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FRP선박의 일괄 재처리 방법의 개선

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Developing Advanced Total Recycling Method of FRP Boats

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요 약

1990년대 이후, 중소형 폐 선박으로부터 생성되는 FRP를 재활용하기 위한 방법으로 층상으로 배열된 로빙층과 매트층을 분리하는 것은 친 환경적이면서도 경제적 재활용의 장점을 가지고 있다. 그러나 효율적으로 로빙층과 매트층을 분리하는 기술과 로빙층은 매트층에 비해 얇은 두께로 존재한다는 이유로 인해 로빙층을 매트층과 분리할 때 기계가 자동적으로 층간의 차이를 인식하는 방법은 아직 개발이 이루지지 않고 있다. 본 연구에서는 유리의 구성비가 다른 두 층의 화학적 성질의 차를 이용하여 광학적으로 층간 인식이 가능한 방법을 모색하였다. 또한 다양한 로빙층의 구성에도 자동적으로 절단위치를 분석하는 절단시스템과 최종생산물의 유용성을 확보할 수있는 다양한 크기의 유리섬유를 생산할 수있는 세단기를 개발하였다. 본 연구 결과로 광학적 인식기술과 유연한 절단기술 그리고 다양한 세단기술이 융합된 폐 FRP의 분리 공정의 단순화와 자동화를 달성하게 되었다.

Abstract – Since 1990s, the major recycling methods for mechanical recycling of FRP(Fiber Reinforced Plastics)boats has involved shredding and grinding of the scrap FRP in a new recycled product. But still it leads to secondary problem such as air pollution, unacceptable shredding noise level and few limited applications. This study is to propose a newly advanced method which is more efficient and environment friendly waste FRP regenerating system. As extracting FRP layer and making the recycled fiber for recycled-fiber reinforced concrete(RFRC) from waste FRP, the recycling process has some merits in a sense of the recycling energy and the environmental effects. In this study, for those tasks, spectro-chemical differentiation method and coloring water-soluble dye treatment makes the roving layer more distinguishable photophysically. Also that has remarkably reduced safety hazards and energy. Using the mechanical properties of polymers and composite, FRP with the orthotropic and laminated plastic structure has been easily separated in the new extracting system. Also the new method has introduced five kind of separating manuals for the some different compositions of FRP boats. The roving fiber of laminated glass-fiber layer is as good as the polyvinyl fiber which is cost-high commercial fiber to increasing strength of concrete products. The early study has shown the effectiveness of laminated glass-fiber layer which also is chemical-resistant due to the resin coating. These results imply that more efficient and environment friendly recycled glass fiber can be better applied to the fiber reinforced concrete(FRC) substitute and this study also has shown wide concrete applications with RFRC from the waste FRP boat.

Keywords: FRP Recycling(FRP재활용), Waste FRP Boat Regenerating(폐FRP선박 재처리), Eco-friendly Mechanical FRP Recycling(친환경-기계적 FRP재활용), RFRC(재활용 유리섬유 강화 콘크리트), Photophysical Differentiation Method(광학적 인식기술)

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I. INTRODUCTION

Many mechanical methods for FRP waste boats recycling have been fully developed last several decades. There are two major classes of mechanical recycling covered in the literature [1-7]. First is traditional mechanical recycling which involves shredding (grinding) of the scrap FRP in a new product or scraping of FRP in a fiber reinforced material. Those processes are solely depending on the mechanical efficiency of recycling. The second and newly one is additionally enforced FRP recycle to focusing on the regeneration/ renewable energy. But Incineration combustion of FRP scrap with energy or “thermal” recycling of FRP scrap, as also known as pyrolysis are current methods of FRP regenerating recycle. Therefore the mechanical method should consider not the efficiency but also the recycled residue as the regenerating or renewable sources in FRP boat recycling [7].

