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Application of Multilayered Paper Processing to Hybrid Random Natural Fiber Mat

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Abstract

Fiber reinforced plastic composite (FRP) has gained remarkable development because of its excellent properties, such as low density, high stiffness, high strength, corrosion resistance, long fatigue life, and so on. However, as more and more products made of FRP, the rubbish of FRP is also increasing which has become an important problem to the environment. Recycling and reusing is a noticeable method to reduce trash discharge and to save resource. Although it is a more challenging work for FRP, many researchers have report their scores in this area, such as the group from The University of Nottingham who have developed a new technology to recycle the carbon fiber. The objective of this research is to make short fiber mat from recycled carbon fiber by paperboard making method. In this method the fiber can be made into very thin layers and be laid into mat. After that the mats were used to fabricate FRP and the tensile property of the materials was investigated. The property was evaluated between recycled carbon fiber and jute fiber as well as hybrid one. It was found that the hybrid one has better performance.

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Keywords: Recycled Carbon Fiber, FRP, Jute Fiber, Hybrid Fabric;

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1. Introduction

Due its advantages on reducing waste emissions and energy consumption, saving resource and cost and environment protection, recycling and reusing have widely used around the world. One of the most successful applications is recycling paper. The Energy Information Administration claims a 40% reduction in energy when paper is recycled versus paper made with unrecycled pulp. In 2004 the paper recycled rate in Europe was 54.6% or 45.5 million short tons and the rate are still growing every year. About waste paper recovery rate and availability in Japan, when the recovery rate was 57.7% in 2000, the availability was approximately equal to 57%. The trend is showed in Fig. 1. However, when the recovery rate was 77.9%, availability became 63.0% in 2010.

The difference between this recovery rate and reuse rate was export to China and main Asia. When it was converted into quantity of collection, the quantity of use become 17 million tons under the 21 million ton of quantity of collection and will be exported approximately 4 million tons.

There is a problem of the wastepaper in 2015. Asia will not demand wastepaper from Japan because a domestic recovery goes up. Then, wastepaper will overflow in Japan. As well as recycling from wastepaper to paper, new recycling is necessary.

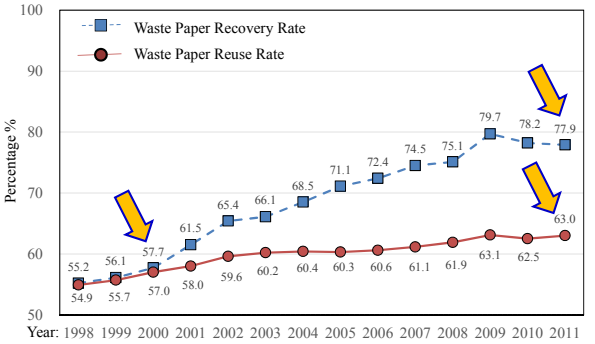

Fig.1 Waste paper recovery and availability in Japan

The similar situation is also happened on FRP. The method and the recycling thoughts can be used in FRP recycling. Due to its versatile properties, FRP has been used in various areas for several decades, such as aircrafts, automobiles, ship building and housing products [1-4]. The demand for carbon fiber approximately 35000t in 2008 and this number is expected to double by 2014 with a growth rate of over 12% per year.

However, as more and more products made of FRP, the rubbish of FRP is also increasing which has become an important problem to the environment. The waste of FRP includes out-of-date pre-pregs, manufacturing cut-offs, testing materials, production tolls and end-of-life components. Manufacturing waste is approximately 40% of all the CFRP waste generated, while woven trimmings contribute with more than 60% to this number [5]. The abandoned composite has an unsatisfactory influence for several reasons, including environmental impact, legislation, production cost, management of resources and economic loss.

Recycling fiber includes two resources, fiber waste from fiber manufacture factory and FRP waste. Compared with directly recycling of fiber waste, FRP waste recycling is not an easy work because of (i) their complex composition (fibres, matrix and fillers), (ii) the crosslinked nature of thermoset resins (which cannot be remoulded), and (iii) the combination with other materials (metal fixings, honeycombs, hybrid composites, etc.) [6].

Two technology families have been proposed to recycle CFRP according to [7]: Mechanical recycling and fiber reclamation.

Mechanical recycling involves breaking-down the composite by shredding, crushing, milling, or other similar mechanical process; the resulting scrap pieces can then be segregated by sieving into powdered products (rich in resin) and fibrous products (rich in fiber) [8].

