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폐FRP 선박으로부터 섬유보강재 추출공정 개선 연구

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Developing a Study on the Extracting Method of Laminated Glass Fiber from FRP Boats

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요 약

폐FRP 선박을 재활용하는 기술은 많은 발전을 이루어왔으며 최근에는 가장 재활용도가 적은 부분인 유리섬유의 고부가치화 재활용이 특히 주목받고 있다. 폐FRP 선박의 재처리 과정에서 추출된 유리섬유는 피막된 수지 성분의 내화학성으로 인하여 섬유보강재로서 사용 가능하다는 것이 보고되었다. 그러나 섬유보강재(laminated glass fiber reinforced material)를 추출하는 공정의 효율성과 경제성의 재고는 개선되어여할 과제이다. 본 연구는 다층구조인 FRP로부터 면포층(roving cloth layer)을 보다 효과적으로 박리할 수 있는 방법을 제시하여 추출공정의 최적화를 도모하고자한다. 새로운 추출공정에서 생산된 섬유보강재를 활용한 섬유강화콘크리트(Fiber Reinforced Concrete, FRC)의 강성은 매우 우수한 것으로 관찰되었다.

Abstract – There is several ways of recycling methods for waste FRP boats. The main one is mechanical recycling that is one of the simple and technically proven methods. It recently has been reported that FRP can be recycled by separating into laminated glass fiber layers instead of crushing into powder. Even though the mechanical recycling is a good way for the eligibility of laminated glass fiber reinforced material, the system should have another option which can collect resin of FRP. Because the resin is still very useful renewable energy source, that cannot be discarded, But FRP is made up of laminated glass fiber (roving cloth layer) which is fire retardant substances and very hard to break into each layer. Due to the high cost of fossil energy the waste plastics should be regenerated to the source of renewable energy. Laminated glass fiber which is recyclable in a very limited way, is currently a serious barrier to waste FRP boat regenerating. This study is to propose a new extracting method which is efficient and environment friendly FRP waste regenerating system. The recycled glass fiber which is obtained by the separation of the roving layer from FRP waste has been found to be useful for concrete(FRC) products or concrete(FRC) structures as fiber reinforced material. And it can be successively applied to renewable energy applications using the waste resins of FRP residue without laminated glass fiber.

Keywords: FRP Laminated Glass fiber(FRP섬유보강재), FRP Boats(FRP선박), FRP waste Boat Regenerating (폐FRP선박 재자원화), Eco-friendly Mechanical FRP Recycling(친환경적/기계적 FRP 재활용), Fiber Reinforced Concrete(섬유보강콘크리트)

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1. INTRODUCTION

Many mechanical methods to recycle the FRP waste boats have been developed last several decades. There are two major ways of mechanical recycling covered in the literature (Majumdar[1975], Defosse[2003], Shoji[2003], Jang *et al.*[2006], Yoon[2008]). First class is the traditional mechanical recycling which involves shredding (grinding) of the scrap FRP in a new product or scraping of FRP in a fiber reinforced material. The process solely depends on the mechanical efficiency of recycling. The second and newly developed one enforced additionally FRP recycle focusing on the regeneration/renewable energy. But "Incineration" combustion of FRP scrap with energy or "thermal" recycling of FRP scrap, known as pyrolysis is the current method of the regeneration. After all the mechanical method should be considered with not only the efficiency but also the recycled residue as the regenerating or renewable sources in FRP boat recycling (Bartholomew[2004], Shibata and Zairyo [2006], Yoon[2008]).