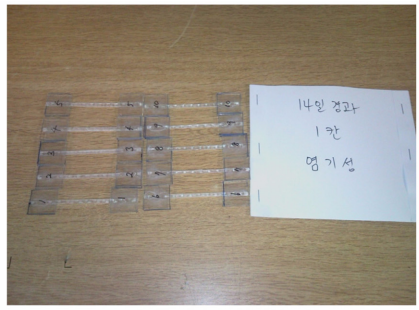
The simpler and more technically proven methods [7-10] have been interested in the recycling FRP. While the effort has been made in mechanical recycling of FRP used for the mediumtosmall size ships, researchers [7,8] try to find out the methods more favorable for the environments and more valueadded. In respect to the fact that the FRP consists of two types of layers, roving cloth and fiber glass mat, our group was able to extract the laminated glassfiber layers of FRP, the fiber glass mat was cut to only the scrap sizes (about 100×0.5 mm) [9]. These resin coated roving glass fiber layers (laminated glassfiber layers) showed increasing tensile and bending strength and chemicalresistance mainly due to the remained resin (about 25% by weight) [10]. Many experiments using laminated glassfiber layers have been performed. FRM (fiberreinforced mortars) and FRC (fiberreinforced concrete) product are made of the roving fiber from a new recycling system of FRP waste boats [10]. The collected results imply that recycled glass fiber can be applied to the ‘fiber reinforced mortar/concrete’. And furthermore laminated glassfiber layers thank to the strength durability (Fig. 1) may be new ecofriendly FRP regenerating system to the FRP waste boats [10-12].

The new extracting FRP recycling system is a total commitment to the evolution of shipbased extracting optimization (evolution with optimal separation) (Fig. 7), separating through the whole body of boat (bottom or side), and capable of composition shape (regular or irregular). In addition, due to the powersaving effects and reducing noise and dusts (totally new, patented extracting mechanism), also new recycle system has enhanced economic efficiency and ecofriendly character.

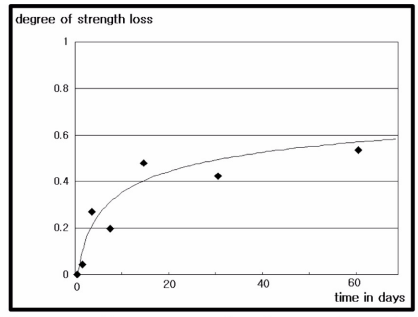
2. ECO-FRIENDLY EXTRACTING METHODS OF FRP BOATS

The FRP in ship building is formed by 3 types of glass fiber and resins, which shows types of glass fiber in FRP composition. Resin will be inserted between the glass fiber for bonding and shaping FRP. The reason why the laminated glassfiber layer of FRP boats is very crucial to regenerating FRP recycle due to the resin composition. If the recycled process has been accompanied by extracting process, then the cutting (separating) energy of FRP waste boat will not be needed as much as in other stage [7]. because of relatively very small fracture energy. Because FRP is shaped with many types of glassfiber and resin, the most effective waste FRP mechanical processing method [10] is cutting the glass-fiber layer of FRP, which is an ecofriendly assortment processing plan with applying complex material quality. However, this

(a) FRP roving layer



(b) a FRP glass fiber size (3×100×0.5 mm)



(c) Tensile strength loss by time (days) after storing in basic solution of pH 12.5 at 50℃.

Fig. 1. Roving layer of FRP and Tensile strength test.

method cannot separate roving cloth or laminated glassfiber in multi layer form which is its original form. 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 through separating layer from composite layer structure of FRP. In other words, it is a method which separates layers more easily by inserting an edged tool between roving cloth and mat containing much resin thanked to new chemical pre-treatments of FRP waste. Another effective and energy saving process is using advanced distracting and extracting system with vision system for layer differentiation.

