MECHANICAL PROPERTIES OF RECYCLED CARBON FIBER REINFORCED THERMOPLASTICS MADE BY CARBON FIBER PAPER

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Abstract

In this experiment, we chose paper making process to mix the recycled carbon fibers (RCF) and fiberized polyamide 6 (PA6 fibers) and then we conducted the compression molding to form the material. The mechanical properties of different content ratio of the RCF derived from T300 to that from T800 were investigated to improve the recycling efficiency of RCF. Additionally, polypropylene was used to compare the effect of different matrix choosing. The scanning electron microscope (SEM) observation was conducted to check the interfacial adhesion between the matrix and the reinforcement.

1. Introduction

Carbon fiber reinforced plastics (CFRP) are broadly accepted by the commercial market and continually improved by the scientific and engineering field. CFRP can replace the steel into the structure resisting fracture and can fit the requirement of the comprehensive light weight structure [1]. Additionally considering the continually deteriorating environment issues, environment friendly material has been listed upward in the bargaining conditions allowing the current social and industrial development. Therefore carbon fiber reinforced thermosets (CFRTS) are gradually losing ground in the industrial area, which is favoring “3R” principles, reduce, reuse, and recycle. On the contrary, carbon fiber reinforced thermoplastics (CFRTP) have attracted a lot of attention from the scientific field because of its recyclability [2]. However, the thermoplastics has the disadvantage of high viscosity inducing impregnation issues [3]. How to improve the impregnation ratio and which form is the appropriate way to realize the potential mechanical properties are the center of the questions.

Additionally, with the increasing replacement of metal, the demand of carbon fibers has been increasing dramatically [4-5]. Until now, the amount of the waste of carbon fibers from the in-plant cut-offs and the end-of-life products have increased to the point threatening the land capacity, and the endless life of the carbon fibers makes the situation even worse. So a lot of attention and effort have been devoted to recycle the carbon fibers [6-7].

In this experiment, we mixed the recycled carbon fibers (RCF) derived from different kinds, T300 and T800, and the fiberized resin into carbon fiber paper (CFP). After choosing the matrix by the same reinforcement of RCF, we mixed the two kinds of RCF by the different content ratio of R-T300 (RCF derived from T300) to R-T800 (RCF from T800). Then the mechanical properties were measured to investigate the content reliance of different kinds of RCF.

2. Material

In this experiment, we used R-T300 and R-T800 as the reinforcements, and we used fiberized polypropylene (PP) and polyamide 6 (PA6) as the matrixes. As shown in Tables 1 and 2, two types of comparison were conducted.
Firstly, by using paper making method, we prepared two types of CFP to investigate an influence of matrix resin. Secondly, the same process was used to make six types of CFP to investigate an influence of the mixture ratio of different types of RCF. Figures 1 and 2 show photo and SEM image of the CFP before compression molding respectively.

RCF/matrix	**Vf of R-T800**
R-T800/PP	20%
R-T800/PA6	20%

Table 1. The component of the two different CFP.

RCF/matrix	**Vf of RCF**	**Vf ratio of R-T300 toR-T800**
RCF(1.0/0.0)/PA6	20%	1.0/0.0
RCF(0.8/0.2)/PA6		0.8/0.2
RCF(0.6/0.4)/PA6		0.6/0.4
RCF(0.4/0.6)/PA6		0.4/0.6
RCF(0.2/0.8)/PA6		0.2/0.8
RCF(0.0/1.0)/PA6		0.0/1.0

Table 2. The component of the mixed different kinds of RCF of RCF/PA6.

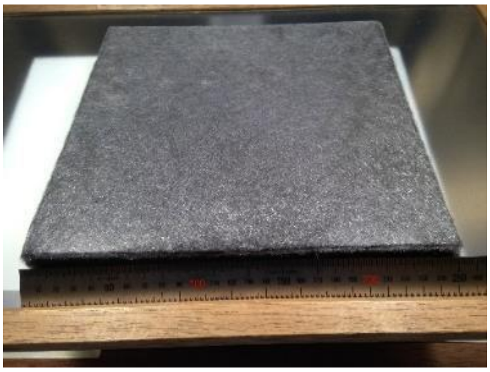

Figure 1. A photo of CFP before compression molding.

