Experimental investigation on flexure and impact properties of injection molded polypropylene-nylon 6-glass fiber polymer composites

D M Nuruzzaman[1]**, N M Kusaseh**[2]**, M A Chowdhury**[3]**, N A N A Rahman**[2]**, A N Oumer**[4]**, N Fatchurrohman**[2]**, A K M A Iqbal**[2] **and N M Ismail**[2]

[1,2] Faculty of Manufacturing Engineering, University Malaysia Pahang, 26600 Pekan, Pahang Darul Makmur, Malaysia.
[3] Department of Mechanical Engineering, Dhaka University of Engineering and Technology, Gazipur, Gazipur 1700, Bangladesh.
[4] Faculty of Mechanical Engineering, University Malaysia Pahang, 26600 Pekan, Pahang Darul Makmur, Malaysia.

[1] E-mail: dewan052005@yahoo.com

Abstract. In this research study, glass fiber (GF) reinforced polypropylene (PP)-nylon 6 (PA6) polymer blend composites were prepared using injection molding process. Specimens of four different compositions such as 80%PP+20%PA6, 80%PP+18%PA6+2%GF, 80%PP+16%PA6+4%GF and 80%PP+14%PA6+6%GF were prepared. In the injection molding process, suitable process parameters were selected depending on the type of composite specimen in producing defects free dog bone shaped specimens. Flexure and impact tests were carried out according to ASTM standard. The important flexure properties such as flexural modulus, flexural yield strength, flexural strength and flexural strain were investigated. The obtained results revealed that flexural modulus of 80%PP+20%PA6 polymer blend is the lowest and the polymer blend composite shows steadily improved modulus as the glass fiber content is increased. Results also showed that flexural strength of pure polymer blend is the lowest but it improves gradually when the glass fiber content is increased. Impact test results revealed that impact strength of 80%PP+20%PA6 polymer blend is the highest whereas all the composites show reduced impact strength or toughness. It is noticed that 80%PP+14%PA6+6%GF composite exhibits the lowest impact strength.

1. Introduction

The applications of polymer blend composites for different engineering components are gaining popularity according to industrial requirements. These polymer blend composites are suitable replacement for conventional materials due to high strength and stiffness. In order to enhance the mechanical properties, different thermoplastic polymer blends can be reinforced by different types fibrous materials. In processing of fiber reinforced polymer composites, different manufacturing techniques are suitable depending on the type of polymer composite [1]. In the past decade, research works were carried out on different types of fiber reinforced polymer composites to investigate different mechanical and tribological properties [2-8]. From these investigations, the obtained results revealed that properties of the composites were influenced by a number of operating parameters, types of matrix and reinforced materials.

Flexural properties of injection molded glass fiber reinforced nylon 6-6 composites were investigated under different operating conditions [9]. Results showed that flexural properties were remarkably improved due to the increase in fiber loading whereas the properties were not much

improved due to the increase in fiber length. Polypropylene and epoxy matrix composites reinforced by the E-glass fiber were fabricated and the impact properties of these composites were analyzed [10]. It was found that type of resin is an influential parameter affecting the impact performance of the composites. Fiber reinforced polymer composites were fabricated and the mechanical properties of the composites were investigated under different strain rate conditions [11]. The experimental data revealed that flexural strength of the composites was remarkably influenced by the application of different strain rates. Moreover, it was noticed that impact strength of the composite was varied depending on the type of fiber reinforcement. Using a 3-point bending test, flexural strengths of hybrid polymer composites were investigated for different thicknesses of composites [12]. It was found that the strength of the composite was markedly influenced by the thickness of composite. Research works were carried out to investigate the mechanical properties of PA66-PP blend composites reinforced by glass fiber [13]. Results showed that flexure and impact properties of PA66-PP blend composites were much different from that of pure PA66-PP blend.