Despite of the safety hazards, mechanical recycling is one of the simple and technically proven methods. While the effort has been made in mechanical recycling of FRP used for the medium-to-small size ships, researchers(Yoon [2007], Yoon *et al.* [2008]) try to find out the methods more favorable for the environments and more value-added. In respect to the fact that the FRP consists of two types of layers, roving cloth and fiber glass mat, differentiated by the 2-dimensional structure (Fig. 1), our group was able to extract the laminated glass-fiber layers of FRP instead of scraping it (Yoon *et al.* [2008]). In the early study, the roving cloth was cut to only the chip sizes (about 8×8 or 16×16 mm) (Yoon[2007]). FRP waste in the new method using the mechanical properties of FRP(polymers and composite) with the orthotropic and laminated plastic structure has been easily separated to laminated glass-fiber layer(roving cloth) and residue (mainly mat with resin). It can separate whole roving cloth layer from FRP waste. These resin coated roving glass fiber layers (laminated glass-fiber layers) increased tensile and bending strength and chemical-resistance mainly due to the remained resin (about 25% by weight)(Lee *et al.*[2008]). Many experiments using laminated glass-fiber layers have been performed. FRM (fiber-reinforced mortars) and FRC (fiber-reinforced concrete) product are made of the roving fiber from a new recycling system of FRP waste boats. The collected results imply that

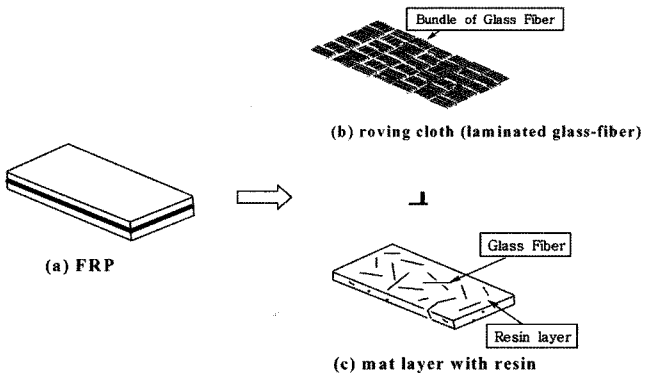


Fig. 1. Scheme of extracting mechanism of laminated glass-fiber.

recycled glass fiber can be applied to the 'fiber reinforced mortar/concrete'. Furthermore laminated glass-fiber layers due to strong durability, may be new eco-friendly (Yoon *et al.* [2008], Lee *et al.* [2008]).

The new extracting FRP recycling system is a total commitment to the evolution of ship-based extracting optimization (evolution with optimal separation) (Fig. 1), separating through the whole body of a boat (bottom or side), and being capable of variations of composition shapes (regular or irregular). In addition, due to the power-saving effects and reducing noise and dusts, new recycle system may enhance the economic efficiency and eco-friendly characters.

Fig. 2. shows standard laminated glass fiber of waste FRP as regenerated product. Also Fig. 3 shows commercial fiber and laminated glass fiber of waste FRP both can be applied for FRC.