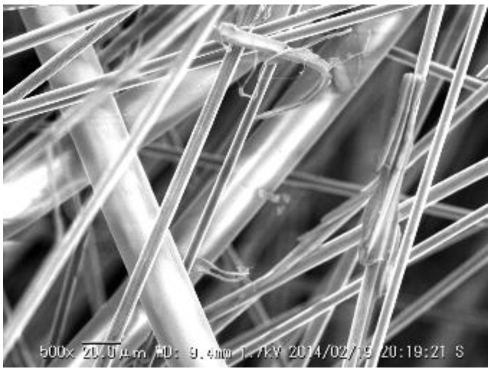

Figure 2. SEM image of the CFP before compression molding.

3. Experiment

We formed the plates by compression molding, of which the temperature is 240 degrees Celsius and the pressure is 5MPa. Then we cut 5 specimens for the three point bending tests by the size of 10mm*50mm*2mm and another 5 for the Izod tests by the size of 10mm*45mm*2mm.

4. Results and discussion

4.1. Choose the matrix

We changed the kind of matrix, PP, to compare the mechanical properties of different kinds of matrixes without changing the reinforcement and V_f. As shown in Figures 3-6, the mechanical properties of R-T800/PP is a little bit poorer than that of R-T800/PA6. This is because of the not enough impregnation reatio of R-T800/PP and a lot of voids left in the composite after compression molding. The volume fractions of voids (*Vv*) are listed in Table 3, the *Vv* of R-T800/PP is almost 6%, however that of R-T800/PA6 is less than 1% . Such amount of the voids in R-T800/PP will induce the fracture happened much earlier and so will the composite failure. The Figure 7 shows the not enough interfacial adhesion between the matrix and the reinforcement of R-T800/PP, because of the viscosity of PP is so high that much higher molding pressure is needed to get enough impregnation ratio. However higher molding pressure will probably make the RCF broken during the compression molding. Therefore, we chose the PA6 as the matrix for the investigation of CFP with mixed different kinds of RCF.

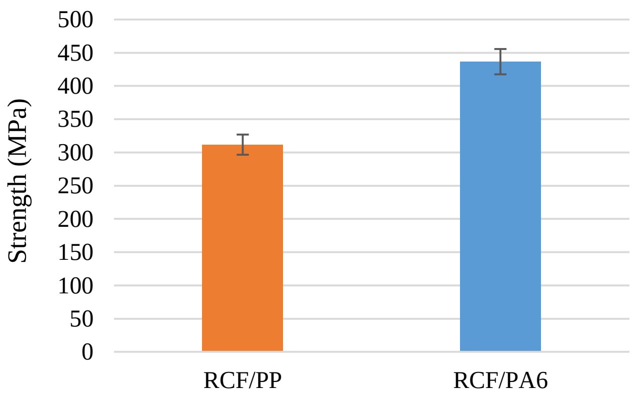

Figure 3. Strength of R-T800/PP and R-T800/PA6 with the V_f of 20%.

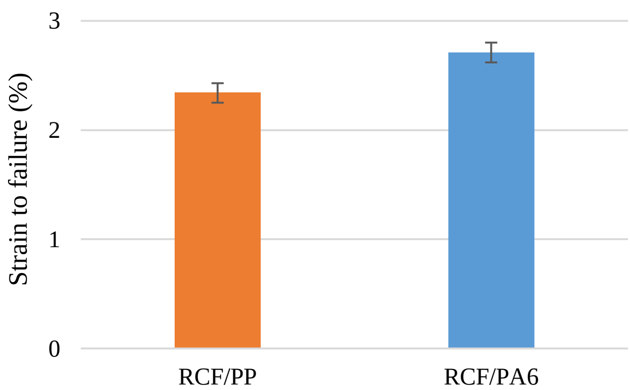

Figure 4. Failure strain of R-T800/PP and R-T800/PA6 with the V_f of 20%.

