MECHANICAL PROPERTIES OF HYBRID BASALT-CARBON FIBER-FILLED RECYCLED POLYPROPYLENE AND POLYAMIDE 6 COMPOSITES

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Abstract

This paper presents results of a study examining novel hybrid recycled polypropylene and polyamide 6 composites using a combination of basalt fibers (BF) and carbon fibers (CF) for potential use in automobile applications. The composites were compounded using a laboratory scale co-rotating extrusion system, and test samples were prepared by injection molding tensile, flexure and impact test specimens. The tensile and flexural properties of the hybrid composites were determined using an Instron testing machine and the Izod impact strength was determined on Ceast Impact tester. Density measurements were made on the resulting composites. The thermoplastic composites made using basalt fibers and carbon fibers were evaluated for their material properties and compared to the properties of composite samples reinforced by glass fibers. Both of the two fibers (CF and BF) significantly increased mechanical properties and the blends of two fibers showed similar trends increasing mechanical fibers. Carbon fiber appears to be superior to BF in enhancing material property improvements which were found to be greater in the PA6 than in PP samples.

Background

Research and development activities exploring the use of hybrid fillers in combination with recycled thermoplastics is gaining attention in automobile applications (Gardner et al. 2016; Koronis et al. 2013; Jawaid et al. 2011). The use of recycled materials offers the opportunity to reduce the carbon footprint and provides a sustainable way to create useful composite materials for the automobile technology sector. The typical synthetic fibers used in automotive composites include glass and carbon fibers. There has also been interest in exploring the use of basalt (volcanic glass) fibers in thermoplastic composites (Czigány 2005). Basalt fiber has been known as a reinforcing additive since its discovery in 1923. The fiber was extensively used in military defense and aeronautical applications during World War II by the US, Europe, and the Soviet Union (Ross 2006; Colombo et al 2012; Pavlovski et al. 2007). The advantages of Basalt fibers are high thermal stability, low thermal conductivity, low heat storage, good resistance to corrosive media, high elastic modulus, and high hardness/wear resistance.

Scope and Objectives

This paper reports on feasibility of creating hybrid composites using basalt fibers and carbon fibers in recycled polypropylene and recycled polyamide 6 for automobile applications. The goal of this project is to explore the feasibility of the hybrid composites by comparisons of the mechanical properties to polymer matrix composite materials currently used in industry. Several formulations of hybrid composites were prepared, compounded, and molded into ASTM standard specimens for material property characterization.

Materials and Methods

The Basalt fibers were supplied from Mafic Black Basalt Ltd, Ireland. The polymer matrices in this study included a grade of recycled polypropylene (RPP) and recycled polyamide 6 (RPA6). The RPP and RPA 6 were selected from grades for general extrusion supplied from The Materials Group, Rockford, MI.

The basalt fibers, carbon fibers and basalt/carbon fiber combinations were compounded with either RPP or RPA 6 using a lab-scale twin-screw extrusion system (CW Brabender Instruments Inc., Hackensack, NJ, USA). Table 1 shows the formulations of the control and hybrid composite samples. All compounds were dried again at 205°C for 4 hours and injected molded into flexural, tensile, or impact testing specimens using a lab mini-injector.

Table 1. Major formulations for this study.

