LIFE CYCLE ASSESSMENT OF CFRP IN APPLICATION OF AUTOMOBILE

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1 Introduction

In recent years, global warming together with oil crisis have become more and more serious problems. Among all the categories, transportation has an increasing emission of CO_2 and also demand on energy (Fig.1) [1], and the main reason of them is automobile (Fig.2). For the special energy consumption composition, transportation strongly depends on fossil resources of existence (Figs.1 and 3). Consequently, weight-lightening of automobile and application of electric vehicle (EV) can be considered as essential and effectual ways to achieve reduction of both CO_2 emission and energy consumption in transportation sector.

CFRPs are well known for their high specific properties (Figs.4, 5 and 6), together with some other outstanding mechanical, physical and chemical properties, leading to a promising application on the weight-lightening of automobile. Still there remain problems as high energy consumption during processing, materials relying to fossil resources, recyclability and so on from point of view of energy. This research thus applied life cycle assessment (LCA) as a tool to evaluate potential and improving direction of CFRP in application of automobile.

2 Inventory data of carbon fiber and LCA of automobile and airplane

To perform LCA of products using CFRP, inventory data of carbon fiber is necessary. Inventory data of standard grade PAN based carbon fiber has been reviewed every five years, as shown in Table 1, based on actual production data of Toray, Toho Tenax, and Mitsubishi Rayon [2]. JCMA (Japan carbon fiber manufacturers association) also performed LCA of automobile and airplane using CFRP as shown in Figs. 7, 8 and 9. Then we have to pay attention to the influence of payload in the cases of truck and airplane (Fig.10), but fuel reduction effect generally becomes larger when vehicle is larger as shown in Figs.9 and 11.

3 Direction of improvement in energy consumption of CFRP production

In the life cycle energy consumption of gasoline vehicles shown in Fig.11, energy consumption of running stage takes main part comparing to that of production stage even in the case of weight-lightened one (Fig.9). On the other hand, in the case of EV, energy consumption and CO_2 emission of running stage become drastically smaller as shown in Figs.12 and 13, and they are almost the same or less of those of production stage. Then in the next step we should consider energy saving and CO_2 emission reduction in the material production stage.

In the production of CFRP, fossil resources consumption of CF is apparently higher than that of resin matrixes (Figs.14, 15 and 16); especially the processing phase plays a main role in energy consumption. And another important aspect in CFRP manufacturing is low yield rate (Fig.17) which is not good as a garbage problem (Table 2) as well as cost issue. Consequently, developing new processes for obtaining CF with less energy, and recycling CF during disposal phase (Fig.18) can be considered as the most effective ways to bring down energy consumption of CFRP production.

Acknowledgement

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References

[1] http://iea.org/
[2] http://www.carbonfiber.gr.jp/english/index.html
[3] J. Kasai, *The International Journal of Life Cycle Assessment*, Vol.5, No.5, p.316, 2000.

2008	Population	Total Primary Energy Supply	Total Final Energy Consumption
OECD	1190 million	4.56 toe/capita	3.11 toe/capita
Non-OECD	5498 million	1.24 toe/capita	0.86 toe/capita

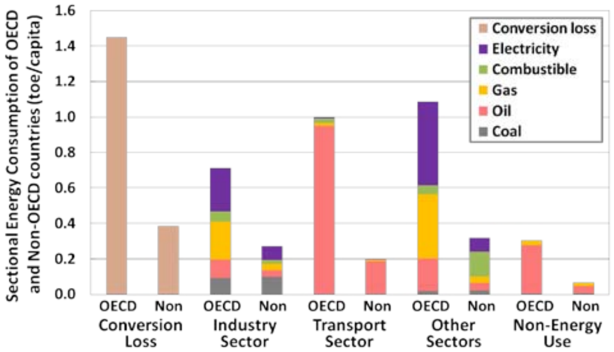

Fig.1 World energy consumption structure.