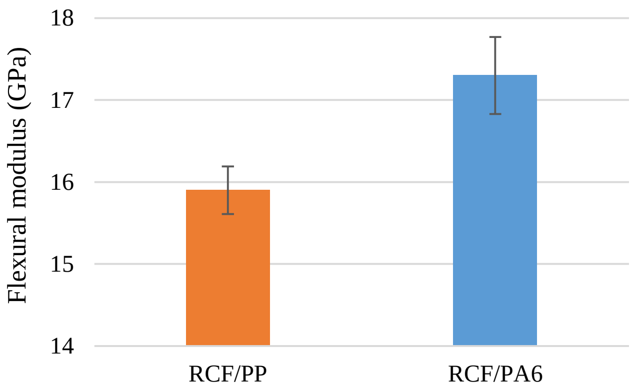

Figure 5. Flexural modulus R-T800/PP and R-T800/PA6 with the V_f of 20%.

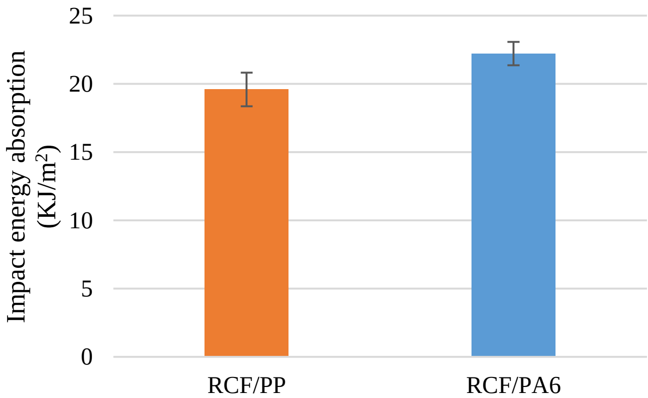

Figure 6. Impact energy absorption R-T800/PP and R-T800/PA6 with the V_f of 20%.

	RCF/PP	RCF/PA6
Volume fraction of voids (%)	5.5	0.5

Table 3. Volume fraction of voids of R-T800/PP and R-T800/PA6 with the V_f of 20%.

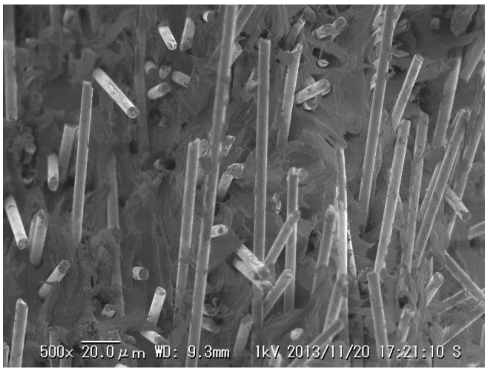

Figure 7. SEM image of fracture surface of RCF/PP after Izod test.

4.2 CFP by mixed different kinds of RCF

4.2.1. Three point bending test

Table 4 shows the basic information of the mechanical properties of fresh T300 and T800. It is clear that the mechanical properties of T800 is very much better than those of T300, and the surface of R-T300 is rough and R-T800 is smooth as shown in Figure 8. From the results of the three point bending test, as shown in Figures 9-11, the strength of the specimens reinforced only by R-T300 is the lowest and otherwise those reinforced only by R-T800 shows the best. The specimens of mixed R-T300 and R-T800 shows the linear change between the strength of RCF(1.0/0.0)/PA6 and RCF(0.0/1.0)/PA6. When the specimens were bearing load during the bending, the load were dispersed among the different kinds of RCF by the content of them respectively. Similarly, the flexural modulus of the specimens shows the linear relationship of the increasing content of R-T800. The results show the rule of mixture by volume fraction. Therefore, we can mix the different kinds of carbon fibers by different content to fulfill the different needs of mechanical properties in the manufacturing.

Mechanical properties	T300	T800
Tensile strength (MPa)	3530	5490
Tensile modulus (GPa)	230	294
Failure strain (%)	1.5	1.9

Table 4. The tensile properties of the carbon fiber of T300 and T800.