Fiber reclamation consists on recovering the fiber from the CFRP, by employing an aggressive thermal or chemical process to break-down the matrix (typically a thermoset); the fiber are released and collected, and either energy or molecules can be recovered from the matrix.

The objective of this research is use paper recycling facilities to make recycling fabric. For paper recycling, various types of wastepaper, including newspaper and corrugated cardboard, a paper pack, poor-quality paper and office wastepaper, cast into water of a big mixer which called the pulper and untie fiber. The fiber was molded which came loose into a seat form, and the paper is made muddy when dried.

In this process, various products were used, for example the decoration sweets of the cigarette, the package of the sweets and the cover of the notebook.

A principle to make the paper which became muddy like sheet is showed in Fig. 2. At first the fiber which became muddy collects in the room called the bat, and the big net called the cylinder spins around in the room, and the clutches scoop muddy fiber.

The scooped fiber contacts with a felt-formed blanket and it becomes the seat by water being squeezed and shifts to a blanket. Similarly, fiber shifts under the seat which even the next bat added to a blanket some time ago, and a layer is formed. The cardboard of 8 layers or 9 layers is made by repeating this 8 times or 9 times. Therefore 8 or 9 layers mat could be made by this process.

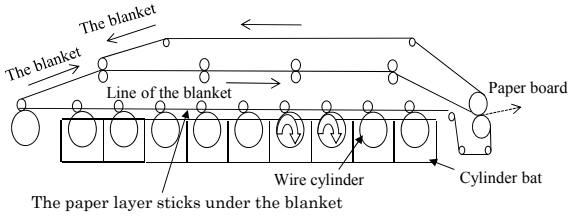

Fig. 2. Fabrication process of paper

After fabricating the mat fabric from paper recycling method, hand layup method could be conducted to make composite. In this research, recycled carbon fiber, jute fiber and resin fiber were used to make mat fabric as well as hybrid ones. Composite plate was fabricated by hand lay-up. Then, tensile test was followed to evaluate the mechanical property.

2. Experiment

When a new wastepaper and fiber thing experimentally whether it is available, it can make into a seat form by a method called handmade paper. This is the first step to examine the feasibility of this research. The handmade paper was used to fabricate composite plate by hand lay-up method.

2.1. Materials

Carbon fiber, Jute fiber, resin fiber (PE) were used in this study. The Fig.3 shows the recycled carbon fiber and jute fiber.

The handmade paper of fiber was made. Comparing the properties of materials was performed after molding into a seat form of FRP.

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2.2. Handmade paper

Fiber and water and make density were mixed by approximately 2% and stir it with a mixer for 30 seconds.

Fiber was scooped with a net and dried with an iron after molding into a seat form afterwards.

2.3. Materials and Fabrication

Unsaturated polyester resin (Showa: RIGORAC 150HRBQNTNW） was used as matrix. (Polymer was mixed with the hardener MEKPO (PERMEK N; NOF Corporation) in a ratio of 100:0.7).

The composite plate was fabricated by hand lay-up method. After fabrication, the materials were disposed on dies in 24 hours for cure. Post cure was followed in the condition of 100 oC maintained 2 hours.

2.4. Mechanical Properties Test

Tensile test and bending test were performed by using an Instron universal testing machine under a speed of 1 mm/min. Strain gage (KYOWA KFG-10-120-C1-11) was used to measure the strain during testing process. Bending test was performed on 4 plies specimens.

Carbon fiber Jute fiber

Fig. 3 Carbon and jute fiber

Fig. 4 Handmade paper mat

3. Results and discussion

3.1. Handmade paper (Single piece of material)

The recycled jute fibers and carbon fibers were used to make mat in this research. The fibers and mat are shown in Fig. 4. It was found that it was difficult to make mat by only carbon fibers because the fiber length was short and the linkage was week between fibers. Compared to carbon fibers, the jute fibers was better to make a mat form fabric. However, the linkage was also week for making composite through hand lay-up method. It was also found that some lump during this process.

Fig. 5 PE fiber

Because the week linkage between different fibers, it was difficult to make hand lay-up. A modification was applied by using resin fibers (PE fibers). The PE fibers and the PE fiber mat is shown in Fig. 5.

3.2. Handmade paper (Combined with resin fibers)

The manmade paper was made combined with PE resin fibers. Mixing ratio with 30% and 50% of PE fibers in weight was used here. After mixing different fibers into mat form, the fabrics were dried and disposed with hot compress.