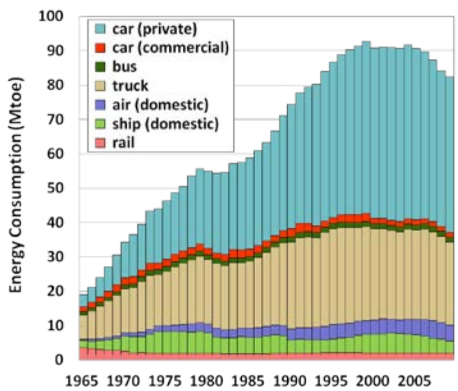

Fig.2 Energy consumption structure of Japanese transport sector.

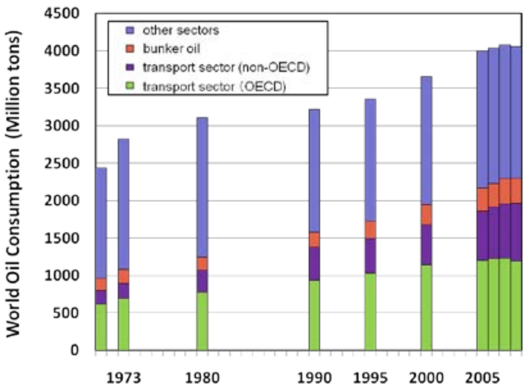

Fig.3 Proportion of the transport sector accounted for world oil consumption.

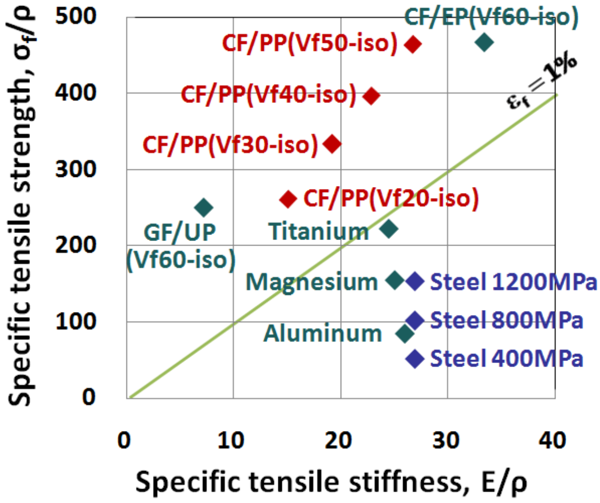

Fig.4 Tensile properties of structural materials.

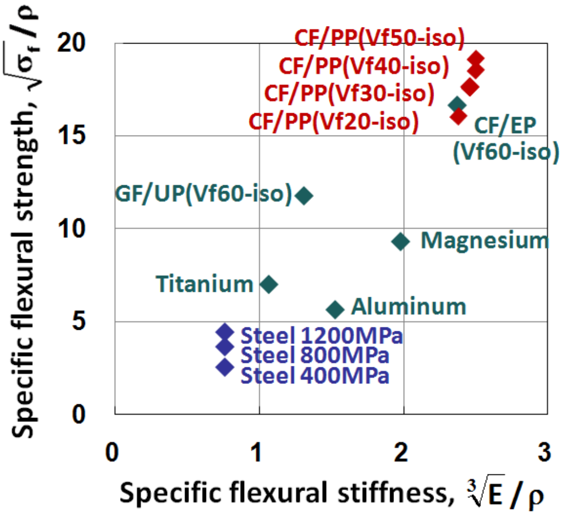

Fig.5 Flexural properties of structural materials.

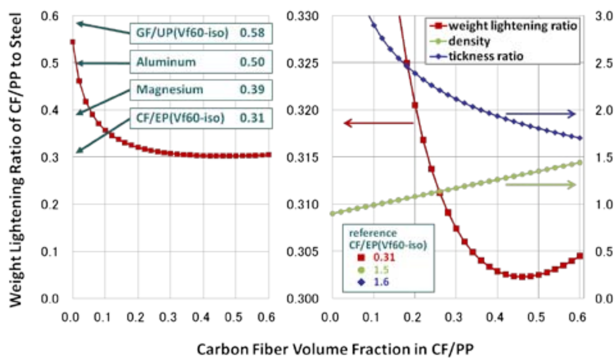

Fig.6 Influence of carbon fiber volume fraction in CF/PP panel on the weight lightening ratio to steel panel under flexural load.