Group Name	***Matrix***	***Additives***	***Loading level***	***Note***
PP	PP	-	-	Plastic control
PA6	PA6	-	-	Plastic control
PP30CF	PP	Recycled Carbon Fiber (CF)	30	Composite control
PA630CF	PA6	Recycled Carbon Fiber (CF)	30	Composite control
PP20CF	PP	Recycled Carbon Fiber (CF)	20	Composite control
PA620CF	PA6	Recycled Carbon Fiber (CF)	20	Composite control
PP30BF	PP	Basalt fiber(BF)	30	Composite control
PA630BF	PA6	Basalt fiber(BF)	30	Composite control
PP20BF	PP	Basalt fiber(BF)	20	Composite control
PA620BF	PA6	Basalt fiber(BF)	20	Composite control
PP10BF10CF	PP	BF:CF	10%:10%	Hybrid of CF and BF
PP15BF15CF	PP	BF:CF	15%:15%	Hybrid of CF and BF
PP20BF10CF	PP	BF:CF	20%:10%	Hybrid of CF and BF
PA610BF10CF	PA6	BF:CF	10%:10%	Hybrid of CF and BF
PA615BF15CF	PA6	BF:CF	15%:15%	Hybrid of CF and BF
PA620BF10CF	PA6	BF:CF	20%:10%	Hybrid of CF and BF

The testing was performed according to ASTM D790, D638, and D256 for flexural, tensile, and impact properties, respectively. Density measurements of the composites were also measured.

Results and Discussion

Tensile properties of the composite samples are shown in Figures 1 to 4. The addition of CF and BF increases both modulus of elasticity and strength. The increases are clearer in the samples filled with CF [Fig 1] and made using the PA6 matrix [Fig 2]. The reinforcing effects of CF/BF with the PP matrix, however, were not dramatically clear regarding tensile strength while the samples with PA6 were.

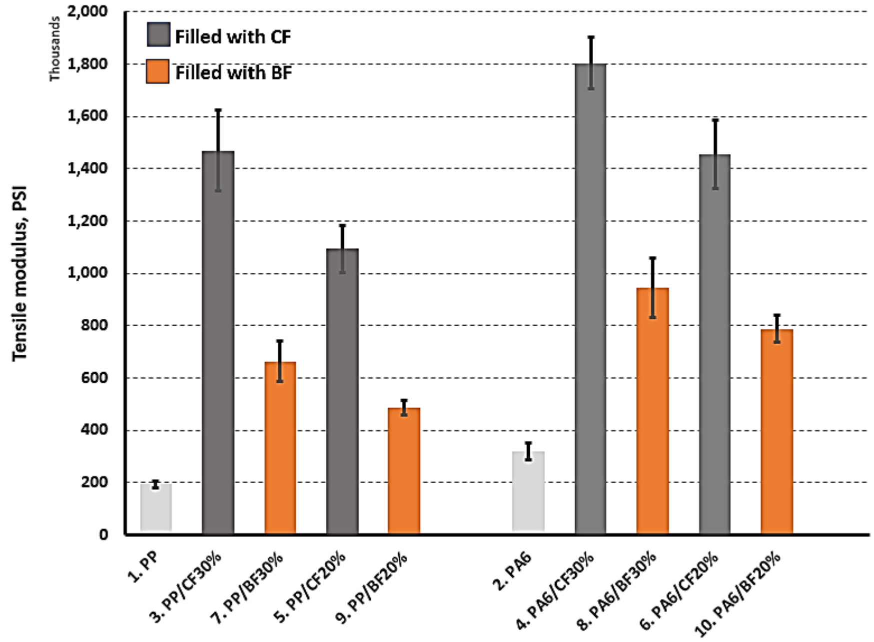

Figure 1. Tensile modulus of elasticity of the samples.