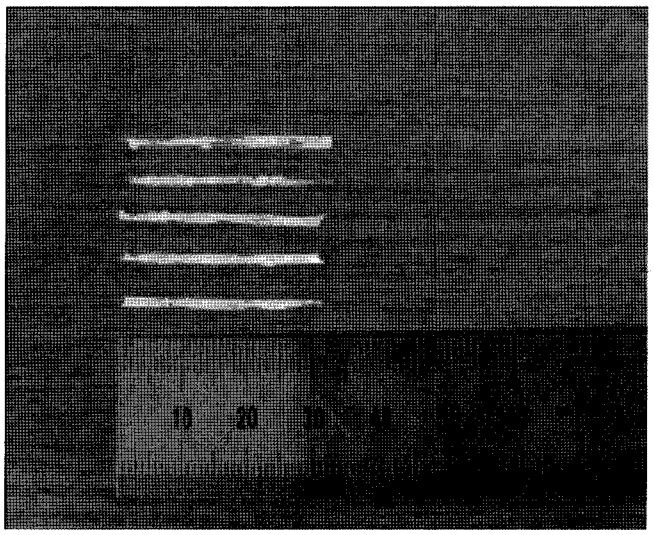
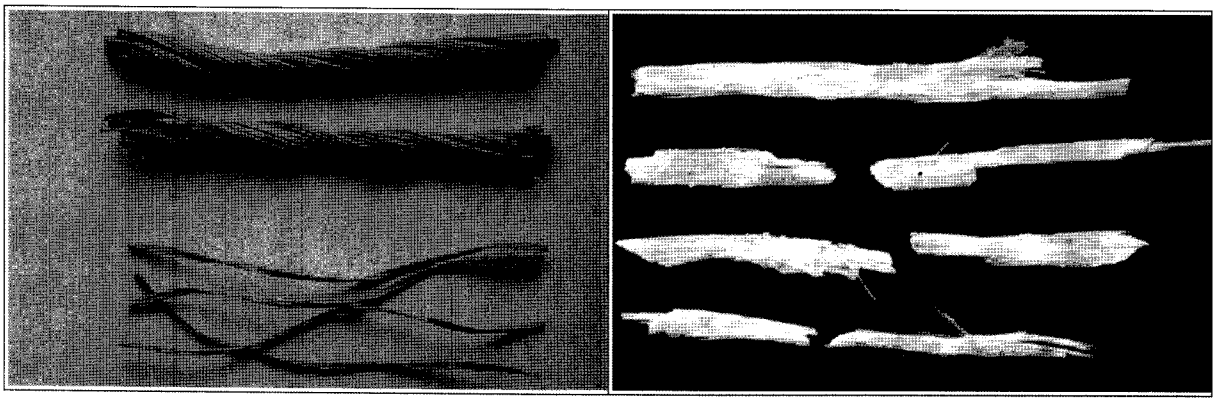


Fig. 2. Standard laminated glass fiber of waste FRP.



(a) (b)

Fig. 3. Sample of (a) commercial fibers and (b) laminated glass fibers of waste FRP.

2. MECHANICAL METHODS

The FRP in ship building is formed by 3 types of glass fiber and resins, that is, surface mat, roving cloth and fiber glass mat. Resin is inserted between the glass fibers for bonding and shaping FRP. The reason why the laminated glass-fiber layer of FRP boats is very crucial to regenerating FRP recycle is that more than 60% of FRP boat composition is resin. In addition, FRP residue without laminated glass-fiber layer should be composed of 83% to 96% of resin (Lee *et al.*[2008]). FRP is an orthotropic and of laminated plastic structure. As FRP boats are exposed to ultraviolet light and water for several decades, the gap between the roving cloth and mat would degrade the strength and lose the bonding endurance. Therefore the cutting (separating) energy of FRP waste boat will not be needed as much as in the initial stage (Yoon[2008], Yoon *et al.*[2008]). That process produces less noise and dust because of relatively very small fracturing energy. Because FRP is shaped with many types of glass-fiber and resin, the most effective way of the waste FRP mechanical processing (Yoon[2008], Yoon *et al.* [2008]) is cutting the layer which is an eco-friendly assortment processing plan with applying complex material quality. However, this method cannot separate roving cloth or laminated glass-fiber in the original multi layers. Another defect is that great amount of resin component is also shattered during the process.

Hence, this study focuses on the exfoliation of mat and roving cloth from composite layer structure of FRP, as shown in Fig. 1. In other words, it is a method which separates layers by inserting an edged tool between roving cloth and mat containing resin.

2.1 Extracting Layers from FRP

New extracting mechanism was introduced to separating the hand lay up FRP (boats) into the relatively soft layer (chopped strand mat) in multi layer structure. Fig. 1 describes a driven overview of extracting (separating) system. Non automatic methods like the hand lay up method have prevalently been used in forming FRP boats. This method is carried out on molding using a roller. After piling up surface mats, do the same with mats and roving clothes to the thickness and strength required. This is a universal method, broadly applied from complex shape to simple small or large shapes. Moreover, one could partially modify components of fiber in layering process or insert other reinforced substance through this method, allowing changing thickness and strength if necessary. Therefore, composition of roving cloth in FRP boats appears in various forms. A broad spectrum can be seen from cases where mat and roving cloth are accurately arranged to cases where position of roving cloth is random or diverse compositions lie scattered about. For this reason, this study designed two methods; Multi-extracting system of laminated glass-fiber for cases for regular composition, also single extracting system with waste FRP driven method or method in which transporting edged tool while FRP is fixated for random composition.