2.1 New chemical pre-treatments of FRP waste

As one of the methods for recycling the FRP from the waste ships, separation of roving layer from the mat has some merits in a sense of the eco-friendly and economical recycling process. Similar characteristics, however, between the roving and the mat even with different ratio of the resin and the glass and the thickness of the roving, much thinner than the mat and no available photophysical application, make the mechanically automatic differentiation difficult. In this study spectrochemical differentiation between the two layers has been made using boiling concentrated sulfuric acid, methanol and isopropanol solution saturated with KOH, or hydrogen fluoride (HF) solution (Fig. 2). Furthermore efficiently coloring water-soluble dye following the HF treatment makes the roving layer more distinguishable photophysically. And a layer differentiation and automatical layer distracting method has been successfully developed.

2.2 Advanced distracting system of FRP layer

New extracting mechanism was introduced to cutting the handlay up FRP (boats) by separating the relatively soft layer

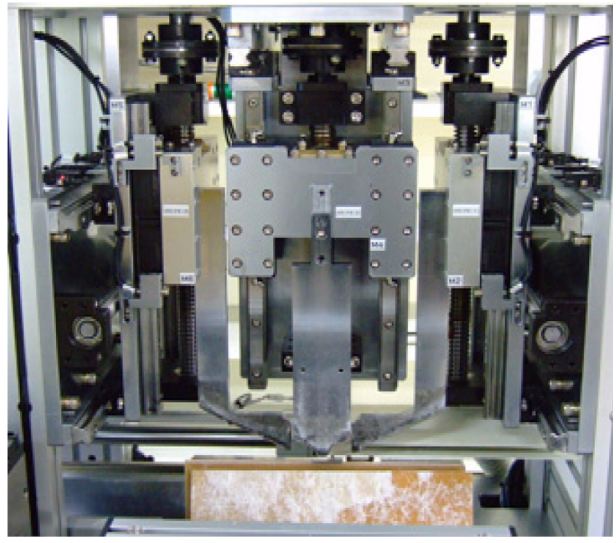
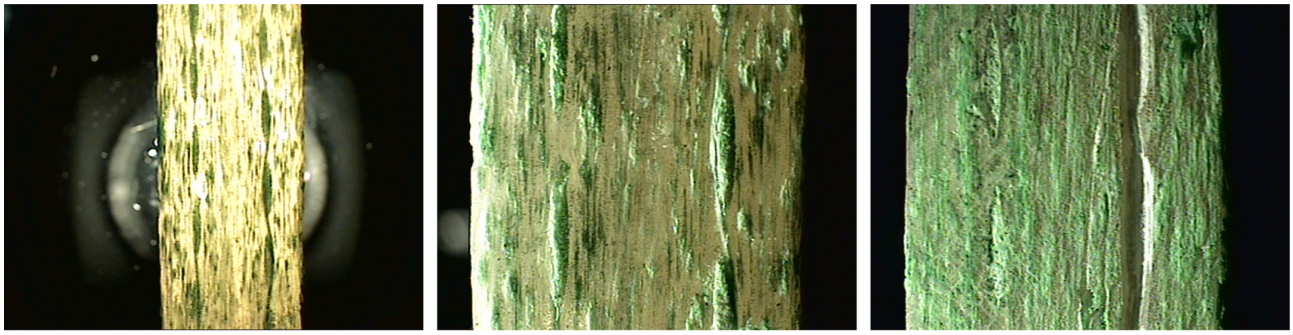


Fig. 3. Advanced distracting system of FRP layer.

(chopped strand mat) in multi layer structure. The following figure (Fig. 3) describes a driven overview of extracting (separating) system. Non automatic methods like the hand lay up method is carried out on molding using a roller. Therefore, composition of roving cloth in FRP boats appears in various forms. A broad spectrum can be seen more than five cases [10] 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 the distracting manual for general FRP which has several types of laminated glassfiber layer (Fig. 4). The manual included automatically distracting laminated glassfiber for regular composition cases from a single layer to three layer and non-automatical method for the random composition with transporting edged tool while the layer differentiating vision system is fully supported.



