IMPROVEMENT OF MECHANICAL PERFORMANCES OF CARBON FIBER/EPOXY COMPOSITES BY INCORPORATING NATURAL NANO MATERIALS

Gibeop Nam, Chang-uk Kim, M. N. Prabhakar, *Song Jung-il

Department of Mechanical Engineering, Changwon National University
Changwon-si, Gyeongsangnam-do, 51140, Republic of Korea
*Corresponding author: jisong@changwon.ac.kr

Keywords: Carbon fiber reinforced composites, Carbon nano tube, Graphene nano plate, Natural material

ABSTRACT

The improvement of mechanical properties of carbon fiber reinforced composites (CFRP) were achieved by surface treatment and resin modification. Those methods are mainly increasing the interfacial share strength between fiber and matrix. However, some of these methods caused damage on fiber surface and decreased elongation ratio of matrix. Therefore, one of the physical method to overcome the above problems is to reinforce nano materials through affordable extraction from such as carbon nano fiber (CNF), carbon nano tube (CNT), graphene nano plate (GNP) and PET nano fiber were used for improving mechanical properties of CFRP [1, 2]. Present study natural nano materials from renewable waste resources were used for replacing previous nano material such as CNT and GNP. Nano materials can increase mechanical properties of CFRP. However, carbon fibers, CNT and GNP are high cost in the market so it has limited application for composite. In this study, tried to find replacing manmade nano material to natural materials with consisted cost and composition of material, i.e., rice husk, rice husk ash and Korean rice wine waste.

Rice husk is a waste bi-product consists high percentage of Si. Literature, some of the researcher study this material for reinforcement of composites as short fiber, so applications and properties are limit. However, if it used as an additive powder for additional natural material for CFRP, so that can avoid limit of fiber length. In addition, low temperature burning treatment on rice husk is an effective and economic way to extract silica there by remove the other weakly bonded constitutes i.e., cellulose, hemicellulose and lignin [3]. The effect of rice husk ash might be increase the wear and friction properties. Preparing rice husk powder by milling is a most simple process. The Korean rice wine (commonly called 'Makgeolli') is a residue left after drained rice liquor, and it has cellulose made by yeast [4]. which has the capable to use as nano material for replacing carbon nano filler. Another hand, the extraction of cellulose nanofibers is mostly based on mechanical nano fibrillation processes relying on expensive devices. Hence, this study assesses low-cost alternative processes of nano fibrillation based on affordable methods like filtration and bio-waste materials. The choice of an adequate source of cellulose and the use of inexpensive fibrillation devices might be decrease the cost of nanofiber extraction process, so as to benefit to the environment as well.

1 INTRODUCTION

The fiber reinforced composites(FRC) are primarily matrix cracking including transverse cracking, debonding between fiber and matrix, delamination between layers. Unidirectional fiber reinforced FRC has benefit to easy to design. It does not have merits of woven fabric reinforcement such as; balanced properties and exhibit excellent drivability reducing manufacturing cost. Many studies were conducted to significantly improve the mechanical properties of FRC by arresting/trapping/delaying the growth of those damages due to an addition of nano fillers to the matrix, such as nano silica, nano rubber particles, nano clay, nano fibers including carbon nano tubes (CNT), nano polyvinyl alcohol (PVA) fibers, cellulose nano fiber and carbon nano fibers [?-?]. Many studies have been conducted to understand the effect of nano fillers. Nano fillers in polymer matrix can delay the onset and propagation of matrix cracks and delamination, which must resultantly increase the mechanical

properties of carbon fiber reinforced composite(CFRC). However, new materials are needed to more apparently over limits its application.

Nano rubber particles, cellulose nano fiber and carbon nano tube can increased mechanical properties and fatigue life of carbon/epoxy composites. But these material cost and carcinogenicity limit its application. Moreover, carbon nano tube based petroleum and other material also need time and energy for producing.

Bio waste material such as rice husk and rice wine draff is second material for own product it usually just waste and useless material it means it does need to compare traditional market competition, such as PLA which usually made by corn have a competition with world food market and common natural fibers(jute, kenaf and etc.) need to competition with clothing market. So it does not get an effect from market price changing. And also it is an independent with petroleum resource moreover if bio waste materials are used for industry, disposal cost of waste will be decreased.

Rice husk is bio waste from rice faming. In Korea, rice producing is around 4.2million tons(2016) it is most largest percent of Korean agriculture. So huge amount of rice husk also produced until now it mostly used for compost or livestock housing. However, it also can use for reinforcement for composite. it has consists high percentage of Si(around 20wt%). In addition, low temperature burning treatment on rice husk is an effective and economic way to extract silica there by remove the other weakly bonded constitutes i.e., cellulose, hemicellulose and lignin [3].