Research works were carried out to investigate the tensile properties of glass fiber reinforced nylon [14]. The experimental data showed that tensile modulus, yield strength, tensile strength and tensile strain were remarkably influenced by the glass fiber content. The impact strength of the nylon composite was also examined in this study. It was apparent that the percentage of glass fiber content has notable effect on the impact strength of the composite. The injection parameters such as pressure distribution, temperature at flow front, fill time etc. were theoretically analyzed for nylon polymer [15]. Carbon and glass fiber reinforced polyester resin composites were fabricated and mechanical properties were analysed [16]. Based on the experimental data, it was concluded that impact and flexure strengths of these composites were remarkably influenced by the percentage reinforcement and the type of composite.

In the present research study, four different types glass fiber (GF) reinforced polypropylene (PP)-nylon 6 (PA6) polymer blend composites were successfully prepared using injection molding process. Flexure and impact properties of these composites were investigated and the effects of glass fiber content on these properties were analysed.

2. Experimental
Using an injection molding machine (NISSEI PNX 60), dog bone shaped specimens of four different compositions such as 80%PP+20%PA6, 80%PP+18%PA6+2%GF, 80%PP+16%PA6+4%GF and 80%PP+14%PA6+6%GF were prepared. The specimens were prepared following ASTM D638 standard. During the injection molding process, suitable process parameters such as melting temperature, injection pressure etc. were selected depending on the type of composite specimen in producing defect-free dog bone shaped specimens. Three point flexural tests were carried out to investigate the mechanical properties of the composite specimens. The flexure tests were carried out using universal test machine Instron (model:3369, maximum load capacity: 50KN) under a crosshead speed of 4 mm/min. All the tests were carried out following ASTM D790 standard. The test results such as flexural yield strength, flexural strength, flexural modulus and flexural strain were generated using Bluehill 2 software. In order to determine the impact strength for different types of composite specimens, impact tests were carried out using an impact pendulum Instron CEAST 9050. Izod impact tests (unnotched) were carried out according to ASTM D4812 standard for different types of composite specimens. During each impact test, a torque of 5 N.m was applied for holding the specimen with the impact fixture. For all the composite specimens, the hammer energy of 11J was applied in order to quantify the impact strength of the composite.

3. Results and Discussion
The flexural test results for different compositions of glass fiber reinforced PP-PA6 polymer blend composites are shown in Figure 1. These results were generated by the test machine using Bluehill 2 software. The tests were carried out under a crosshead speed of 4 mm/min for all the composite specimens. From the flexural stress-flexural strain diagrams as shown below for different types of composites, the obtained important parameters such as flexural modulus, flexural yield strength, flexural strength and flexural strain are discussed in the following sections.
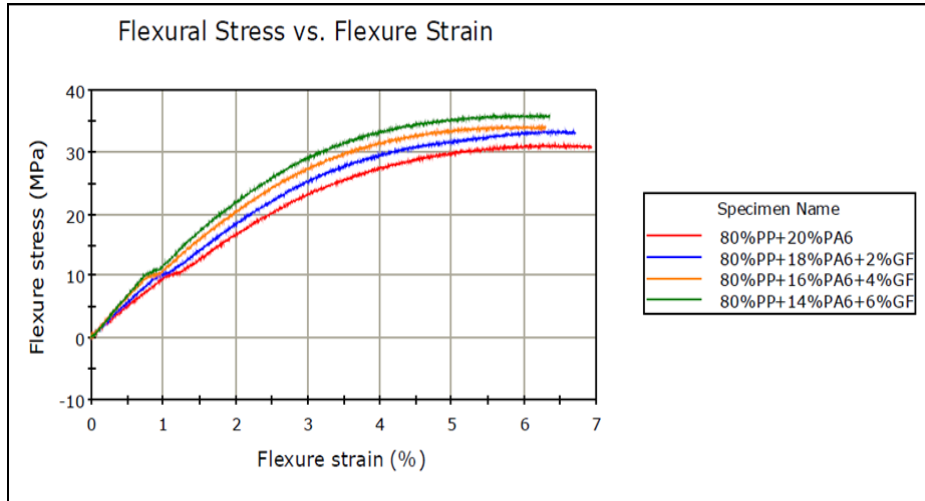
Figure 1. Flexural stress - flexural strain diagrams of glass fiber reinforced PP-PA6 polymer blend composites.