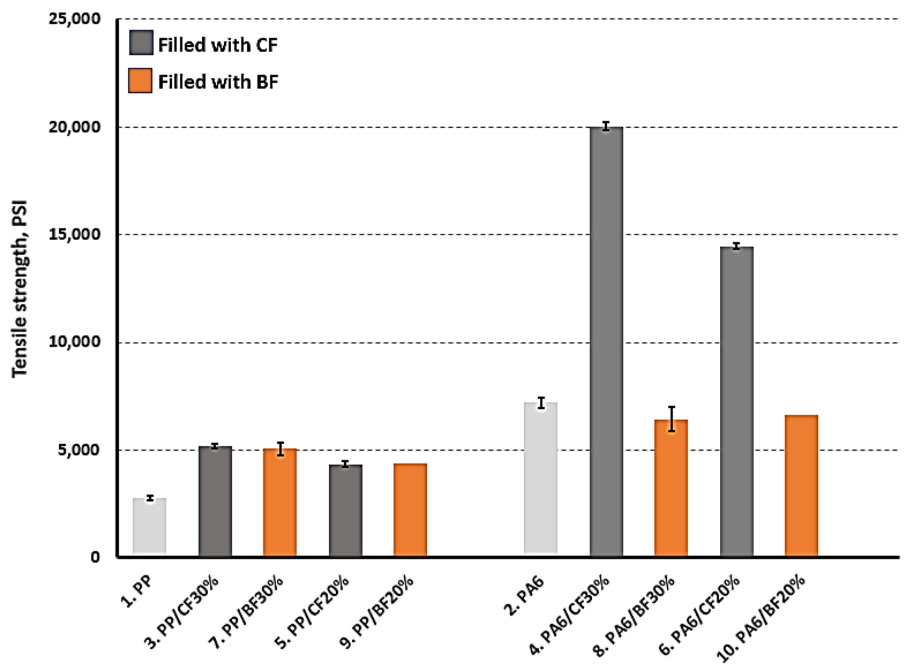

Figure 2. Tensile strength of the samples.

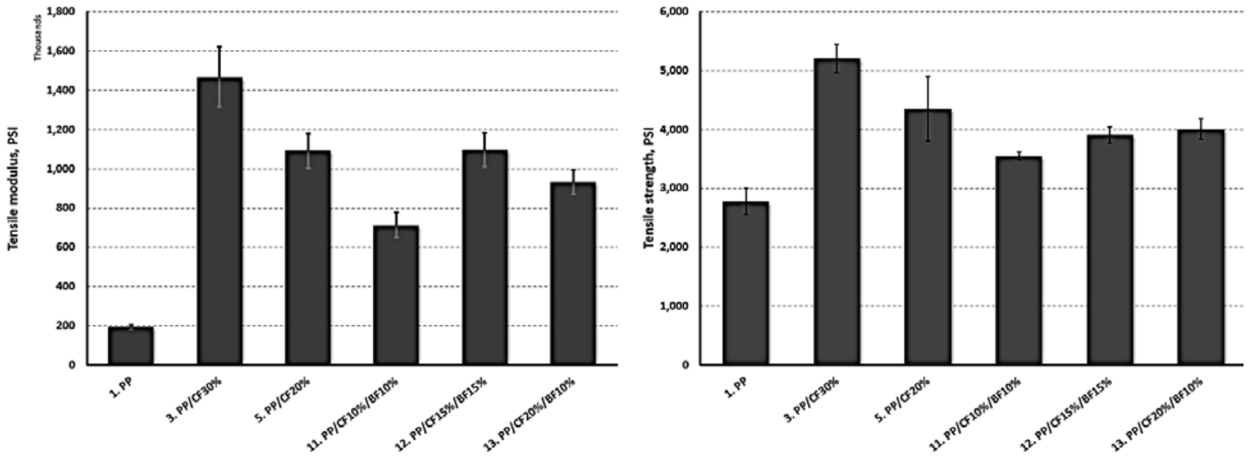

Figure 3. Tensile modulus of elasticity and strength of samples made using the PP matrix.