Fig. 6 Recycle fibers mat combined with PE fibers

3.3. Tensile Test

The composite specimen was prepared by hand lay-up method. The stress-strain curves of tensile test are shown in Fig. 7. In the PE 30% group, 1 ply of carbon composite has highest modulus and strength. Jute fiber composite has lowest modulus and strength. The hybrid one was in the middle. In the PE 50% group, the tensile results of hybrid one was very close to carbon fiber composite.

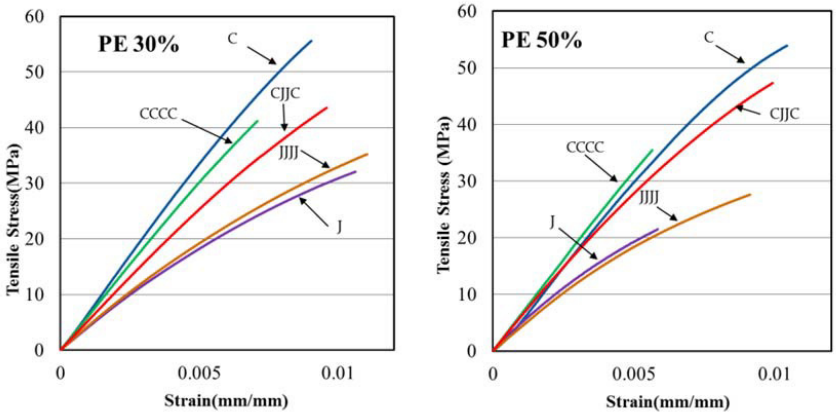

Fig. 7 Stress-strain curve of different specimens

The young's modulus results are shown in Fig. 7. From the results, it was found that the modulus was very close in C, CCCC, JJJJ, and J type specimens between PE30% and PE 50% specimens. But for CCCC and CJJC specimens the modulus was higher in PE 50% specimens.

The tensile strength results are shown in Fig. 9. From the results, it was found that the strength was higher in PE 30% specimens compared with PE 50% specimens except CJJC specimens. But for CCCC and CJJC specimens the modulus was higher in PE 50% specimens.

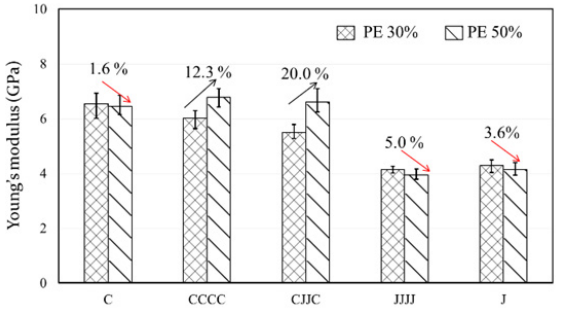

Fig. 8 Results of Young's modulus

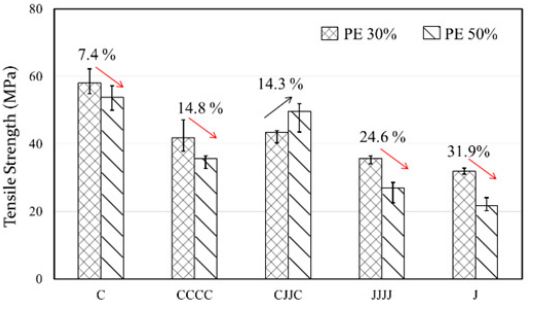

Fig. 9 Results of tensile strength

3.4. Bending Test

The bending test was conducted on 4 plies specimens, such as CCCC, CJJC and JJJJ type specimens. The results of bending modulus and bending strength are showen in Fig. 10 and Fig. 11 respectively. From the modulus, it was found the bending property of hybrid specimens are very close to CCCC specimens and much higher then JJJJ specimens.

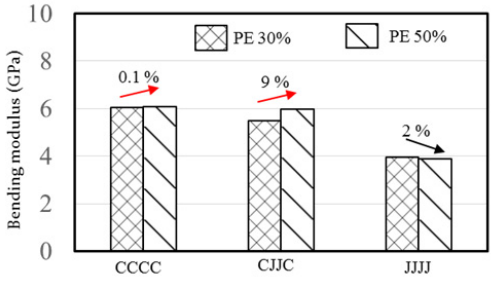

Fig. 10 Results of bending modulus

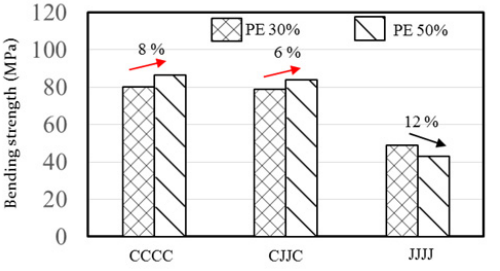

Fig. 11 Results of bending strength

The bending strength also shows similar trend which was consider the hybrid structure can effectively take advantage of each materials in bending test.