Figure 2 shows the flexural modulus of glass fiber reinforced PP-PA6 polymer blend composites of different compositions. Flexural modulus or bending modulus is the measure of stiffness of the composite to bending deformation. From the figure below, it can be seen that 80%PP+20%PA6 polymer blend exhibits a low flexural modulus of 0.93 GPa. The obtained results show that due to the addition of glass fiber, 80%PP+18%PA6+2%GF composite shows slightly improved modulus of 1.01 GPa which is 8.60% higher in comparison with the modulus of pure polymer blend. The 80%PP+16%PA6+4%GF composite reveals further improved modulus of 1.10 GPa which is 18.28% higher than that of neat polymer blend. Finally, the composite 80%PP+14%PA6+6%GF shows a further increased flexure modulus of 1.24 GPa which is 33.33% higher in comparison with neat PP-PA6. From these results, it is apparent that due to the increased glass fiber content, the stiffness of the composite increases gradually under flexure loading, which means that more resistance to bending deformation as the content of glass fiber increases.
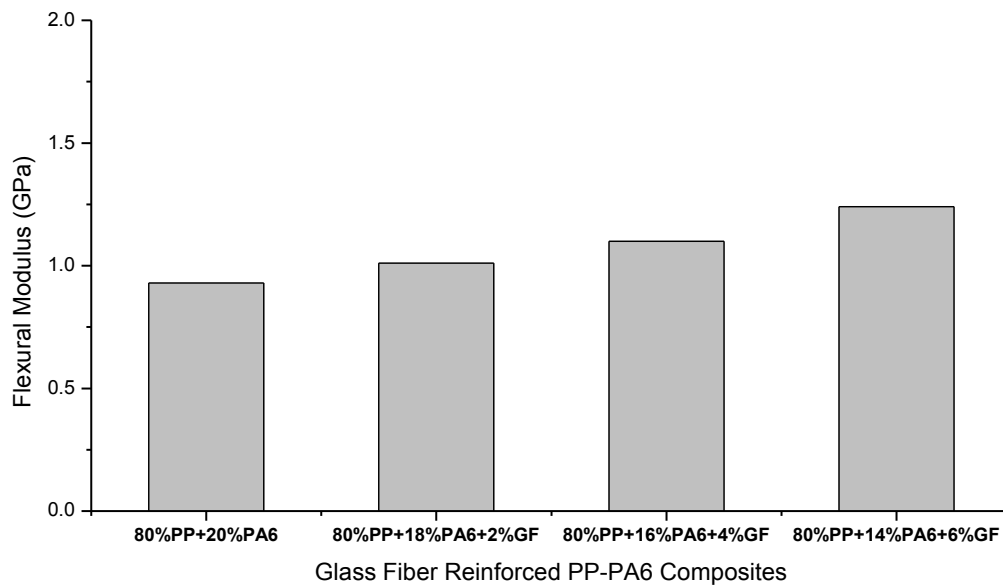

Figure 2. The flexural modulus of glass fiber reinforced polypropylene-nylon 6 composites.