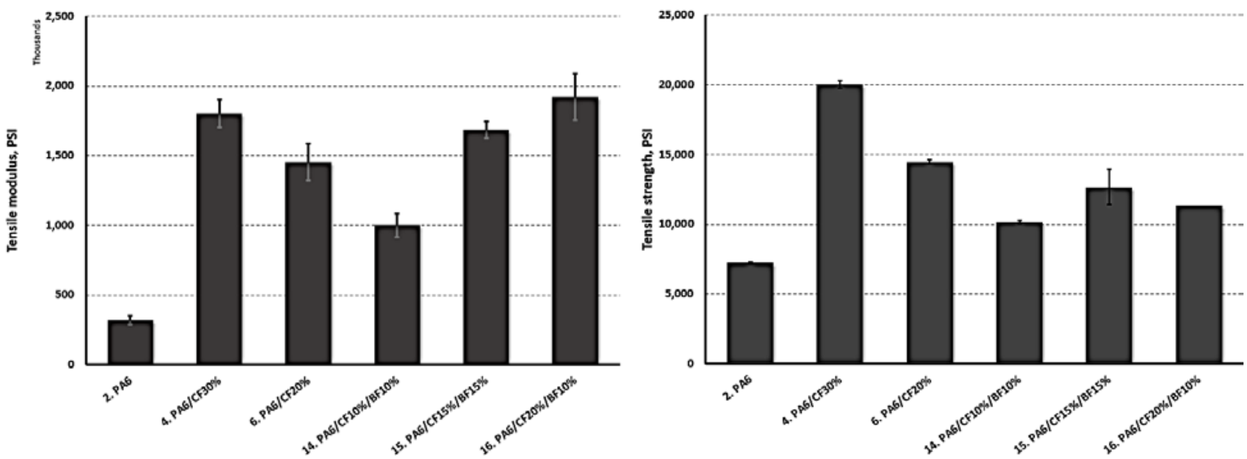

Figure 4. Tensile modulus of elasticity and strength of samples made using the PA6 matrix.

It was observed that the tensile properties of the samples, where CF is partially replaced with BF, were slightly lower in tensile properties. It implies that BF may not be a suitable alternative to CF in PP- or PA6 composites. It is, however, worthwhile to consider the use of BF as an alternatives because of its lower cost since the properties are still much higher than the pure PP samples.

Flexural properties of the samples are shown in Figures 5 to 8. The results of flexural properties show similar trends compared to the tensile property results. The reinforcing effects of CF are clearer than the samples containing BF [Figures 5 & 6]. The addition of BF in PP composite samples shows similar improvements of flexural strength compared to the CF addition [Figure 6]. Even though BF does not improve the properties to the extent that CF does, a partial replacement of CF with BF sustains the original flexural strength of the PP composite samples, which shows the potential of BF as an alternative for CF [Figure 7].