Table 1 Inventory data of standard grade PAN based carbon fiber [2].

	Energy (MJ/kg-CF)	CO_2 (kg/kg-CF)	SO_x (kg/kg-CF)	NO_x (kg/kg-CF)
First data at 1999	478.5	29.7	0.068	2.009
Recalculated data at 2004	285.9	20.5	0.02	0.146
Recalculated data at 2009	286	22.4	0.019	0.121

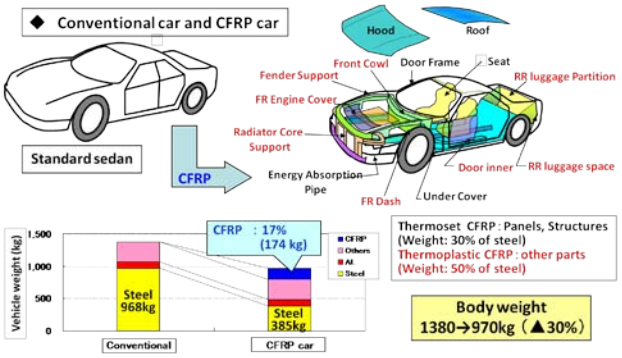

Fig.7 "JCMA Model" for LCA of Automobile [2].

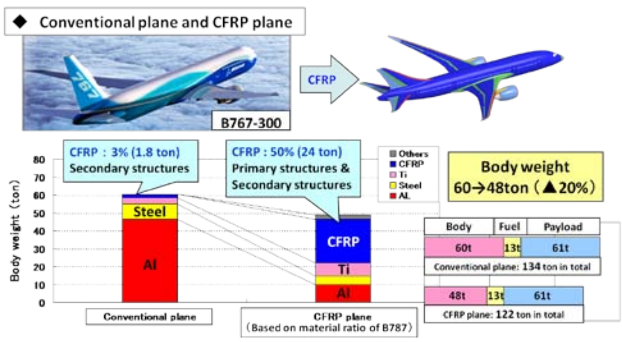

Fig.8 "JCMA Model" for LCA of Airplane [2].

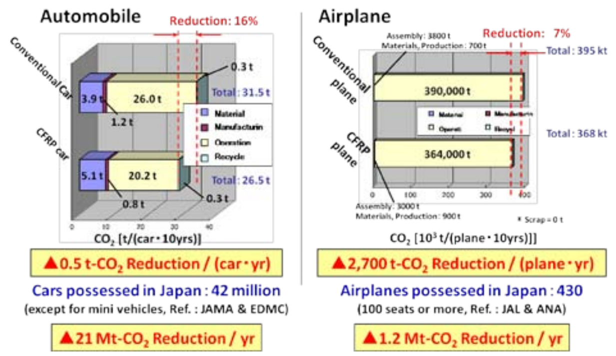

Fig.9 CO_2 reduction effects by applying CFRP [2].

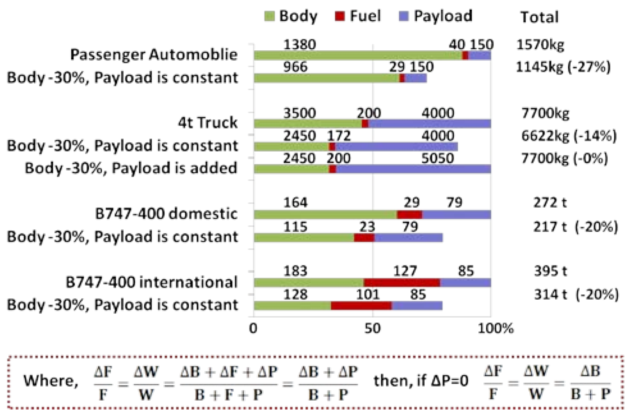

Fig.10 Influence of payload on the reduction of fuel consumption.

