IMPREGNATION STATE IN SHORT FIBER THERMOPLASTIC PELLET AND MECHANICAL PROPERTIES OF COMPOSITES

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ABSTRACT: In order to satisfy both requirements for environment protection and high mechanical property of composites, hybrid of nature fiber and glass fiber in polypropylene is proposed and carried out in the current study. In particularly, hybrid pellet was adopted to mold hybrid composites by injection process. Firstly, the impregnation station of two fibers in both pellet and dumbbell shape composite were investigated before and after molding process by microscope upon the polished surface. Then the mechanical properties were discussed based on tensile tests. Finally, the measurement methods of fiber content in the natural fiber hybrid composites were discussed. It is found that the traditional burn-out and density method are not suitable for those composites. Therefore, image analysis method was proposed.

KEYWORDS: short fiber; injection molding; nature fiber; hybrid.

INTRODUCTION

In recent years lignocellulose has been a growing interest as reinforcing fiber in polymeric composites because of the consciousness-raising of environmentally friendliness of materials. The research for the natural fiber reinforced polymeric composites has started in 1980s [1-5]. However there is little research on the injection molded natural fiber reinforced composite.

In current study, hybrid concept for natural fiber reinforced composites by injection molding was proposed in order to increase the mechanical strength and to reduce the scatter of mechanical properties. This concept is not fully environmental friendly but it would be easily accepted in actual industries. In injection molding the fiber content is always measured by weight because the ratio cannot be determined by volume in compounding process. Therefore the volume fraction of fiber is usually calculated from the weight fraction of fiber in injection moldings. In this paper the fiber content in natural fiber composites and natural fiber/glass fiber hybrid composites was measured by different methods. First, the fiber content was measured by the conventional method (density method and burn-out method), and the problems in these method for measuring the fiber fraction in hybrid composites were clarified. Then, a new method for measuring the fiber content by applying image analysis was proposed.

MATERIALS AND EXPEREMAENTAL

Long fiber pellets (LFP)and the composites

Jute fibers (JF) and glass fibers (GF) were used as reinforcements, and polypropylene (PP) was used as matrix resin. By using long fiber pellet production machine LFP including JF/PP and GF/PP were fabricated. Those lengths were 8mm and 11 mm respectively. The tensile dumbbell type specimens with different fiber volume as shown in Table 1 were fabricated by 100ton injection machine. In the case of GF/PP specimen weight fraction of glass fiber was 10wt%, and in JF/PP specimen weight fraction of jute fiber was varied from 5 to 30wt%. Additionally, hybrid specimen was also prepared by dry blending of JF/PP and GF/PP pellets in injection molding. In hybrid specimen the weight fraction of glass fiber was kept in 10wt%, whereas the weight fractions of jute fiber were varied from 5 to 30wt%.

Long hybrid Fiber pellets (LHFP)and the composites

Particularly, in this study, the JF/GF/PP hybrid pellet also made by long fiber pellet machine in which two fibers i.e. JF and GF are included in one pellet. Then hybrid composite G25J15(LHFP) which was molded by using JF/GF/PP LHFP pellets was made by the same injection molding process . In order to compare the effect from LHFP and LFP, G25J15(LFP) was also molded by using JF/PP and GF/PP pellets.

Experimental method

Static tensile tests were conducted for G25J15(LHFP) and G25J15(LFP) specimens at an Instron type universal testing machine at a constant cross-head speed of 10mm/min. (the room temperature was about 25ºC and the humidity was about 55%).

In order to discuss the fracture behavior, AE signals from the specimen during tensile tests were monitored by 7600 series AE instrument (NF Corporation, Japan). Here two types of AE transducers with different resonant frequencies at 140 kHz and 1 MHz were attached to the specimen on two points where with a distance of 10mm from the central line.

MEASUREMENT OF FIBER FRACTION BY CONVENTIONAL METHOD

Measurement Method

In measurement of fiber fraction inside composites, there are two conventional method; density method and burn-out method [6]. In density method, the weight and volume of composites were measured firstly to calculate its densities (r_c). (r_f , r_m are the known density of fiber and matrix, respectively. Then the fiber volume fraction of reinforcing fiber (V_f) was calculated by using equation (1).

$$V_f = \frac{r_c - r_m}{r_f - r_m} \qquad (1)$$

In burn-out method the weight of composite W_c was measured at first, and the weight of reinforcing fiber (W_f) can be got based on the residue after burning out. The volume fraction of fiber was calculated by equation (2).

$$V_f = \frac{W_f / r_f}{W_f / r_f + (W_c - W_f)/ r_m} \qquad (2)$$

Table 1 Weight fraction of fibers in dry blend specimens.

