Thermoplastic Composites Recycled from Fishing Rope Fiber and Crushed Rice Hull

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Abstract: In order to extend utilities of recycled plastics made from fishing ropes fibers, which consisted of synthetic fibers, polyethylene, and polypropylene, the composites with crushed rice hull (RH) used as filler was investigated. The elastic modulus of the composites in tensile and bending modes increased by adding the rice hull. While the degree of elongation decreased, the RH may act as a mechanical hardening additive for resin. Though, weak interface interaction between RH and resin made composite brittle. The particle size of RH also affects those mechanical properties. Fine RH particles can disperse in resin homogeneity, which realized modulus to be increased.

Keywords: Fishing rope, Rice hull, Composites

1. Introduction

1.1 Problem of sea waste by plastics A plastic has sufficient mechanical strength in practical use and can be manufactured to suitable shape for many applications. This has caused the mass production of plastic. However, the increase in the waste of plastic has induced a severe social problem. The environmental destruction by the increase in plastic wastes has been a problem all over the world. Especially, the sea polluted by plastics, the concern is increasing in the area along the shore in the world. Of these, the amount of waste fishing rope is vast, and waste treatment is also difficult. Many fishing ropes in recent years are made from synthetic fibers, such as polyethylene and polypropylene. Moreover, since they have been placed under the environment for a long time, mechanical properties of them may be degraded by ultraviolet irradiation and oxidation. Therefore, reuse as a fishing net is not realistic. As a new trial, reproducing as a plastic article from waste fishing rope had been studied. The problem, in that case, is the decreasing of mechanical properties, which is peculiar to recycled products. In order to tackle the problem, there is a method by which fillers, such as glass fiber, are added to the plastic. On the other hand, it is desirable to utilize biomass resources as an additive agent from viewpoints of a stable supply of materials, and safety. Therefore, a technology which considered environment-friendly is needed for those recycled products.

1.2 Rice hull as plastics filler Investigations of technical potentiality for using rice hull (RH) parti-

cles as high-performance materials have been received much attention from the viewpoints of the utilization of agricultural wastes. The amount of production of RH is estimated to be 2.6 million tons per year in Japan [1]. The rice hull contains about 20wt% of an inorganic compound and 80% of organic compounds [2]. Main of the inorganic compound is silica(SiO_2). Silica possesses molecular network structure by joining -Si-O- and forms crystalline, which give unique properties. Since silica possesses its advantages, the utilization of filler of silica in plastics should give the benefits. The RH fillers/polymer composites are expected to be high tensile and compression and elastic modulus [3]~[6]. The authors have chemically analyzed the molecular structure of waste ropes and revealed that these are composed of thermoplastic synthetic polymers [7]. Thermoplastic plastics can be recycled by melting and processing at high temperature under high pressure. If the composites of RH with the polymers obtained from fishing ropes would be high-performance materials, they might be contributing to solving the environmental problem. Sato et al. investigated basic characterizations of the composites from viewpoints of mechanical properties [7]. The main objective of this study is to investigate the breaking stress, degree of elongation and elastic modulus, in tensile and bending mode, for the RH/thermoplastic resin recycled from fishing ropes. Besides, a comparison of such mechanical behavior by the different particle sizes of RH was also investigated.

2. Methods

2.1 Materials The RH was dried for 8 hours at 120°C, and crushed by using the ball mill and then sieved. Three types of particle sizes were used, *i.e.*,

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Figure 1: Outline shapes of rice hull and crushed ones with different diameters.

Figure 2: Fishing ropes used in this study.

710~350 μm (RH1), 180~160 μm (RH2), and about 17 μm as an averaged diameter (RH3). The recycled resin used was made from waste fishing ropes, which have been drifted ashore on the coasts and have been collected by authors. They were cut into pieces by the shear and then washed by water several times followed by drying under an atmosphere. Fig. 1 shows the photographs of RH before and after crushing. Fig. 2 shows fishing ropes before and after the cutting. Analysis of fourier transformed infrared spectrometry (FTIR) and differential scanning calorimetry (DSC) were conducted in order to obtain information about chemical components and thermal properties of the fishing ropes, respectively. Spectra of the FTIR were obtained between from 4000 to 750 cm^{-1} of wave numbers with a resolution of 4 cm^{-1} using attenuated total reflection method. DSC thermograms were obtained from 100 to 200°C at a heating rate of 10°C/min under the nitrogen atmosphere.