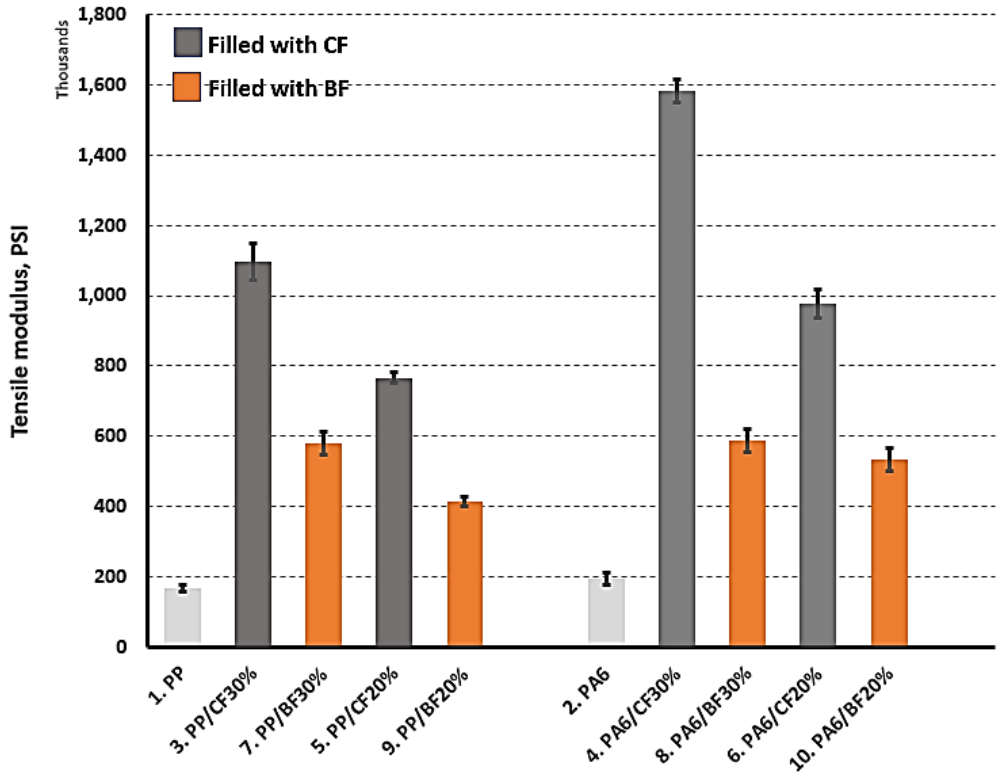

Figure 5. Flexural modulus of elasticity of composite samples filled with CF & BF.

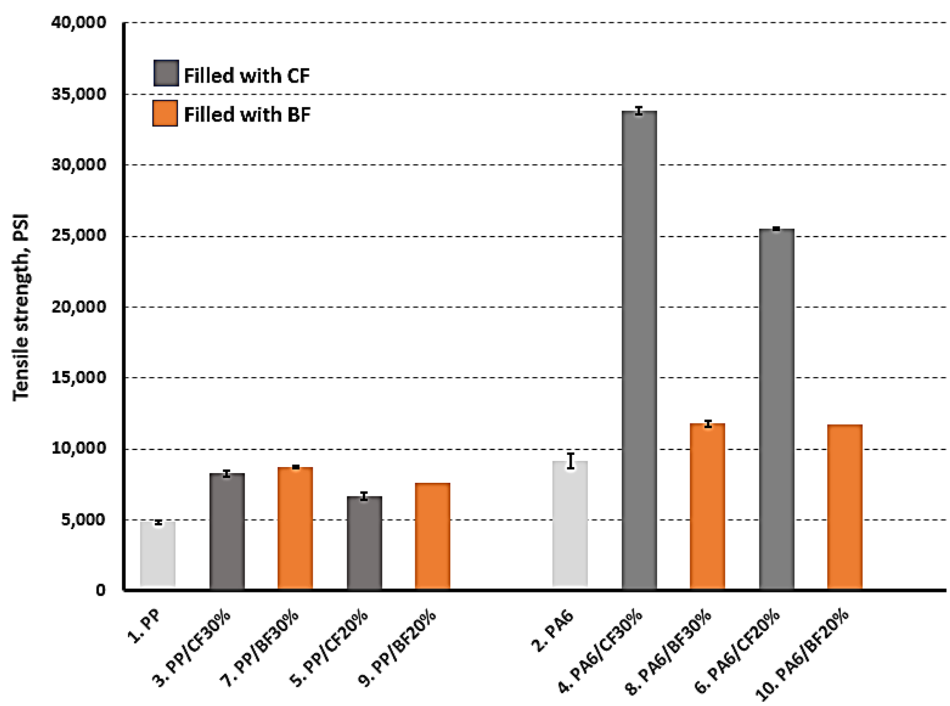

Figure 6. Flexural strength of composite samples filled with CF & BF.