(a) Cross section view after treating (b) Two lines of glass fiber (c) Scratched dyed roving layer

Fig. 2. Treatment of hydrofluoric acid in FRP layers.

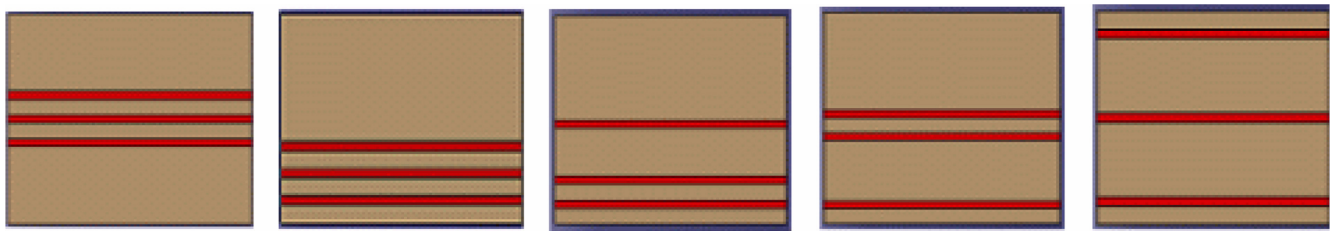


Fig. 4. Several samples of FRP layer with three glass fiber layers.

2.3 Advanced vision system for layer differentiation

Principal part of the recent extracting system of laminated glassfiber consists of cutting the layer, an extracting mechanism of laminated glassfiber. Exfoliating function is the essential factor of this system; this extracting system includes patent pending extracting laminated glassfiber layer which cuts waste FRP, strictly speaking, cutting roving cloth and mat, into a single layer. The shape is the same with Fig. 1 and separates roving cloth one layer at a time from FRP waste by controlling the vision system. Extracting laminated glassfiber layer system consists of light generation part for layer (glassfiber) differentiation and three vision sensor for dyed glass fiber lines detecting.

After transporting and placing edged tool correctly that was cut in projecting standard at preprocessing stage on prop, push the edge of blade to the plate, while fixating the FRP and compressed air so that it would not move. With the pressure of forwarding cylinder, height of waste FRP reaches the other five blades. At this point, blade pass through space between layers of laminated glassfiber and slice each layer. Fig. 5 shows glassfiber layers after the treatment of hydrofluoric acid in waste FRP. The model shows that two dyed glass-fiber lines are arranged in a row. This is to cut multiple layers simultaneously and run the process smoothly even if waste FRP with differing thickness is supplied, when waste FRP passes above the solid model. Extracting laminated glassfiber layer is driven by airpressure operated cylinder; this cylinder's role is to sustain the adhered state of waste FRP, which is driven, to the blades and push the waste plate until the severance is complete. It has been found that control of air pressure greatly affects driving efficiency. Smallsized cylinder that is adhered to a side of cutting blade supplies previously cut waste FRP so that continual severance of waste is possible and sustains the exact position of blades and waste from the beginning of cutting. To conclude, pressure set up of two cylinders is a major variable in systematic operation and forms of waste and properties of blades write out operation manual for pressure controlling device of two cylinders. Fig. 5 also shows the severance of waste FRP through extracting laminated glassfiber layer system. Thickness of cut waste FRP is around 1 mm and width arranges from 30 to 50 mm. The reason for this is speculated to be caused by differences in thickness of waste FRP and slight bends of formed in layer itself.

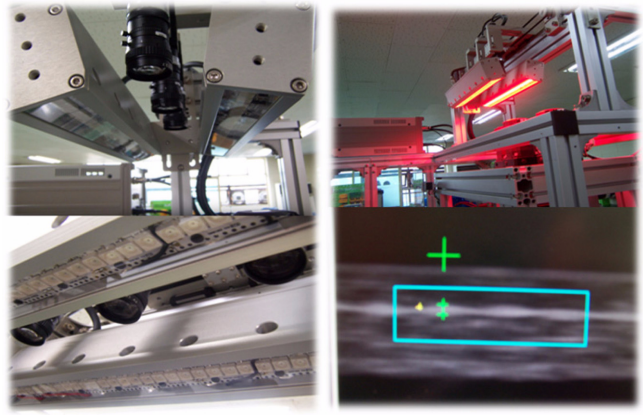


Fig. 5. Advanced vision system for layer differentiation and a sample of a real photo.