Figure 3 shows the flexural yield strength (offset 0.2%) for different compositions of glass fiber reinforced polypropylene-nylon 6 composites. From the obtained results it was found that beyond the elastic limit, permanent deformation of 80%PP+20%PA6 neat polymer blend took place at low stress level of 30.83 MPa. The obtained data also revealed that plastic deformation of 80%PP+18%PA6+2%GF composite started at 33.20 MPa which is about 7.69% higher than the yield strength of PP-PA6 polymer blend. For 80%PP+16%PA6+4%GF composite, yielding started at slightly higher stress level of 33.92 MPa which is about 10% higher than that of neat polymer blend. Finally, for the 80%PP+14%PA6+6%GF composite, the result showed an improved value of yield strength 35.46 MPa which is almost 15% higher than the yield strength of pure polymer blend. From these results, it is very clear that due to the increased glass fiber content, plastic or nonlinear deformation of the composite started at little higher stress level.
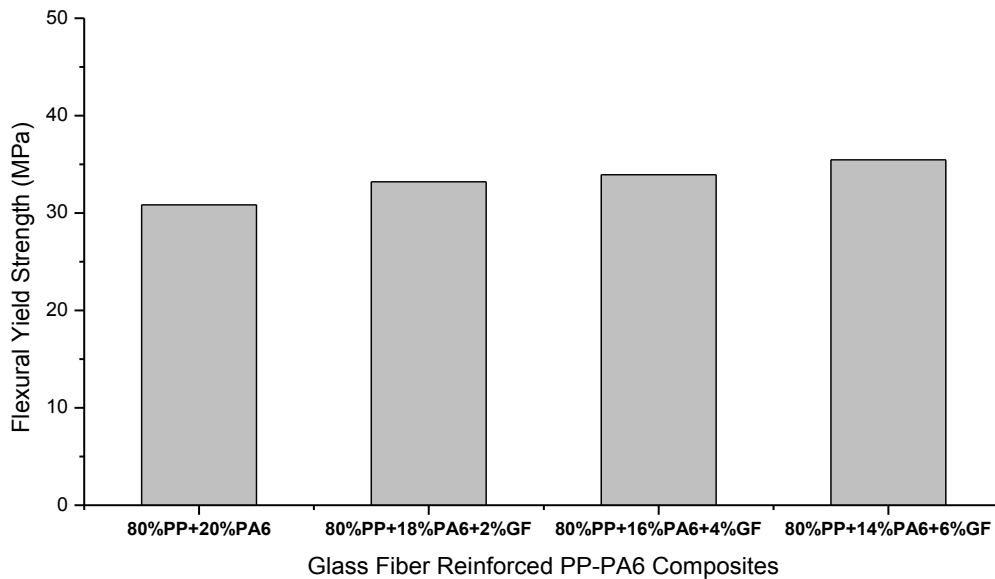

Figure 3. The flexural yield strength (MPa) of glass fiber reinforced polypropylene-nylon 6 composites.

Figure 4 shows the three point bending strength or flexural strength of PP-PA6-GF composites. This strength is the highest stress experienced by the composite specimen at extreme fibers on the tension side of the composite. The obtained result shows that maximum flexural strength of 80%PP+20%PA6 polymer blend is 31.40 MPa. The 80%PP+18%PA6+2%GF composite shows the strength of 33.57 MPa which is 6.9% higher than the pure polymer blend. Flexural strength of 80%PP+16%PA6+4%GF composite is 34.33 MPa which is 9.3% higher as compared with that of pure polymer blend. Lastly, 80%PP+14%PA6+6%GF composite shows a further improved flexural strength of 36.13 MPa which is about 15% higher as compared with that of neat polymer blend. From these experimental results, it is evident that there is a steady improvement in the flexure strength due to the increase in glass fiber content.