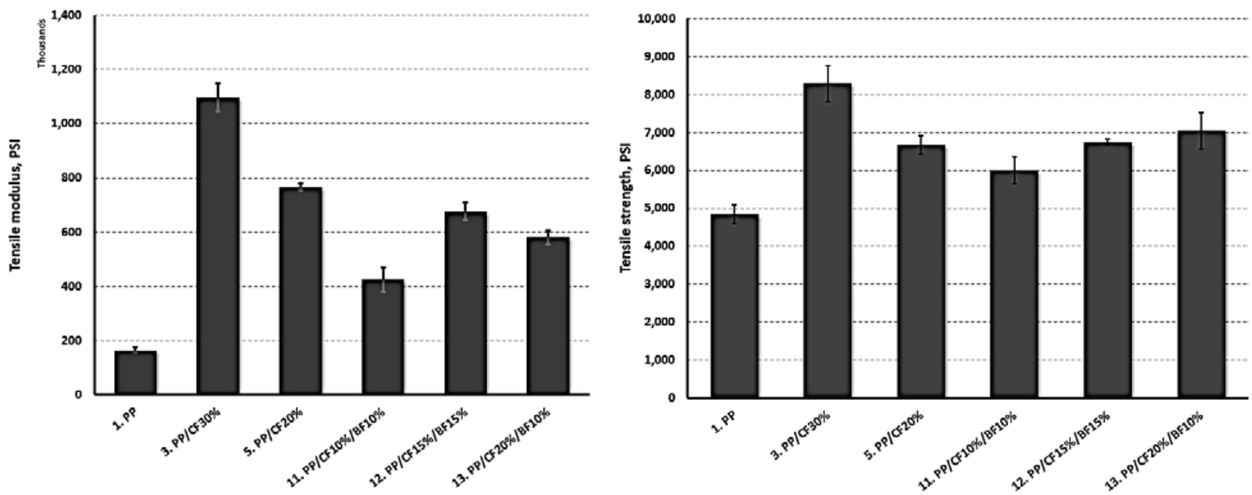

Figure 7. Flexural modulus of elasticity and strength of composite samples made using PP.

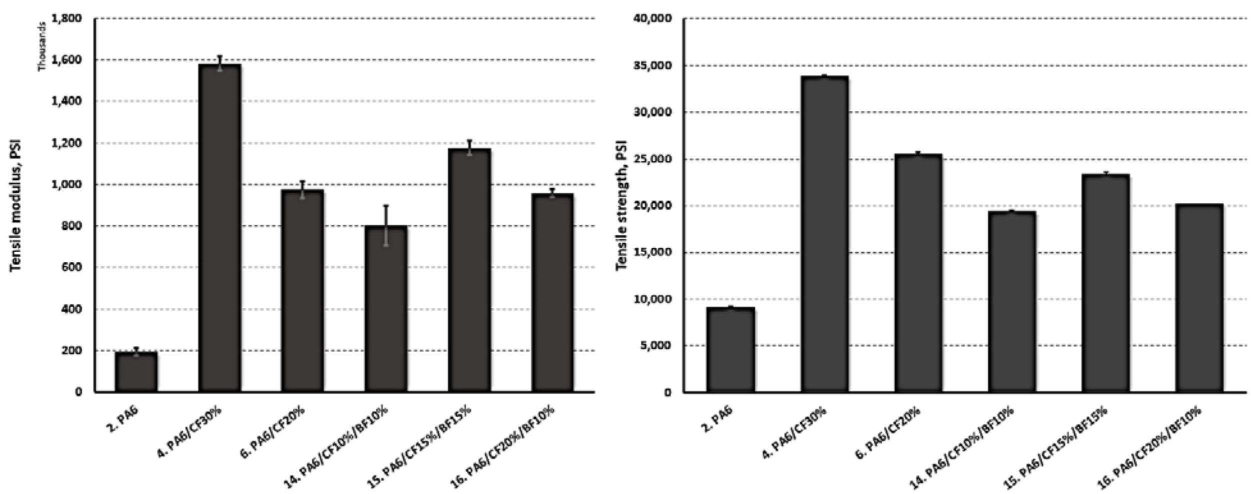

Figure 8. Flexural modulus of elasticity and strength of composite samples made using PA6.

