Preliminary Study of Energy and GHG Footprint of CFRP Recycling Method using Korea Database

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ABSTRACT

Awareness of resource conservation and pollution prevention has been continually increasing. The proven benefits from CFRP's unique combination of light weight and high strength compare to conventional material is well suited for minimizing fuel consumption during vehicle in particular rail operation. Responding the awareness, this work intends to study CFRP's recycling method that is not only technical performance but also environmental view point. According to prior work of technical performance test, this work aims at quantifying the footprint of energy and GHG derived from the two appreciated performance of pyrolysis and acids recycling methods. The streamline LCA is the concept for systematic assessment. The boundary is scoped at the recycling activity, consequently, the data in and out from the specific target activity are obtained under the gate to gate data collection. Its function is recovery carbon fiber. To count and compare function, functional unit is set at 60% of recycling rate. Korea database is mainly source for acquiring the footprint of both. The numerical results presented that the energy footprint of acids and pyrolysis is 164.95 and 1,199.88 MJ-eq., respectively. Meantime, the GHG footprint of is 1,196.22 and 5,916.08 g CO2 eq. for acids and pyrolysis. In summary, the acids recycling method is, in regarding the environmental performance, better than pyrolysis recycling method.

1.Introduction

The carbon fiber composite material produced from organic polymer, for instance polyacrylonitrile,has unequal properties over other materials, such as corrosion resistance, environmental durability, and stiffness to weight. (Uno, H, et al, 2007) Carbon fiber reinforce plastic, CFRP, due to its ease of application, is extremely attractive for panels used in civil construction projects, such as bridges, vacuum tubes, particle accelerators, aircraft, cars, and rail cars. The type of epoxy resin used in the case of lightening railway cars in Korea is normally a combination of bisphenol A and epichlorohydrin. Another benefit of using CFRP is environmental view point, due to it intends to minimize the energy used during rail operation as a results the emission of greenhouse gas and other air pollution are decreased.

Prior work implemented and evaluated by Korea Railroa Research Institute and partner is about the appropriated recycling method of CFRP in regard to technical term. The output of that strongly indicated that acids and pyrolysis recycling method are suited for our study of environmental impact. An acid recycling is the method for recover carbon fiber. The sample, 6 gram of CFRP, is

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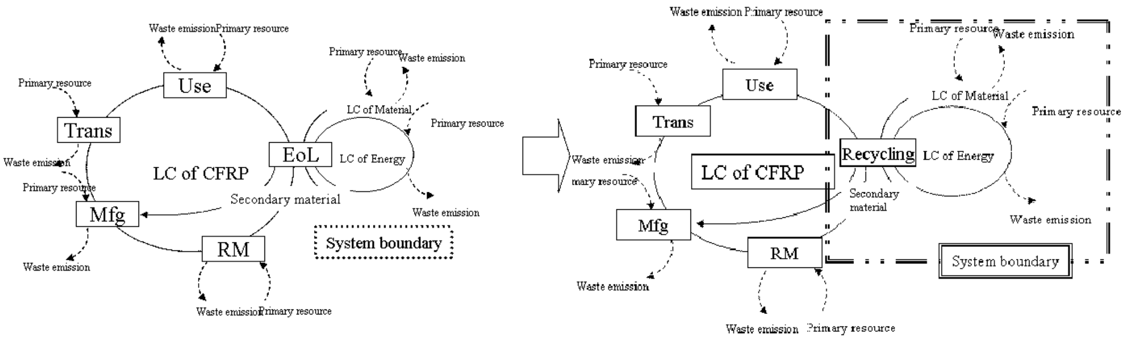
solved in the nitric solution controlling with 90 ℃ of temperature for 5 hrs. Meantime, Pyrolysis in air is analyzed under the high condition of temperature at 500 ℃ for 4 hr.

2.Methodology

The objective of this is to evaluate environmental impact using the footprint of energy consumption and greenhouse generation occurred from the two CFRP recycling methods, those is acids and those is pyrolysis. The concept of life cycle assessment (ISO 14040−14043) is applied for the analytic evaluation.

The functional unit is 3.6 g, account to 60% recycling rate, of carbon fiber. Fig.1(a) illustrate the relationship among life cycle of CFRP particularly at end of life stage and other life cycle of material and energy. The solid line show the way of cycle stage while the dash line present the natural resource and emission flow. Fig.1 (b) outline the system boundary that mainly scoped at the recycling treatment system, so the input and output data collection is captured under the scope of gate to gate. Obtaining the energy and GHG footprint, the system needs to draw back to the stage of resource acquisition. Of these, Korea database and available database are useful at this step.



(a) (b)

Fig.1Life cycle of CFRP, material and energy

3.Results and discussion

Inventory results were conducted to identify and quantify input and output data i.e. raw materials use, energy consumption, emissions waste to air, water and soil to and from the recycling system. Using the mass allocation approach (ref.), 95% by weight of reference flow, the parameters that influence to footprint analysis and scope of study above, the quantitative data derived from both recycling activities are expressed in fig 2. The data are measured in the unit of gram (g) for mass and kilowatt−hour (kWh) for energy. At most, the data is measured in the experiment scale implemented by prior study of project.