Compared to the existing shredding system [7], the new extracting system is greatly improved in mechanical efficiency, stability, and curtailment of dust and noise; its biggest advantage is that it makes extraction of glassfiber layer possible. This substantiates application possibility of extracted glassfiber as reinforced fiber for RFRC purposes. The new system can extract of glass-fiber layer from FRP waste, which could substitute the costly imported fiber of FRC.

The glassfiber from the current shredding system had limitations as a reinforced fiber because of its long fiber's length, 16 mm at maximum, is far shorter than long fiber's length of existing FRC fiber which is around 50 mm. This study made extraction of long glassfiber up to the length of original waste FRP possible with laminated glassfiber extracting system, for the first time.

Fig. 5 is a real model of advanced vision system for layer differentiation and a sample of a real photo with two lines for differentiation.

2.4 New extracting system of differentiated layer (glass-fiber)

Although the current extracting system has high production efficiency, it cannot accommodate the diverse forming component of domestic FRP boats that is shaped in various forms. In other words, administration of the new extracting system trying to satisfy diverse combination of mat and roving cloth affected by features of ship building industry is extremely inefficient. To improve this defect, patented new extracting system of laminated glassfiber 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. 6 shows new extracting system of laminated glassfiber. That is operated in pilot plant stage. That is greatly supported by administration of the flexible extracting system. The main difference is which part will be driving in the extracting system of laminated glassfiber. In new system, it can be applied to any combination of mat and roving cloth of FRP boats in ship building. In addition the dimension or size of laminated glassfiber layer also could be varied for necessity. Fig. 6 also shows the separated glass-fiber layer from the new extracting system in real process.

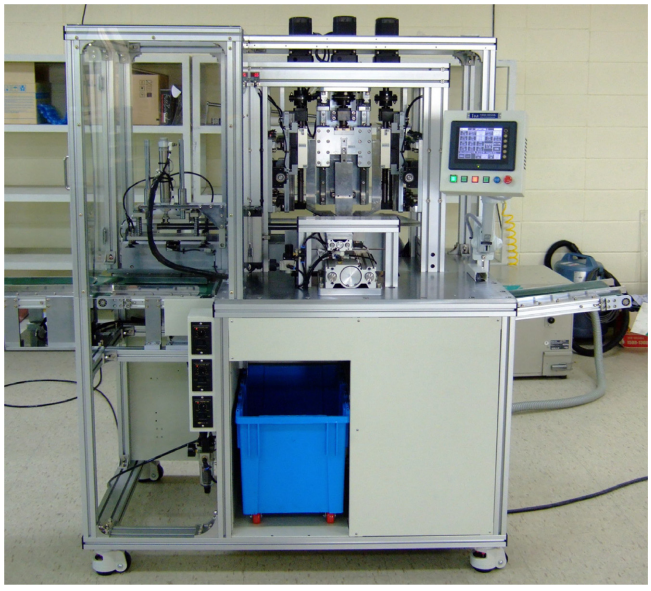


Fig. 6. Advanced cutting system of RFRC fiber.

2.5 Advanced practical recycling method of FRP boats

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 accelerating the amount of separating laminated glassfiber layer. To increase efficiency and regenerations of recycling FRP boats, disjointing crusher operation should require ecofriendly and regenerating operations. Fig. 7 and 8 were new system of recycling FRP boats process which also indicated that the total automatical process considered.