Impact strength of samples are shown in Figures 9 and 10. The reinforcing effects of CF and BF on the impact strength are only observed in the samples made using the PA6 matrix [Figure 9]. The composite samples made using the PP matrix were significantly reduced in impact strength since the pure PP shows superior impact properties and the addition of fillers is known to decrease the impact properties in PP composites. The addition of BF in the PA6 composite samples showed a potential of BF as a reinforcing filler [Figure 10] since it doesn't significantly degrade the impact strength and it improves the other mechanical properties.

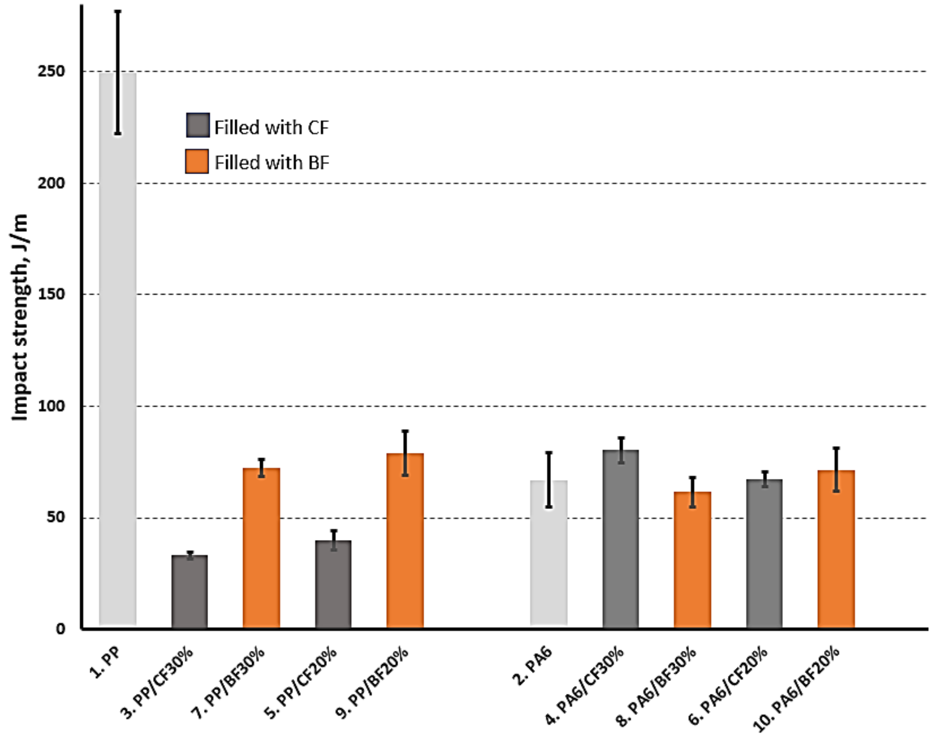

Figure 9. Impact strength of composite samples reinforced with CF and BF.