The important input of acids recycling method, choice no.1, is nitric acid, water and electricity. 2,4 dinitrophenol and 2−nitro−4 carboxylphenol are main output of this method. For the pyrolysis recycling method that operates in oxygen atmosphere, the most importance input is electricity together the list of output is Sulfur dioxide, Hydrogen cyanide, 1−Butene, 2,3−dimethyly and etc.

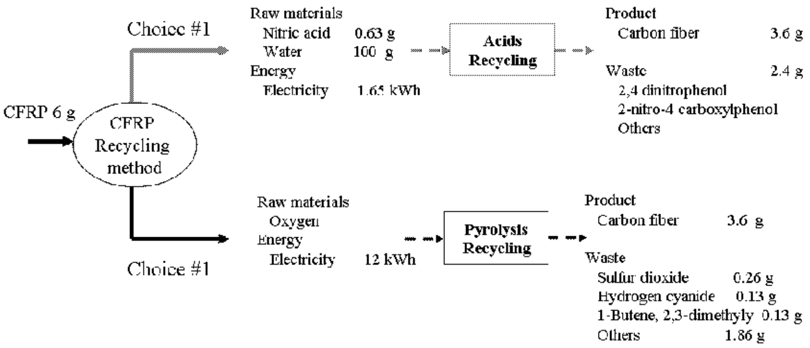


Fig.2 Flow diagram of data collection

Impact assessment and interpretation

The footprint of energy consumption and greenhouse gas generation respect to the acids and pyrolysis recycling methods are examined on the basis of functional unit. As shown in table 4 the actual energy consumption during the recycling activity of the acids and pyrolysis, is 1.65 and 12 kWh, respectively. The footprint of energy are first examined and expressed in the unit of MJ-eq.(Mega Joule equivalent). (Lee et al, 2004), usable electricity generated in Korea per unit is 98.2% approximately produced from the nonrenewable resource and the rest, 1.8%, is hydro power. CO2 emitted from 1 kWh of usable electricity production is 0.49 kg. Analyzing the Korea database, anotherGHG that is methane is found out and calculated to CO2 eq.

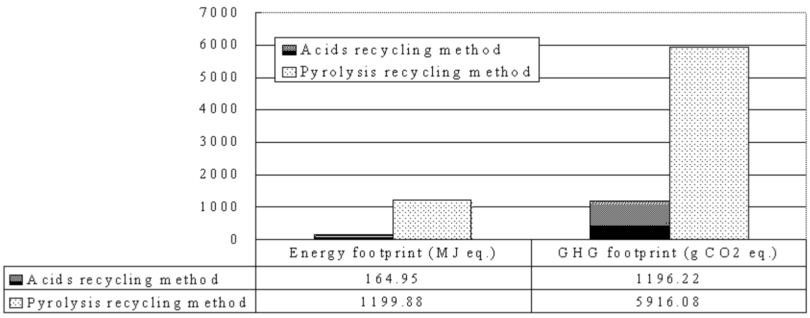


Fig. 3 The comparison of energy and GHG footprint between acids and pyrolysis recycling method

As shown in the fig. 3, the energy footprint of acids and pyrolysis recycling method is 164.95 and 1,199.88 MJ eq, respectively. As the results, the energy footprint of pyrolysis is greater than acids for 7 times approximately. Obviously, the trend of GHG footprint from pyrolysis is greater than acids recycling method, for 5 times, with magnitude of 5,916.08 and 1,196.22 g CO2 eq, respectively. The contributors including proportion of energy and GHG footprint of each are analyzed and presented in table 1 and 2. The main contributor of both methods is electricity.

Table 1: The magnitude and contributor of both footprints of acids recycling method

Footprint of	Nitric acid	Water	Electricity	Carbon fiber	Total
Energy (MJ-eq)	7.37E-02	1.91E-03	1.65E+02	-1.22E-01	1.65E+02
% contributor	0.04%	0.00%	100.03%	-0.07%	100.00%
GHG (g CO_2-eq.)	387.20	55.80	823.06	-69.84	1196.22
% contributor	32.37%	4.66%	68.81%	-5.84%	100.00%

Table 2: The magnitude and contributor of both footprints of pyrolysis recycling method

Footprint of	Electricity	Carbon fiber	Total
Energy (MJ-eq)	1200.00	-0.12	1199.88
% contributor	100.01%	-0.01%	100.00%
GHG (g CO_2-eq.)	5985.92	-69.84	5916.08
% contributor	101.18%	-1.18%	100.00%

4.Conclusion

Comparison between two recycling methods using those footprints, the energy footprint of acids and pyrolysis recycling method is 164.95 and 1,199.88 MJ eq, respectively. As the results, the energy footprint of pyrolysis is greater than acids for 7 times approximately. Obviously, the trend of GHG footprint from pyrolysis is greater than acids recycling method, for 5 times, with magnitude of 5,916.08 and 1,196.22 g CO2 eq, respectively. So, using the two footprints, the acids recyling method is more environmental friendly compare to the pyrolysis recycling method.

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