2.2 Processing The pieces of fishing ropes were introduced at 185°C toward extrusion machine (Imoto Seisakusho PPKR IMC-1895) with certain content of RH particles. Moldings were conducted using pressure of 10 MPa at the temperature from 175 to 180°C for 10 min (Fig. 3). The dimension of the test specimens was 80(w) $\times$ 5(d) $\times$ 0.5(t) mm for tensile and 40(w) $\times$ 10(d) $\times$ 1(t) mm for bending tests, respectively.

Figure 3: Process of manufacturing the composites.

Figure 4: FTIR spectrum for the fishing ropes used in this study.

2.3 Mechanical Tests The tensile and bending tests were conducted based on the Japanese Industrial Standards of JIS-K7162 and 7171. These tests were operated by using Shimadzu EZ Test (type EZ-S) with 100 N maximum load. The crosshead speed was 1 mm/min for tensile and 10 mm/min for bending modes, respectively.

3. Results and Discussion

Fig. 4 shows the typical infrared spectroscopic data for the fishing ropes obtained. The chemical bonds between atoms always have stretching and bending motions in molecular structures. The infrared irradiation with specific vibration resound characteristic chemical bonds. At that time the infrared energy was transferred to chemical bond motions. This is called infrared absorption (IR). The absorption bands at 2900, and 1450-1550 cm^{-1} correspond to vibration of chemical bond between carbon and hydrogen atoms, which suggesting hydrocarbon structure such as polyethylene (PE) and polypropylene (PP). The band at 1370 cm^{-1} implies existence of methyl group (CH_3), which is the part of structure of PP.

Fig. 5 shows the DSC curve for the fishing ropes. DSC observes changes of heat flow between samples and surrounding. Thermal changes like as phase transition (melting, crystallization, decomposition, and so on)

Figure 5: DSC curve for the fishing ropes.

Figure 6: Typical plots of stress-strain curves by the tensile mode for the composites with the RH1 of 50 phr.

were detected by changes of heat flow curve. The endothermic peaks were observed at about 138 and 170°C, which correspond to melting peaks of the PE and PP, respectively. From the results of FTIR and DSC, it was found out that the fishing rope used in this study was composed of PP and PE materials.

Fig. 6 shows the typical plots of stress-strain curves by the tensile mode using the testing machine for the composites with the RH1 of 50 phr content (phr: parts per hundred parts of resin). The tests were conducted using at least 5 pieces of the samples. It can be seen that stress increased markedly as the strain increases. As the values of stress passed through the maximum point on the curves, the specimen was broken and the stress suddenly decreased. Fig. 7(a)-(c) show results of the stress at maximum point (breaking point), degree of elongation at maximum point and modulus for the composites containing 50 phr of various sizes RH. The blue bar corresponds to results obtained under tensile mode and the red bar corresponds to bending mode,

(a) Stress at maximum point

(b) elongation at maximum point

(c) modulus

Figure 7: Results of mechanical tests under tensile (blue) and bending (red) modes.

respectively. As shown in (a) of the figure, the stress was decreased by adding RH under both for tensile and bending modes. However, the stress for tensile mode for RH composites somewhat increased as RH size decreasing. The elongation at maximum point was remarkably decreased by adding RH for tensile mode (Fig. 7(b)). While for bending mode, the values were slightly decreased with RH size decreasing. Increasing of the modulus for RH3 composite in tensile mode was outstanding (Fig. 7(c)). From these observations RH may change the mechanical properties of material to be hard and brittle nature at tensile mode. Of these, RH3 composite shows remarkable feature.

The reason why the composite became brittle by

adding the RH is due to weak interface interaction between the filler and resin, which leads to lower efficiency of mechanical energy transfer from resin to the filler through the interface [8]. In general, as particle size of the filler become smaller, the tensile strength and modulus of the composites increases. This may be due to the homogeneity on mixture of resin with the fine RH particles in composites. As well, the surface area between the resin and the RH3 particles is considerably larger than that of RH1 and RH2. Large surface area between the resin and RH causes the energy transfer more dispersive.

4. Conclusions

The composite of resin made from fishing ropes and RH has been manufactured, and the mechanical behavior has been investigated. FTIR and DSC measurements revealed that the fishing ropes used in this study were composed of PP and PE materials. The elastic modulus of the composites in tensile and bending modes increased by adding the RH. While the degree of elongation decreased. The particle size of RH also affects those mechanical properties. The breaking stress and the modulus in the tensile mode substantially increased by using fine particle RH3.

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