Rice wine (commonly called ‘Makgeolli’) draff is also one of bio waste. The Makgeolli brewery use filter for gathering that after brewing. The bacterial consumed starch and carbohydrate part so very small size of dietary fiber part is left. Usually until now it just use for compost. Therefore, if it used for composite save the cost and eco-friendly material.

Literature, some of the researcher study this material for reinforcement of composites as short fibers, so applications and properties are limit. However, if it used as an additive powder for additional natural material for CFRP, so that can avoid limit of fiber length. In this study, the effect of rice husk powder, rice husk ash powder and rice wine draff on the mechanical properties incorporating CFRP and natural fiber observing are investigated.

2 EXPERIMENTAL METHOD

2.1 Rice husk powder(RHP)

The rice husk was prepared 24hours dry in 60℃ oven. Than ball mill was used for making powder.

2.2 Rice husk ash powder(RHA)

The rice husk was prepared 24hours dry in 60℃ oven. Than using electronic over 220℃ during 15mins for carbonization. After carbonization ball mill was used for making powder.

2.3 Rice wine draff(RWD)

Using filter rice wine draff was collected from rice wine. Rice wine draff is always supplied as liquor slurry since rice wine draff is very hydrophilic. The solvent exchange method with ethanol was used to remove the water in RWD. Also still the bacterial is alive in draff so high percentage ethanol was used for pasteurization. During 3hour dried in 60℃ oven. Than ball mill was used for making powder.

2.4 Preparation of carbon fiber reinforced epoxy composites

Uni- directional carbon fiber sheets and epoxy(YD-128, Kukdo) were used for composites. 8layer sheets were laminated by the hand lay up method[0/90/0/90/90/0/90/0]. Incorporating materials (RHP, RHA, RWD) were mixed with epoxy and epoxy harder by 3 roll mill method. Then, using Vacuum Assisted Resin Transfer Molding was used for manufacturing. After resin impregnated to sheet heat pressed(150℃) 2hours.

2.5 Mechanical tests

Tensile strength and modulus of the composites were calculated in this study using tensile testing. ASTM D3039 was followed for composites testing. The tensile testing was carried out using MTS 97 kN load cell by adjusting the head speed to 1m/min. To measure the strain readings, MTS extensometer model 634.11F-24 was used. Bending behavior of materials can be evaluated by Flexural test. Three points bending test was conducted in this study according to ASTM D790 guidelines. In this test, a rectangular specimen is bent by a vertical load between two supports. The load is applied until the outer surface of the specimens is ruptured, strength at rupture is called flexural strength of the specimen.

3 RESULTS AND DISCUSSION

3.1 Tensile test

The effect of RHP and RHA addition on the static tensile properties of carbon fiber reinforced epoxy composites is shown in Fig.1. With this results over mount of incorporating material can caused decreased static mechanical properties. Specially few hundreds of nm case can decreased CFRP but those material with 2nd filler MFC, whose transverse dimensions and longitudinal length are 5–20 nm and from 10 nm to several mm case can increase more higher then when they only used MFC[5]. We can guess nano material has Van der waals force so it hard to spread in matrix but first filler can help to homogenised so our next work will incorporating more small material such as; Korean rice wine draff.

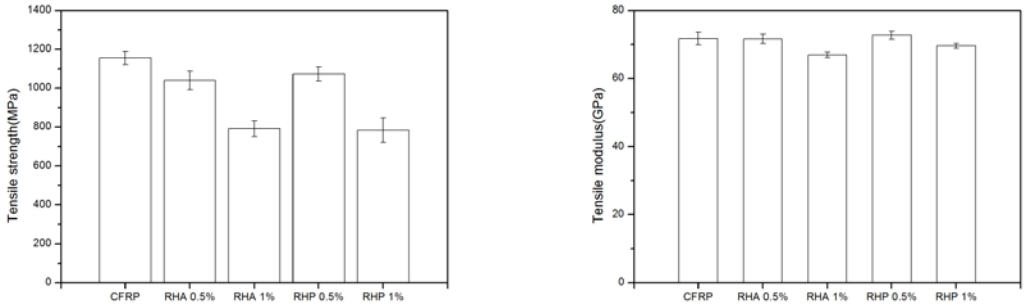
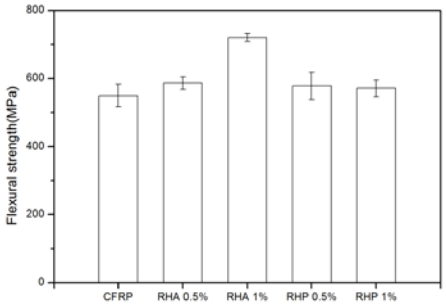


Figure 1: Tensile test results of CFRP with incorporating RHA and RHP.