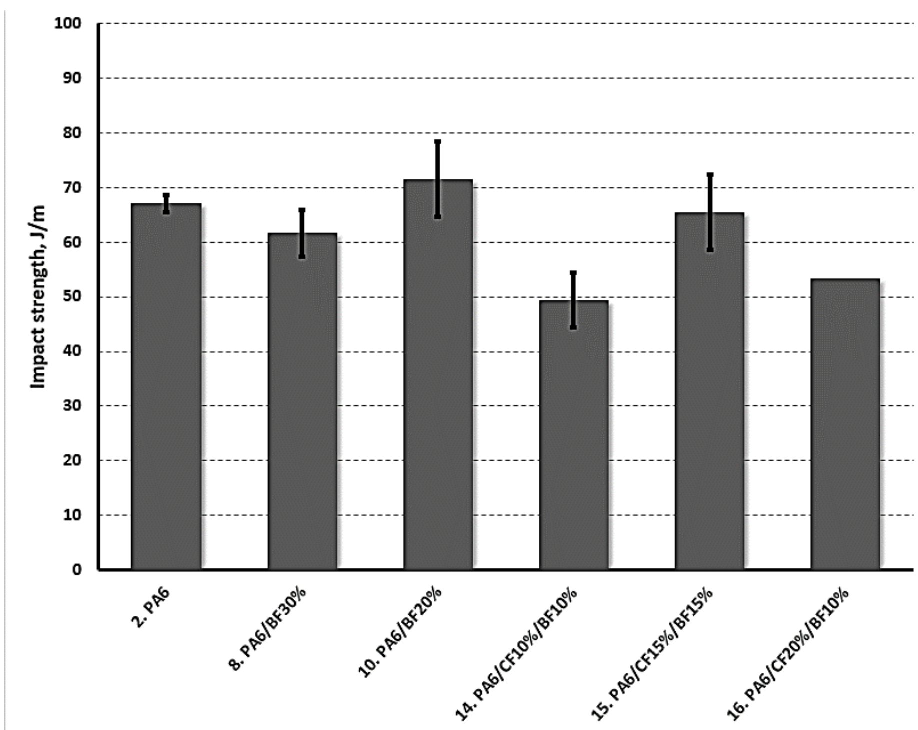

Figure 10. Impact strength of samples made using the PA6 matrix and BF/CF.

Other reinforcing fillers are compared to the CF and BF utilized in this study in Figure 11. The increased percentages are charted by the different fillers compared to the neat PP matrix. The CF and BF shows good reinforcing effects.

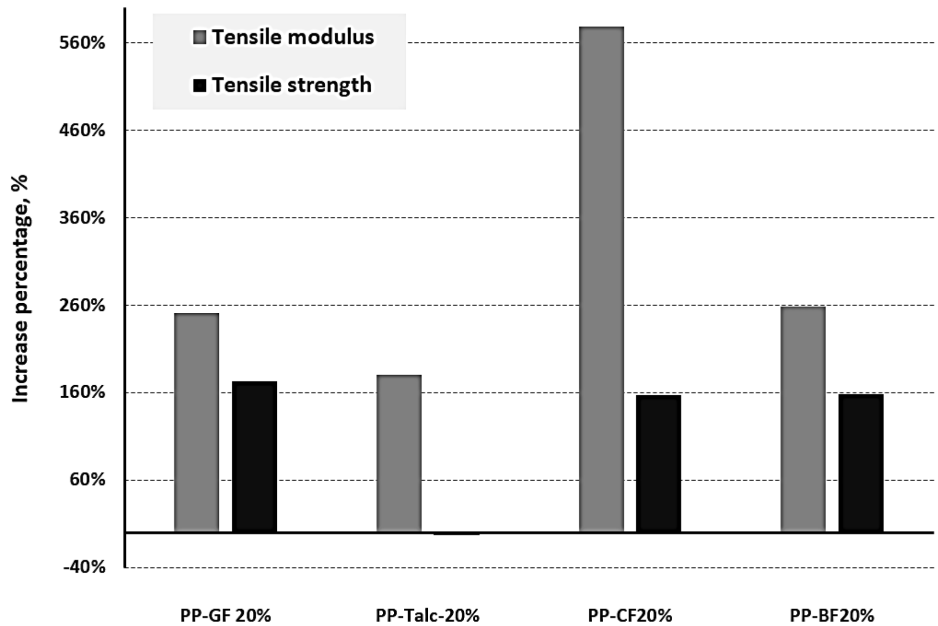

Figure 11. The reinforcing effects of various fillers in PP composites on the mechanical properties [The increase percentage is based on the pure PP.]

Conclusions and Future Work

Both CF and BF fibers increased the mechanical properties of PP/PA6 composites. The reinforcing influence was clearer in the PA6 composites than the PP composites. The potential of BF as a partial replacement of CF can be found for all mechanical properties reported. Especially, the impact properties can be clearly improved by the addition of BF or blends of BF and CF. The potential of BF needs to be studied more systematically since the use of BF can contribute to the cost savings in manufacturing.

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