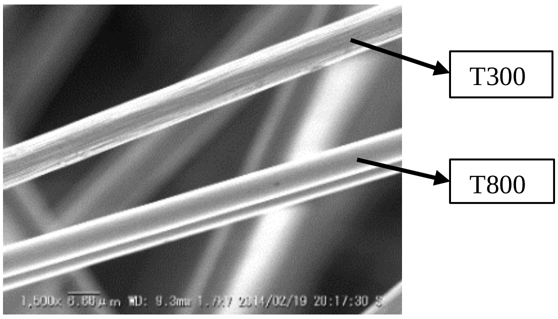

Figure 8. SEM image of R-T300 and R-T800.

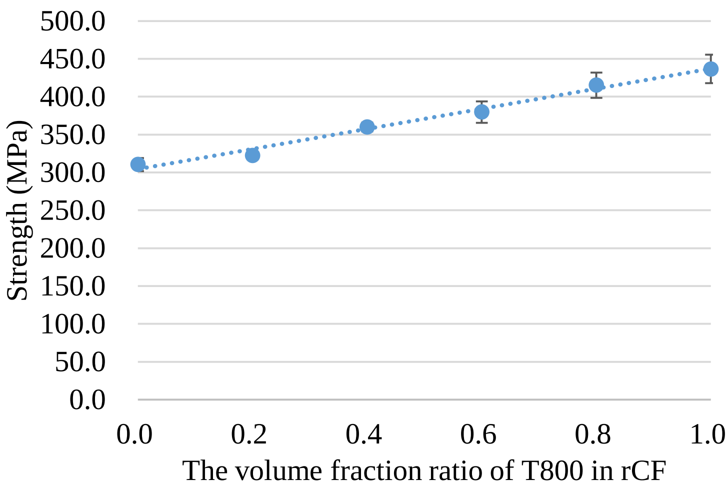

Figure 9. Strength of the CFP with the V_f of 20% by mixed RCFs.

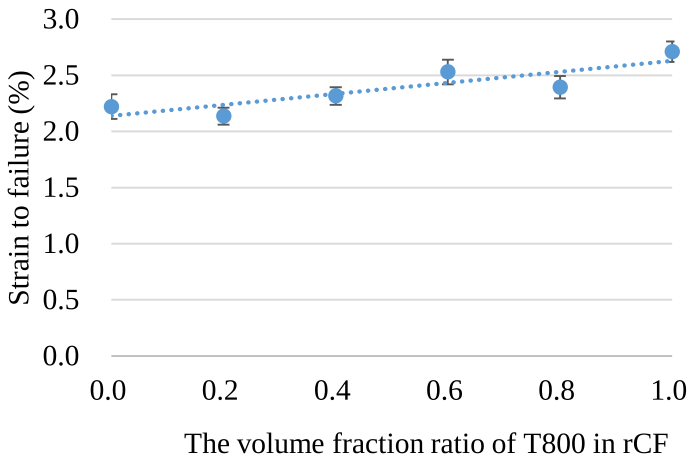

Figure 10. Failure strain of the CFP with the V_f of 20% by mixed RCFs.

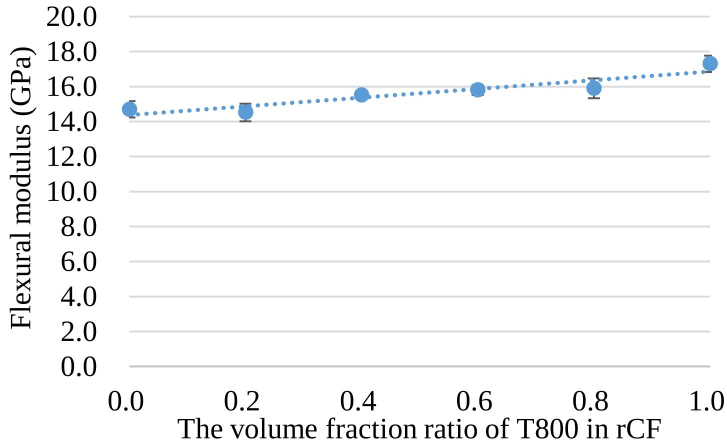

Figure 11. Flexural modulus of the CFP with the V_f of 20% by mixed RCFs.