Specimen ID	Glass (wt%)	Jute (wt%)
G10J30	10	30
G10J20	10	20
G10J10	10	10
G10J05	10	5
G00J30	0	30
G00J20	0	20
G00J10	0	10
G00J05	0	5

In this paper two different types of fibers i.e. jute and glass, were adopted, so that these two methods enable to measure fiber contents. The density method was applied for JF/PP composites because jute fibers are very weak at heat, whereas both methods were adopted for the hybrid composites. By measuring density the following equation was established for hybrid specimen.

$$r_c = \frac{W_c}{V_c} = r_g V_g + r_j V_j + r_m \left(1 - V_g - V_j\right) \tag{3}$$

In order to measure the fiber volume fractions the burn-out method was adopted for hybrid samples. By burn-out, only the glass fiber was remained as residue and its weight could be measured. The glass fiber content was calculated by equation (4);

$$V_g = \frac{W_g / r_g}{V_c} \tag{4}$$

where W_g is the weight of glass fibers. From equations (3) and (4) the volume fraction of jute fiber was derived as

$$V_j = \frac{r_c - r_m - (r_g - r_m)V_g}{r_j - r_m} \tag{5}$$

Table 2 Volume and weight fractions of fibers in JF/PP and GF/PP specimens.

Specimen ID	W_c (g)	V_c (cm^3)	ρ_c (g/cm^3)	V_g or V_j (vol%)	W_g or W_j (wt%)
G00J30	2.13	2.10	1.01	19.0	28.1
G00J20	1.76	1.82	0.97	11.7	18.0
G00J10	1.98	2.11	0.94	6.4	10.2
G00J05	1.85	2.02	0.92	2.6	4.2
G10J00	1.89	1.97	0.96	3.7	9.8

Results and Discussion

Table 2 shows the fiber volume fractions for JF/PP and GF/PP composites obtained by the density method. Here, the densities of glass fiber and jute fiber were 2.54g/cm^3 (2.49X10^{4}N/m^3) and 1.5g/cm3 (1.47X10^{4}N/m^3) and the density of PP was 0.9g/cm^3 (0.88X10^{4}N/m^3). The weight fractions of fiber converted from the volume fraction were also shown In Table 2. The weight fractions were almost the same values as listed in Table 1. From this result, the volume fraction of fiber in natural fiber composites can be evaluated by the density method.

The volume and weight fractions of fibers in hybrid composites used by both burn out and density methods were summarized in Table 3. In G10J30 and G10J20 the content of glass fiber was a little lower than the expected in Table 1, while the content of jute fiber was almost the same as listed. On the other hand, the content of jute fibers was much lower than the expected in G10J10 and G10J05. In this case, jute fiber is supposed completely burn out and the residue is glass only. However, some residues remained even after burn-out of JF/PP pellet. This result suggested that the above assumption was not suitable for estimation of fiber content in natural fiber hybrid composite.

Table 3 Volume and weight fractions of fibers in jute/GF/PP hybrid specimens

Specimen ID	W_c	V_c	ρ_c	W_g	glass		Jute	
	(g)	(cm^3)	(g/cm^3)	(g)	(vol%)	(wt%)	(vol%)	(wt%)
G10J30	2.16	1.97	1.09	0.18	3.7	8.5	22.4	30.7
G10J20	2.03	1.95	1.04	0.17	3.4	8.2	14.0	20.2
G10J10	2.27	2.29	0.99	0.22	3.7	9.6	4.4	6.7
G10J05	1.96	2.01	0.98	0.21	4.2	10.8	1.4	2.14

NEW METHOD TO MEASURE FIBER CONTENT IN BOTH LFP AND LHFP

In order to measure the volume fraction of fibers in natural or natural fiber hybrid composites, here image analysis which is illustrated in Figure 1 for the LFT pellets for JF/PP and JF/GF/PP were carried out. Firstly the cross-section of the pellet was polished and the cross-sectional micrograph was captured by the digital camera. Secondly, the outline of the pellet was traced automatically or manually and the area inside was blackened. Then, the blackened area was calculated by image analysis software as the area of pellet (A_p). Then, the fiber region was cut out from the original image and this image was binarized to detect the area of fiber itself (A_g or A_j). Here, the used samples were the LHFP and the fibers were aligned in each pellet. Therefore the ratio of the cross-sectional area corresponded to the ratio of the volume. From these values the volume fractions of fiber (V_g or V_j) were obtained by;

