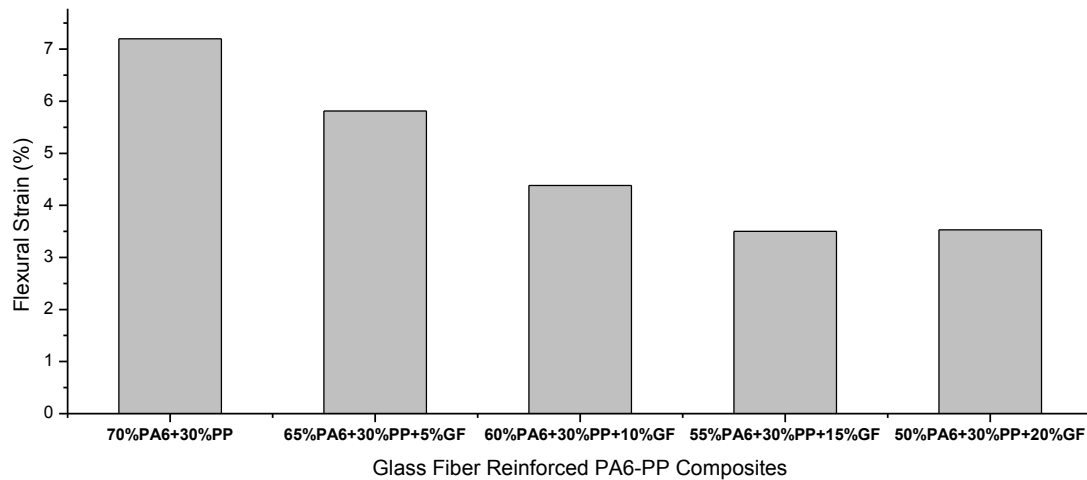
The flexural strength of glass fiber reinforced PA6-PP composite is shown in figure 3. Flexural strength is defined as the maximum stress at the outermost fiber on tension side of the specimen under a strain rate of 2 mm/min. The obtained result shows that flexure strength of 70%PA6+30%PP neat polymer blend is 26.07 MPa. The 65%PA6+30%PP+5%GF composite shows the strength of 32.17 MPa which is 23.4% higher than neat polymer blend. Flexure strength of 60%PA6+30%PP+10%GF composite is 36.11 MPa which is nearly 38.5% higher in comparison with neat polymer blend. For 55%PA6+30%PP+15%GF composite, the flexure strength is slightly improved to 37.24 MPa. Lastly, 50%PA6+30%PP+20%GF composite shows further improved strength of 42.61 MPa which is about 63.4% higher in comparison with neat polymer blend. From the obtained results, it is apparent that flexure strength of the composite improves gradually with the increase in glass fiber content.



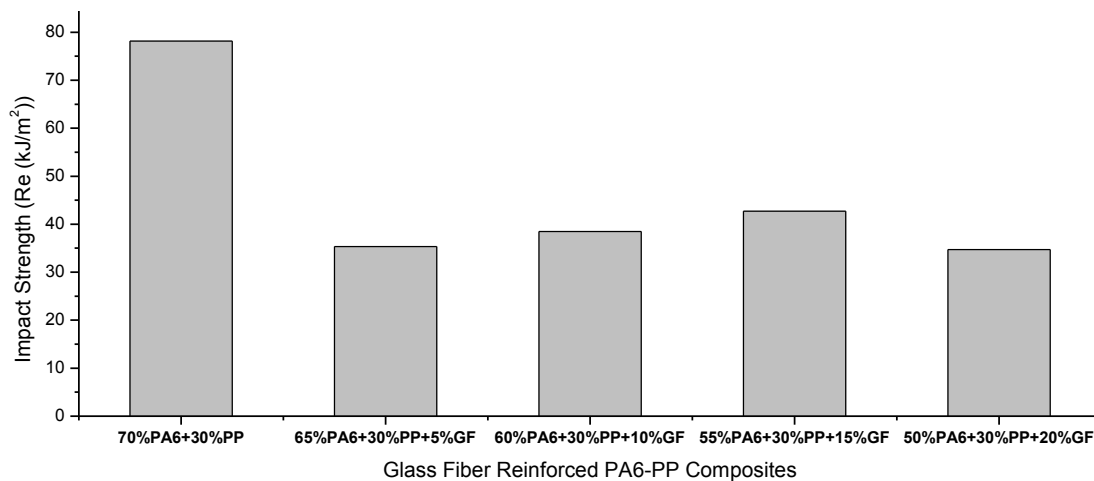
**Figure 3.** The flexural strength of different compositions of glass fiber reinforced nylon 6-polypropylene composites.

Figure 4 shows the flexural strain at break for different compositions of glass fiber reinforced nylon 6-polypropylene composites. The composite specimen showed this unit deformation (%) at the outermost surface before failure occurred under a strain rate of 2 mm/min. The obtained results show that PA6-PP polymer blend experiences a plastic deformation by absorbing high energy after it reaches to yield point and in this case the flexure strain is 7.20%. The results also show that for the fiber content of 5%, 10%, 15%, and 20%, the composite experiences the strain 5.81%, 4.38%, 3.50% and 3.53% respectively. This shows that in general, the flexure deformation gradually decreases as the glass fiber content increases.

The impact strength of glass fiber reinforced PA6-PP composite is shown in figure 5. All the impact tests were carried out under an applied torque 4 N.m and the hammer energy of 11 J was used. From the obtained results, pure polymer blend 70%PA6+30%PP shows significantly high impact strength of 78.17 kJ/m<sup>2</sup>. On the other hand, all the composites show reduced impact strength. The impact strength of 65%PA6+30%PP+5%GF composite is 35.33 kJ/m<sup>2</sup> which is much lower than that of neat polymer blend. The impact strength of the composite is improved to 38.50 kJ/m<sup>2</sup> when the glass fiber content is increased to 10%. For 55%PA6+30%PP+15%GF composite, the impact strength is further improved to 42.73 kJ/m<sup>2</sup>. It can be noticed that for the glass fiber content 20%, the impact strength of the composite is decreased to 34.70 kJ/m<sup>2</sup>. It is believed that due to the increase in the glass fiber content from 15% to 20%, the polymer blend composite behaves as ductile to brittle transition which results in reducing the impact toughness [17].



**Figure 4.** The flexural strain (%) of different compositions of glass fiber reinforced nylon 6-polypropylene composites



**Figure 5.** The impact strength, Re (kJ/m<sup>2</sup>) of different compositions of glass fiber reinforced nylon 6-polypropylene composites (Torque: 4 N.m)

#### 4. Conclusions

Within this research, five different types of glass fiber reinforced nylon 6-polypropylene thermoplastic blend composites were successfully prepared. The effects of glass fiber content on flexural and impact properties of the composites were investigated. The main conclusions are:

1. The flexural modulus of 70%PA6+30%PP pure polymer blend is the lowest whereas the polymer composite shows increased modulus as the glass fiber content is increased and 50%PA6+30%PP+20%GF composite shows significantly high modulus.
2. Flexural yield strength of pure polymer blend is the lowest and it increases gradually for the polymer composite as the glass fiber content increases. Flexural strength of pure polymer blend shows the lowest value but it improves gradually with the increased glass fiber content.
3. Pure polymer blend shows the highest impact strength and all the composites show reduced impact strength. It is noticed that 50%PA6+30%PP+20%GF composite shows the lowest impact strength.

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