Principal part of the recent extracting system of laminated glass-fiber, consists of layer cutting mechanism, that is an extracting mechanism of laminated glass-fiber. Exfoliating function is the essential factor of this system; this extracting system separates roving cloth and mat, into a single layer.

Thickness of cut waste FRP is around 1 mm and width ranges from 30 to 50 mm. Compared to the existing shred-

ding system (Yoon[2008], Yoon *et al.*[2008]), the multi-extracting system greatly improves the mechanical efficiency, stability, and curtailment of dust and noise; its biggest advantage is that it makes extraction of glass-fiber layer possible. This substantiates the application possibility of extracted glass-fiber as reinforced fiber for FRC purposes. The multi-extracting system can extract of roving cloth from FRP waste, which could substitute the costly imported FRC.

Glass-fiber from the current shredding system had limitations as a reinforced fiber because of its long fiber's length, 16 mm at maximum, which is far shorter than existing FRC fiber of 50 mm. This study made extraction of long glass-fiber longer than 50 mm possible from waste FRP for the first time.

2.2 Preparation of Laminated Glass-fiber from Roving Cloth

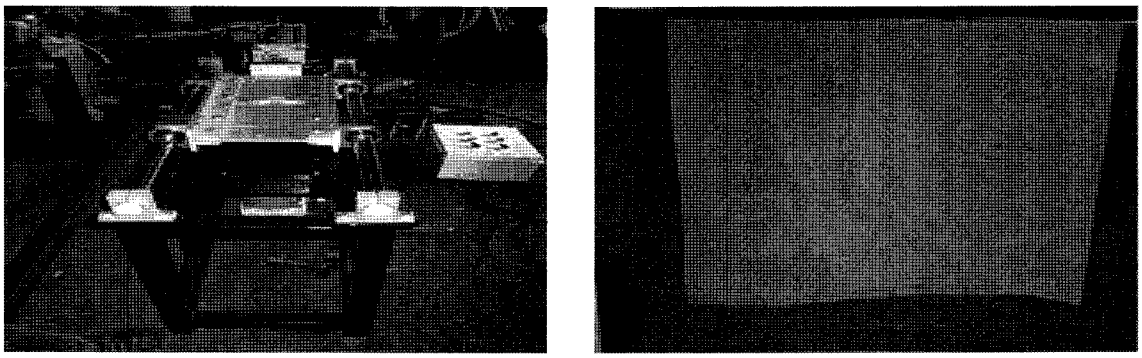
Although the multi-extracting system has high production efficiency, it cannot accommodate the diverse forming component of FRP boats. To improve this defect, patented single extracting system of laminated glass-fiber was developed. This method allows control of extracting system for all composition of FRP and establishes diverse administration system for the separation of roving cloth.

Fig. 4 shows a single extracting system of laminated glass-fiber. It is now being operated in pilot plant stage. That is greatly supported by administration of the multi-extracting system. The main difference is which part will be driving in the extracting system of laminated glass-fiber. In new system, it can be applied to any combination of mat and roving cloth of FRP boats. In addition the dimension or size of laminated glass-fiber layer also could be varied for necessity.

Fig. 5 shows the shredder machine and products(laminated roving cloth) after process of the single extracting system.