3.5. Scanning Electron Microscope (SEM) Observation

The SEM observation was conducted on failure specimens from tensile test. The observation results are shown in Fig 12 and Fig. 13 respectively.

From the observation of 30% PE fibers specimens, it was found that the many fibers were pulled out during tensile test.

Compared to the observation of 30% specimen it was found that the PE fibers were melted during fabrication process. The carbon fibers and PE were mixed together. Many carbon fibers were pulled out from melt PE.

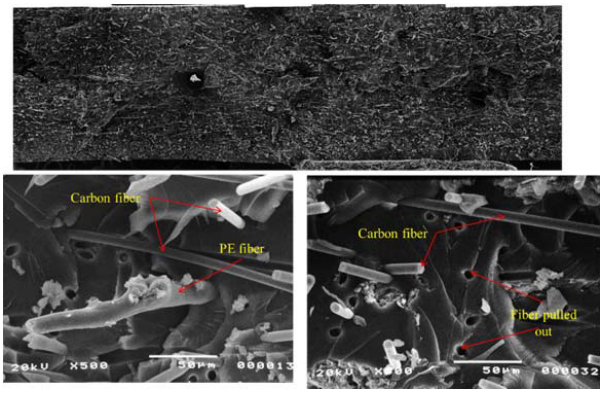

Fig. 12 SEM observation of tensile specimen with 30% PE fibers

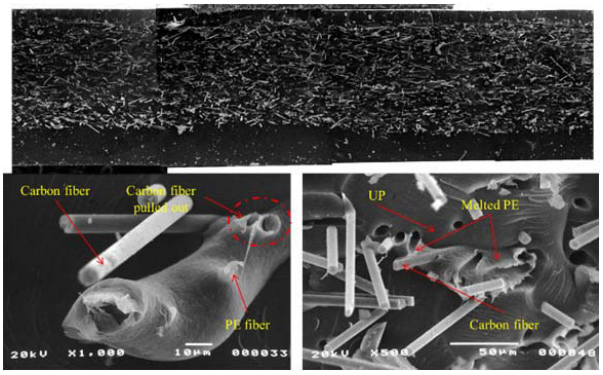

Fig. 13 SEM observation of tensile specimen with 50% PE fibers

In order to explain the results of the SEM observation and relation with mechanical property, a sketch is shown in Fig. 14.

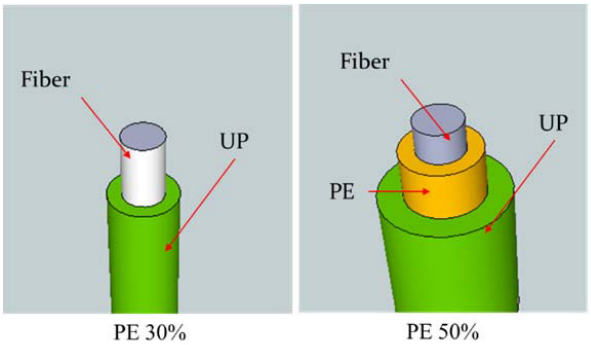

Fig. 14 Sketch of interface condition of specimen with PE fibers of 30% and 50%

The sketch illustrated that most of the fibers in 30% PE contents was directly contact with UP, but for 50% PE specimen, most of the fibers were directly contact with melted PE. It was supposed that the interface was strength between fiber and UP compared to PE which caused higher modulus but lower strength in 50% PE specimens.

4. Conclusion

In this study, recycled carbon fiber and Jute fiber were used to fabricate composite as well as resin fiber (PE). In order to utilize the advantage of jute and carbon fiber, the hybrid type mat was developed. The following conclusion was obtained.

(1) It becomes a sheet Mixing 30% of resin fibers carbon fibers and jute fibers, and can be used in the machine
(2) The elastic modulus was improved and the hybrid structure jute fibers and carbon fibers.
(3) From the SEM observation, it was found that most of the fiber was directly contact with PE in 50% PE specimens which caused it had higher modulus and lower strength in tension.

Acknowledgements

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