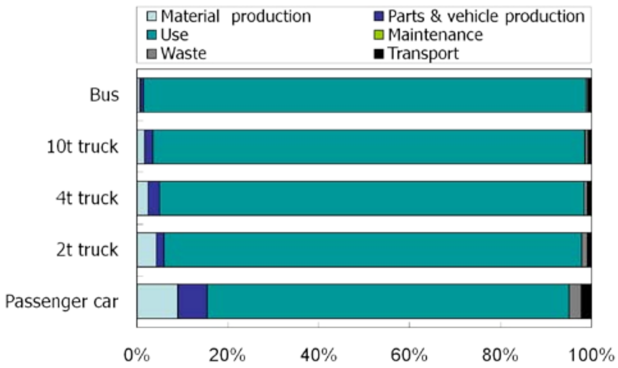

Fig.11 Life cycle energy consumption of various types of vehicles [3].

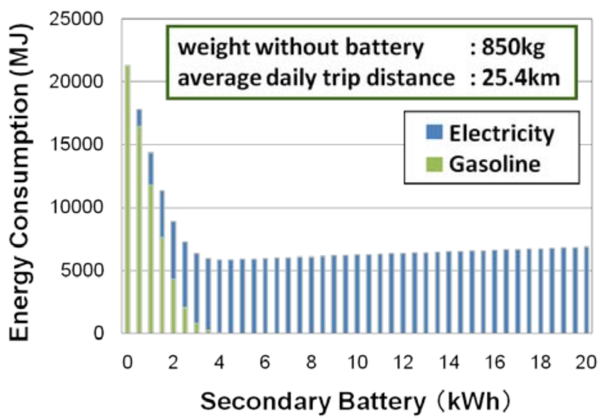

Fig.12 Energy consumption structure of plug-in hybrid electric vehicles.

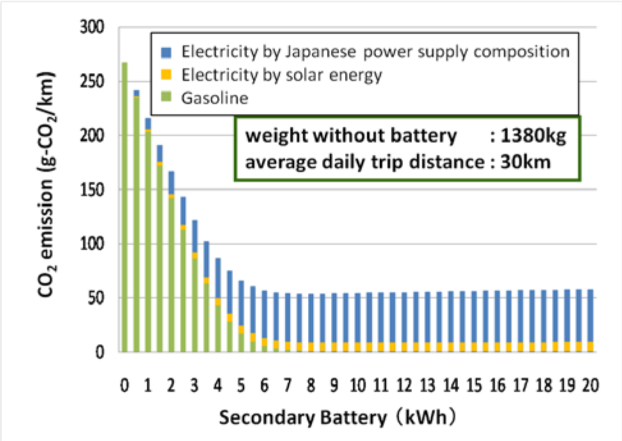

Fig.13 CO_2 emission structure of plug-in hybrid electric vehicles.

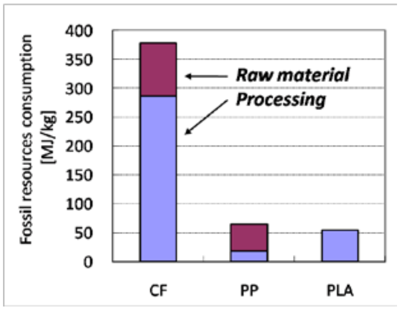

Fig.14 Fossil resources consumption in material production.

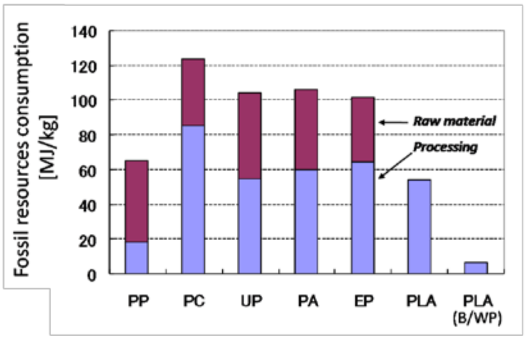

Fig.15 Fossil resources consumption in resin matrix production.