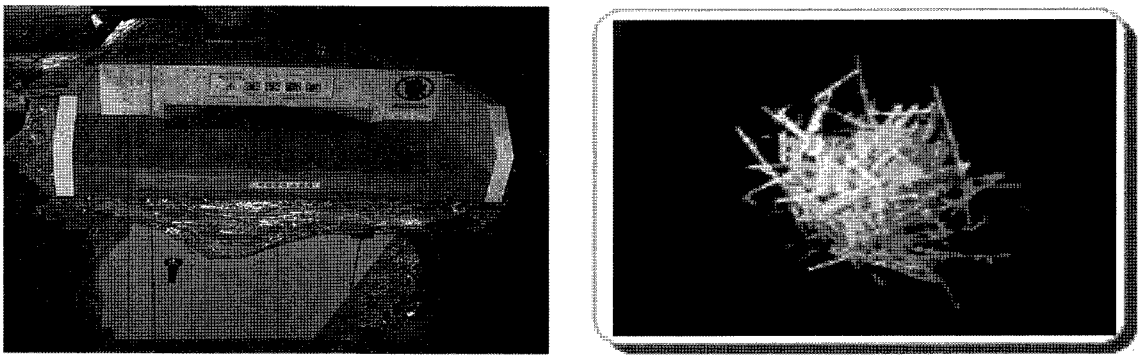
2.3 Active Extracting System of Laminated Glass Fiber

There is still some study going on transporting edged tool while FRP is fixated for random composition. That could be great adjusting to varying composition of FRP boats and separating laminated glass-fiber layer. To increase efficiency and regenerations of recycling FRP boats, disjointing crusher operation should require eco-friendly and regenerating oper-



(a) (b)

Fig. 4. Extracting system and laminated roving cloth.



(a) (b)

Fig. 5. The shredder machine and product(laminated glass fiber).

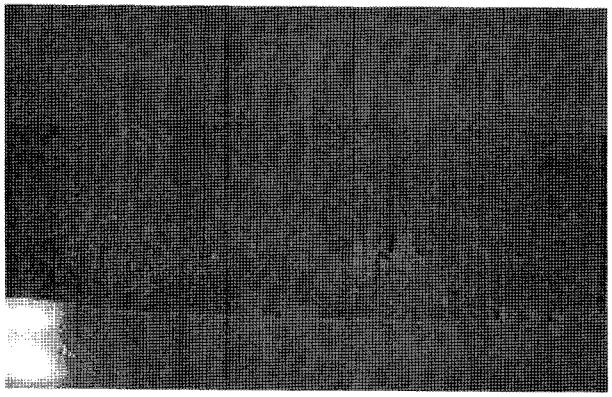


Fig. 6. Sample of laminated glass fiber layer from active extracting system.

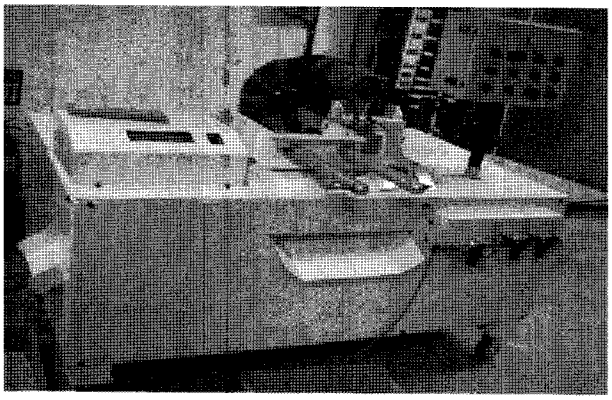


Fig. 7. Active extracting system of laminated glass fiber.

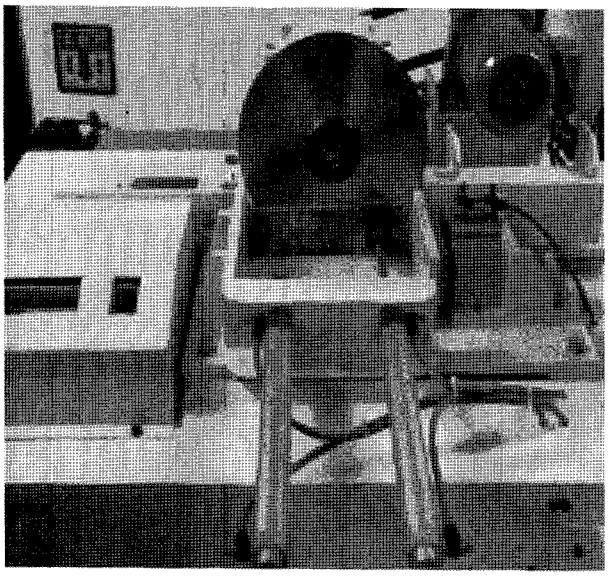


Fig. 8. New extracting mechanism.