Fig. 8 is a fair bulk of the real extracting system. Noise and dusts are reduced favorably due to energy-saving separating process 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 cutting tool shreds the laminated glassfiber layer into glass fiber for RFRC, at the same time prevents dust and glass/resin powder scattering out.

Traditional cutting system has two step process for the size of standard fiber for RFRC. Such as cutting for the proper length and width. But newly developed system is only one step process for the same task with better efficiency and ecofriendly. The stathe nndard size of FRC fiber is suggested from early study [12]. The new system has the key cutting tool

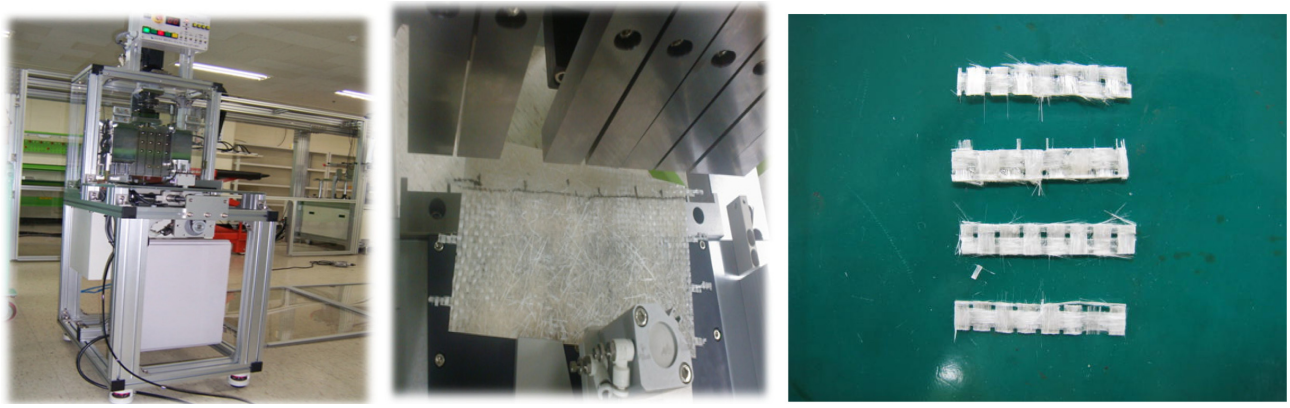


Fig. 7. Advanced cutting system of RFRC fiber with final product (30 mm×3 mm).

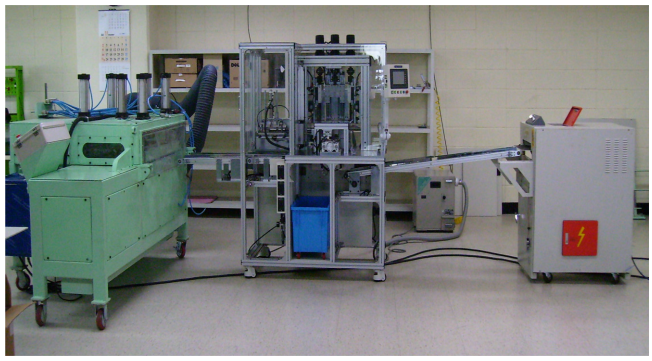


Fig. 8. Total extracting system of RFRC fiber from waste FRP.

which is developed for the only standard size of FRP fiber. Therefore, if the optimum size of FRP fiber will be changed for other type of appication, the key cutting tool would be modified. But those process is not a difficult task at all.

The new FRP fiber cutting system has no side effects, such as noise, dust and irregular size. Also productivity is great improved.

Composite materials (FRP scraps) due to simple crushing have lost the matrix structure and strength, but laminated glassfiber layers of new system still is to be remained original structure after the extracting process. It can be seen easily by the structure of layer. The advanced extracting mechanism with approaching to the correct direction of the evolution of FRP can successfully separate glass fiber layer from FRP waste in the Fig. 7. Also totally automatical extracting system (Fig. 8) has been showed better efficiency and ecofriendly mechanical FRP recycling.