4.2.2. Izod test

As shown in the Figure 12, there is a transit point at the higher content of R-T800 than that of R-T300. The composite will break when the absorbed energy is over than the limit of R-T300 when the content of R-T300 is higher than that of R-T800, even though R-T800 is believed absorbed a limit amount of impact energy. The composite failed at higher impact energy absorption after increasing the amount of R-T800 over than R-T300. The R-T800 contributed more to resist against the impact fracture.

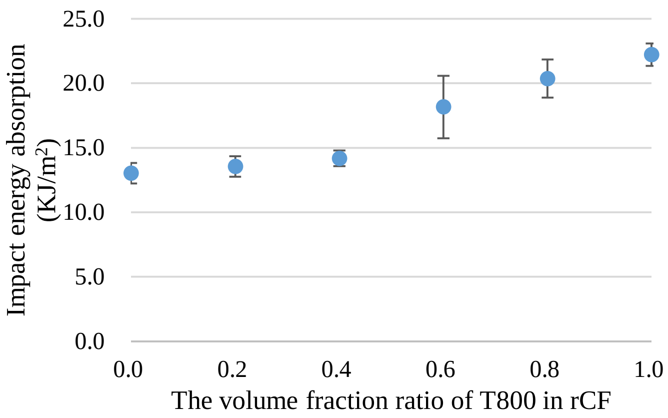

Figure 12. Impact energy absorption of the CFP with the V_f of 20% by mixed RCFs.

4.2.3 SEM

As shown in Figures 13-16, the interfacial adhesion between the matrix and the reinfocement is good enough.

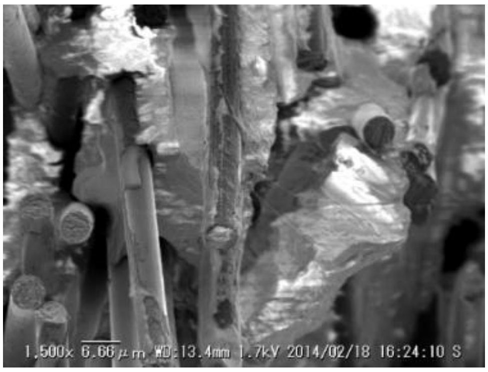

Figure 13. The SEM image of the fracture surface of RCF(0.2/0.8)/PA6.

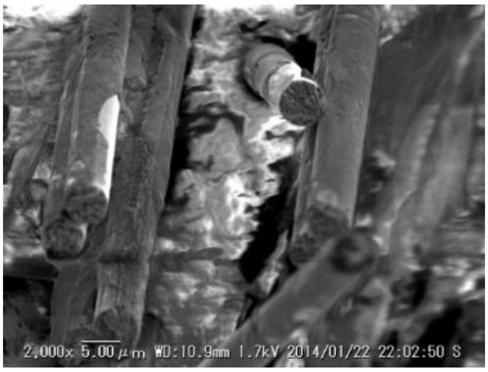

Figure 14. The SEM image of the fracture surface of RCF(0.4/0.6)/PA6.

Figure 15. The SEM image of the fracture surface of RCF(0.6/0.4)/PA6.

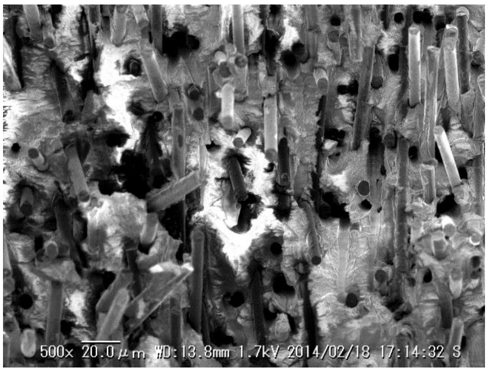

Figure 16. The SEM image of the fracture surface of RCF(0.8/0.2)/PA6.

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