The effect of RHP and RHA addition on the static flexural properties of carbon fiber reinforced epoxy composites is shown in Fig. 2. Incorporation cases increased flexural strength than only epoxy used for matrix. With tensile test incorporating material can cause crack when combine RHA and RHP but 3 points bending test got a less effect than tensile test.



.

Figure 2: 3point bending test results of CFRP with incorporating RHA and RHP.

3.2 EDS analysis

Fig. 3 and 4 shown EDS images of CFRP and CFRP cross section area without incorporating material (Fig. 3) cannot be observed Si but with incorporating 1% RHA Si was observed. Epoxy and carbon fiber do not have Si in their own so it can prove VARTM can use for manufacturing CFRP with incorporating method.

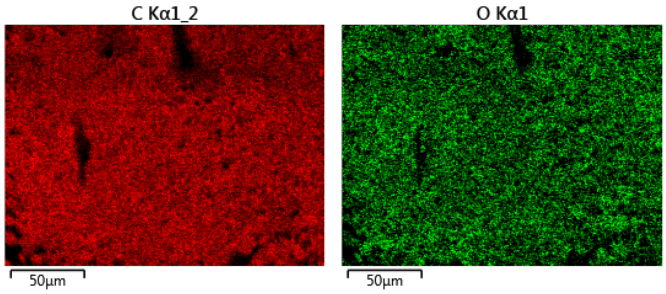


Figure 3: EDS images of CFRP.

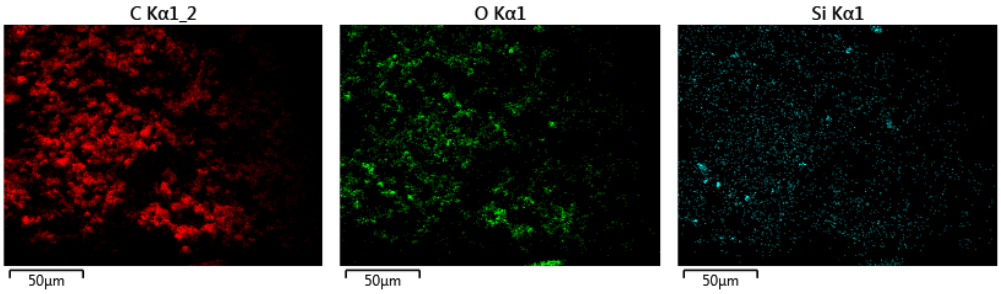


Figure 4: EDS images of CFRP with 1% RHA

9 CONCLUSIONS

The experimental study presented in this paper was focused on effects of epoxy resin with bio waste material RHP and RHA on tensile test and 3 points bending test of carbon unidirectional fabric reinforced epoxy composites. RHA and RHP does not provide relevant variations of static tensile strength and modulus, while the flexural strength increases of about 20% for a mix of RHA 1%. EDS observations of the fracture surface of incorporated specimens when Si tracking incorporation material well spread into the specimens.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Government of the Republic of Korea (Ministry of Science, (NRF-2017R1C1B2012027).

REFERENCES

[1] Fujii T., Okubo, K. et al.; “Effect of cellulose nano fiber (CNF) on fatigue performance of carbon fiber fabric composites”, *Composites: Part A*, **76**, 2015, pp. 244-254.

[2] Fujii T., Okubo, K. et al.; “Improvement in the mechanical performances of carbon fiber/epoxy composite with addition of nano-(Polyvinyl alcohol) fibers”, *Composite Structures*, **99**, 2013, pp. 380-387.

[3] Reports of the government industrial development laboratory, Hokkaido, **59,** 1992

[4] Yun-Sang Choi, Kwaon-Sik Park, et al.; “Quality characteristics of reduced-fat frankfurters with pork fat replaced by sunflower seed oils and dietary fiber extracted from makgeolli lees”, *Meat Science*, **93**, 2013, pp 652–658.

[5] Valter Carvelli, Andrea Betti, et al.; “Fatigue and Izod impact performance of carbon plain weave textile reinforced epoxy modified with cellulose microfibrils and rubber nanoparticles”. *Composites: Part A*, **84**, 2016, pp. 26-35.