ations. Fig. 6-7 was new modeling of recycling FRP boats process which also indicated that the active (flexible) process considered.

Fig. 8-9 is a fair bulk of the real extracting system. Noise and dusts are reduced favorably due to separating process

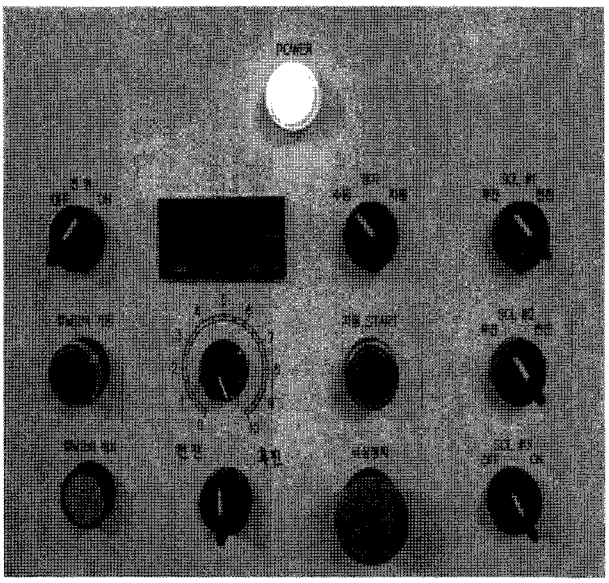


Fig. 9. Control panel of the system.

instead of shredding which is very effective process for regenerating the FRP waste. All of the open portions of the system are sealed to prevent the passing the dust and noise out. Directly under the blade, the circulated air facilitates this process and inhales the dust into the hall to prevent from emitting out. Inside the hall a rotated screw tool shreds the laminated glass-fiber layer into glass fiber, at the same time prevents dust and glass/resin powder scattering out. The separation between the mat and roving cloth layer is preceded in top of system.

Composite materials (FRP scraps) due to simple crushing have lost the matrix structure and strength, but laminated glass fiber layers of new system still is to be remained original structure after the separating process. It can be seen easily by the structure of layer (Fig. 6). The cross cutting mechanism with approaching to the tangential direction of the evolution of FRP can successfully separate glass fiber layer from FRP waste.

3. CONCLUSION

1. New proposed mechanical recycling system is not just efficient but also eco-friendly FRP waste regenerating system. It has fundamentally reduced air pollution and shredding noise and crushing energy. Using the mechanical extracting system, FRP which has the orthotropic and laminated plastic structure, has been easily separated in the layers. Also modified separating system have been introduced for the different composition of FRP boats.

2. The roving fiber of laminated glass-fiber layer is as good as the polyvinyl fiber which is high cost commercial fiber to increasing strength of concrete products. The early study has shown the effectiveness of laminated glass-fiber layer which is also chemical-resistant due to the resin coating.

3. The application of laminated glass-fiber layer has been to be very effective and value added. The concrete product with roving fiber has been to increase compressive and bending strength and reduce weight and production cost compared with the commercial fiber.

4. The residue of FRP waste boats without laminated glass-fiber layer will be a great potential to be renewable energy, thus its process to produce shall be a promising recycle system of FRP waste boats regenerating.

The active extracting system of laminated glass-fiber layer in FRP waste should be more studied for mass production and industrialization. It will also be eco-friendly regenerate recycling of the troublesome FRP waste.

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