$$V_g = \frac{A_g}{A_p} \quad \text{or} \quad V_j = \frac{A_j}{A_p} \qquad (6)$$

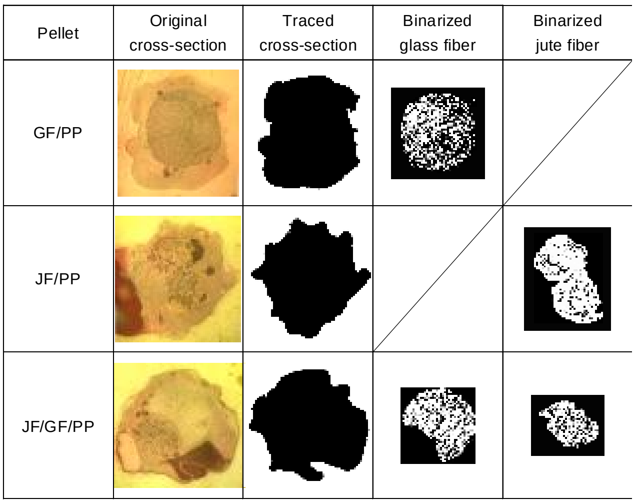


Fig.2 Images used for image analyses; GF/PP, JF/PP and JF/GF/PP pellets

Results and Discussion

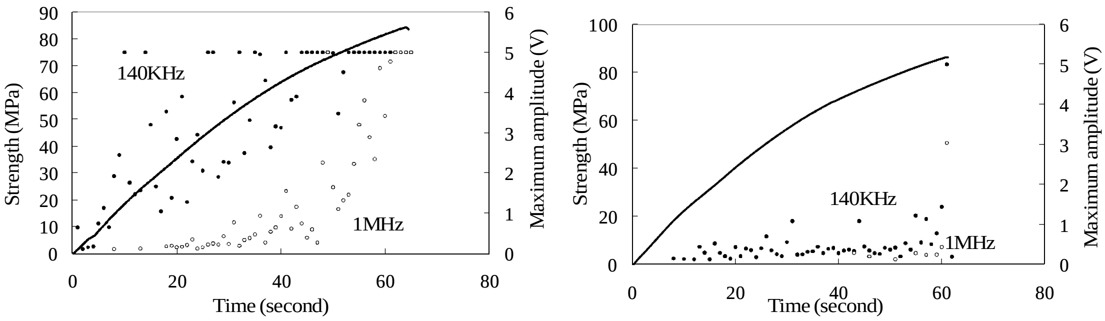
As summarized in Table 4, the volume fractions of glass fiber obtained by the burn-out method were also listed as references. In the case of GF/PP pellet the fiber volume fraction obtained by the image analysis method almost agreed with that obtained by the burn-out method. This result confirmed that the proposed image analysis method was applicable to estimate the volume fraction of fiber in the pellet. The volume fraction of jute fiber in JF/PP pellet was almost the same with that in GF/PP pellet, and it was acceptable value because the production process was the same in both pellets. In the hybrid (JF/GF/PP) pellet the volume fraction of jute fiber was 13% and it was almost the half of JF/PP pellet, while that of glass fiber obtained by image analysis method was not agreed with that by the burn-out method. The glass fiber volume fraction was much higher than that by the burn-out method. This disagreement might be affected by the threshold level for the binarization. In addition, the binarized glass fiber in hybrid pellet was much expanded in comparison with in GF/PP pellet. These results may suggest that the threshold level for binarization is most important factor for estimating the fiber volume fraction precisely in the hybrid pellet. This problem might be derived from 2 different types of the fibers existing in the same pellet and the contrasts of these fibers in the image were quite different. Therefore the determination of the threshold level should be done after sampling the great number of images for the hybrid pellet.

Table 4 Analysis results of GF/PP, JF/PP and JF/GF/PP pellets estimated by image analysis and burn-out method.

Image Analysis Method					
Pellet	Pellet area (mm^3)	JF area (mm^3)	GF area (mm^3)	V_j (vol%)	V_g (vol%)
GF/PP	3.616	---	1.012	---	28.0
JF/PP	3.284	0.920	---	28.0	---
JF/GF/PP	3.432	0.457	0.845	13.3	24.6
Burn-Out Method					
Pellet	Pellet weight (g)	JF weight (g)	GF weight (g)	V_j (vol%)	V_g (vol%)
GF/PP	2.002	---	1.074	---	29.1
JF/GF/PP	2.010	---	0.677	---	15.2

MECHANICAL PROPERTY

The tensile test results were illustrated in Figure 3. G25J15(LHFP) had a tensile modulus of 7.09±0.92 and a tensile strength of 80.08±6.07. On the other hand, G25J15(LFP) had a relative higher mechanical property because of the modulus 8.66±0.15 and strength 86.47±1.72. It is considered that the composite made from LHFP have weaker interface between fiber and resin because of many AE fractures (140kHz) generated as shown in Figure3 (a).



(a) G25J15(LHFP) (b) G25J15(LFP)

Figure 3 Tensile test results

CONCLUSION

This study discussed the measurement methods of fiber content in the natural fiber reinforced composites. The density method could be applied both to the glass fiber only and the natural fiber only reinforced composites. The burn-out method could not be applied to the natural fiber composites and the natural fiber/glass fiber hybrid composites. Then, the new method for measuring fiber content by introducing the image analysis was proposed. It was found that this image analysis method should be much effective than the other method for the hybrid composites. However, the results measured were quite sensitive to the threshold level, and it should be taken account for getting more reliable results.

Additionally, long fiber pellets (LFP) and long hybrid fiber pellet(LHFP) were used to mold composites to compare their mechanical property. The results shows that the composite molded from LHFP have many 140kHz AE fractures. It is considered that the composite molded from LHFP have a weaker bonding which led to a relative lower tensile property.

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