Figure 5 exhibits the flexural strain of glass fiber reinforced polypropylene-nylon 6 blend composites. In the experiments, this was the unit deformation (%) at the furthest layer of the composite specimen under a crosshead speed of 4 mm/min. The obtained results reveal that PP-PA6 pure polymer blend undergoes a plastic deformation after reaching the yield point and absorbs much energy. In this case, the flexural strain at break is 6.92%. The obtained results also reveal that for the glass fiber content of 2%, 4% and 6%, the composite experiences the flexural strain 6.70%, 6.29% and 6.34% respectively. These results generally indicate that flexural deformations are nearly equal for different types of composites and not much influenced by the content of glass fiber up to 6%.
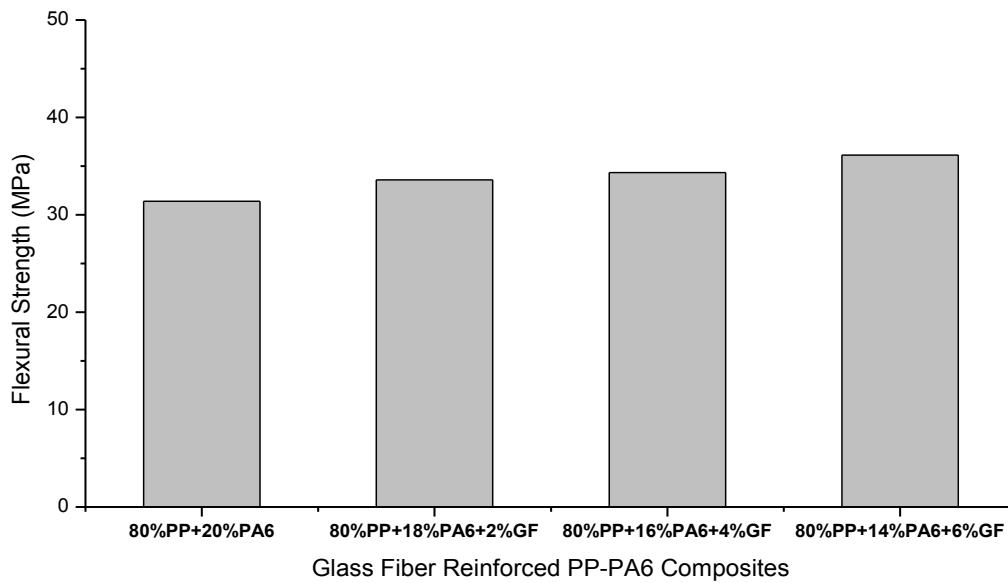
Figure 4. The flexural strength of glass fiber reinforced polypropylene-nylon 6 composites.
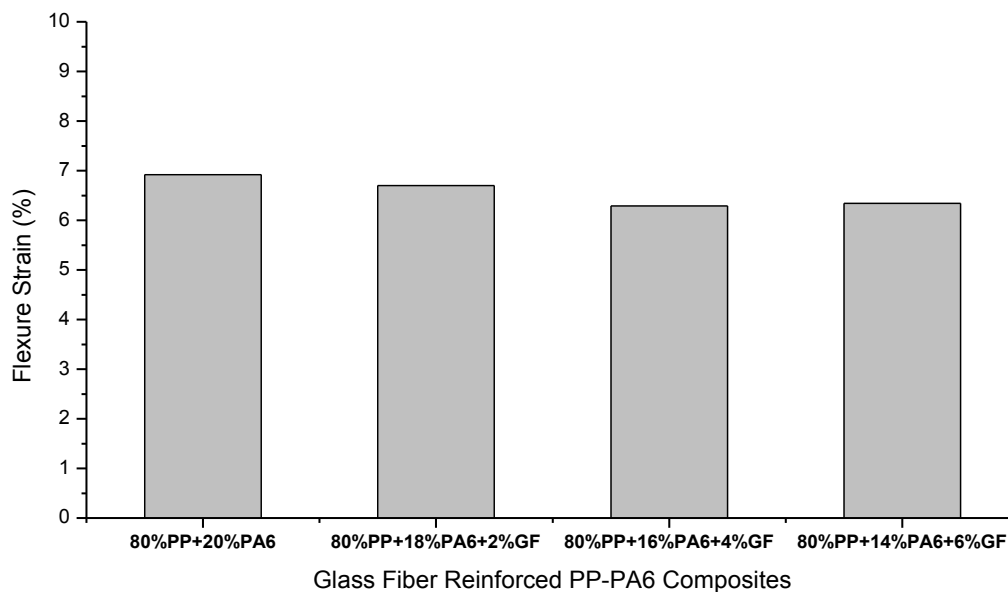

Figure 5. The flexural strain (%) of glass fiber reinforced polypropylene-nylon 6 composites.