3. CONCLUSIONS

1. New proposed (patent) mechanical recycling system is not just efficient but also ecofriendly FRP waste regenerating system. That has remarkably reduced safety hazards (air pollution and shredding noise) and crushing energy. Using the mechanical properties of polymers and composite, FRP with the orthotropic and laminated plastic structure has been easily separated in the new photophysical extracting system.

2. New extracting system trying to satisfy diverse combination of mat and roving cloth affected by features of ship building industry is extremely inefficient. To improve this defect, patented new extracting system of laminated glassfiber was developed. Also the extracting manual have been introduced for the several different composition of FRP boats.

3. Improving efficiency and regenerations of recycling FRP boats, disjointing crusher operation should require ecofriendly and regenerating operations. The new real extracting system is suggested. Noise and dusts are reduced favorably due to energy-saving separating process which is very effective process for regenerating the FRP waste.

4. Newly developed system is only one step process for the same task with better efficiency and eco-friendly. The new system also has the key cutting tool which is developed for the only standard size of FRP fiber.

Therefore the new total extracting system of laminated glassfiber layer in FRP waste should be more studied for mass production and industrialization. It will also be good for ecofriendly regenerate recycling of the troublesome FRP waste.

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REFERENCES

[1] Bartholomew, K., 2004, “Fiberglass Reinforced Plastics Recycling”, Dec. Report, MnTAP.

[2] Defosse, M., 2003, “Composites: European industry hunts for recycling solutions under new EOLV laws”, Modern Plastics, Vol.80, No.6, 73.

[3] Lee, S., Kim, Y. and Lee, J., 2012, “A Study on the Chemical Pre-Treatments Suitable for the Layer Differentiation of FRP Waste”, J of the Korean Society for Marine Environmental Engineering, Vol.14, No.1.

[4] Lee, S., Kim, Y. and Yoon, K., 2010, “A Study on the Chemical Treatments of Recycling FRP Ship”, J of the Korean Society for Marine Environmental Engineering, Vol.13, No.1.

[5] Majumdar, A.J., 1975, “Properties of fiber cement composites”, in Proceedings of the RILEM Symposium on the Fiber Reinforced Cement and Concrete, edited by Neville, A., pp 279314, The Construction Press, England.

[6] Park, J. and Back, J., 2009, “Mechanical Properties of High Strength Concrete Reinforced with Recycled Fibres from Fiber-Reinforced Plastics”, Journal of the Architectural Institute of Korea, Vol.25, No.8, pp 127-134.

[7] Shibata, K. and Zairyo, K., 2006, “Desired environmental response from FRP/FRTPFRP recycle technology using atmospheric pressure dissolution method”, Engineering materials, Vol.54, No.4, 58-61.

[8] Shoji, Y., 2003, “Recycling FRP waste From pure research to practical use”, J of the Japan Society for Composite materials, Vol.29, No.6, 210-216.

[9] Tsutomu, S., Shoji, N., Katsuto, O. and Takeshi, S., 2001,

"Supercritical fluid in polymer science and technology. I. Decomposition of fiber reinforced plastics using fluid at high Temperature and pressure", Japanese J. of Poly. Sci. and Tech., Vol.58, No.10, pp. 557-563.

[10] Yoon, K., 2007, "New Practical and Ecofriendly Recycling method of FRP", J of the Korean Society for Marine Environmental Engineering, Vol.10, No.3, pp. 181-186.

[11] Yoon, K., Kim, Y. and Lee, J., 2008, "Developing an Extracting Method of Laminated Glassfiber from FRP Boats", Proceedings of IEEE KOBE-TECO-DCEAN'08.

[12] Yoon, K., Kim, Y. and Lee, S., 2007, Recycle of Glass Fiber Obtained from the Roving Cloth of FRP 1: Study for the Physical Properties of Fiberreinforced Mortar", J of the Korean Society for Marine Environmental Engineering, Vol.10, No.2, pp. 102-106.

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