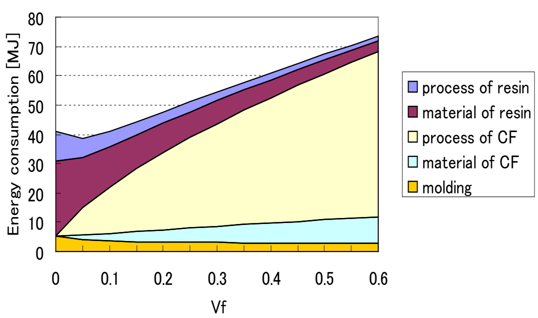

Fig.16 Energy consumption structure of CF/PP.

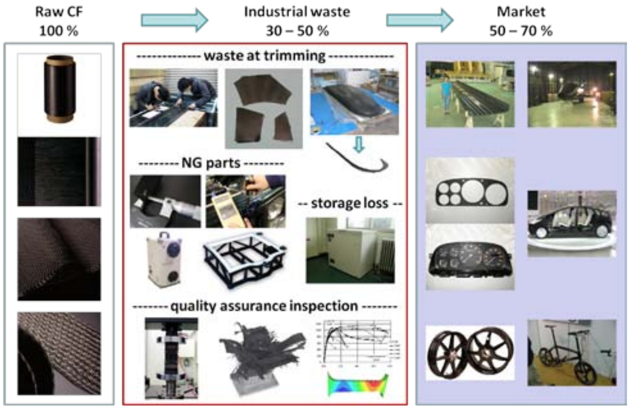

Fig.17 Schematic diagram of the occurrence of industrial CFRP waste.

Table 2 World carbon fiber potential demand by application.

	unit	passenger automobile	truck	wind turbine blade	commercial airplane (L)
world stock	10^3	700,000@2010 1,000,000@2030 1,300,000@2050	260,000@2010 380,000@2030 500,000@2050	120@2010 1,000@2030 1,500@2050	15@2010 30@2030 45@2050
world annual production	10^3	53,000@2010 75,000@2030 100,000@2050	20,000@2010 30,000@2030 40,000@2050	25@2010 50@2030 60@2050	0.6@2010 1.2@2030 1.8@2050
CF demand per product	ton	0.1	0.4	4	25
world annual CF demand	10^3 tons per year	5,300@2010 7,500@2030 10,000@2050	8,000@2010 12,000@2030 16,000@2050	100@2010 200@2030 240@2050	15@2010 30@2030 45@2050
production volume per plant	per year	200,000	50,000	5,000	300
	per day	800	200	20	1.2
	per hour	50	13	1.25	0.075
number of plants (Assuming an ideal production plant)		265@2010 375@2030 500@2050	400@2010 600@2030 800@2050	5@2010 10@2030 12@2050	2@2010 4@2030 6@2050
CF demand per plant	10^3 tons per year	20	20	20	7.5

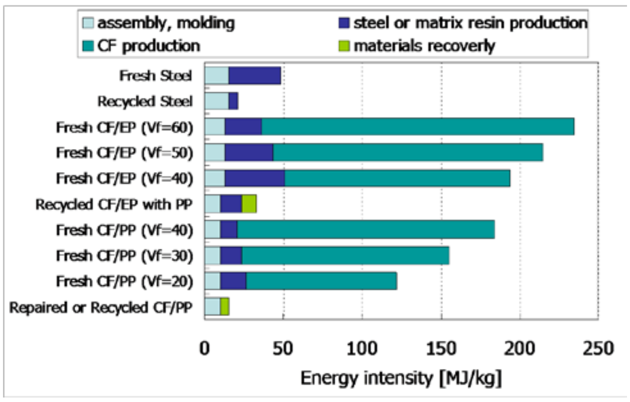

Fig.18 Energy intensity in parts production by fresh and recycled materials.