Figure 6 shows the impact strength of glass fiber reinforced PP-PA6 blend composites. In the experiments, impact tests were carried out using an applied torque 5 N.m to the specimens. Moreover, the hammer energy of 11 J was applied in order to break the composite specimens. From the obtained results, neat polymer blend 80%PP+20%PA6 shows the impact strength of 25.10 kJ/m^2. The 80%PP+18%PA6+2%GF composite shows a reduced impact strength of 22.80 kJ/m^2 than that of pure polymer blend. For the 80%PP+16%PA6+4%GF composite, the impact strength is again reduced to 22.33 kJ/m^2 when the glass fiber content is increased to 4%. Finally, it can be noticed that the impact strength of the composite is further decreased to 19.81 kJ/m^2 when the fiber content is 6%. From these results, it is obvious that the impact toughness of the composite gradually decreases due to the increase in the glass fiber content.
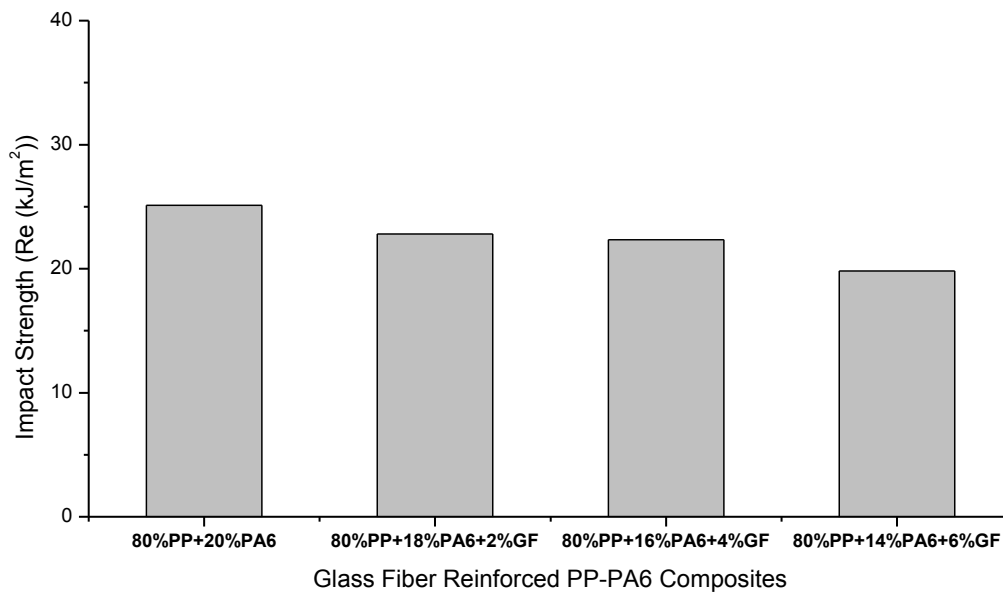
Figure 6. The impact strength, Re (kJ/m^2) of glass fiber reinforced polypropylene-nylon 6 composites (Torque: 5 N.m).

4. Conclusions

In this research, glass fiber reinforced polypropylene-nylon 6 polymer blend composites of different compositions were successfully prepared using injection molding process. Flexural and impact properties of these composites were investigated. The following conclusions are drawn:

1. The flexural modulus of 80%PP+20%PA6 polymer blend is the lowest and the polymer blend composite shows steadily improved modulus as the glass fiber content increases up to 6%.
2. Flexural yield strength of 80%PP+20%PA6 polymer blend is the lowest and it increases steadily for the blend composite as the glass fiber content is increased. The flexural strength of pure polymer blend is the lowest but it improves gradually when the glass fiber content is increased up to 6%.
3. The impact strength of 80%PP+20%PA6 polymer blend is the highest whereas all the composites show a little reduced impact strength. It is noticed that 80%PP+14%PA6+6%GF composite exhibits the lowest impact strength or toughness**.**

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