PROPOSAL OF A LOCAL CIRCULATION BUS MADE BY CFRP

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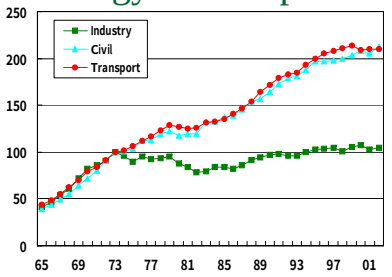
Introduction 1

Trend of energy consumption in Japan



1973=100

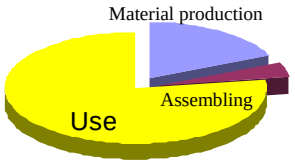
Transportation sector is constantly increasing

- Energy consumption by *automobiles* accounts for 87%
- People who have car license will *increase*

It is important to save energy by *automobiles*

Introduction 2

CFRP for saving energy by automobiles



Energy consumption of automobiles

To progress of fuel efficiency

- Lightening of vehicles
- Improvement of engine
- Reduction of friction

Application of **CFRP** (carbon-fiber-reinforced-plastic)

- Lightweight
- Good at specific strength and specific rigidity

Introduction 3

Application of CFRP to private vehicle

Examples of application to the car

NSX-R (HONDA)：hood、rear spoiler
Chevrolet (GM)：hood
Carrera (Porsche)：chassis、panel
RX8 (MAZDA)：propeller shaft
Fairlady Z (NISSAN)：propeller shaft

Only for expensive car and parts substitution

- Slow production speed
- High cost
- Too large specific energy consumption

Difficulty of introduction CFRP

NSX-R Source：Honda Motor limited HP

carrera Source：Porches-Japan HP

Introduction 4 (Target of this research)

BUS made by CFRP

Production speed, Cost

- Various shapes of bus
- High flexibility of design

Specific energy consumption

- Run long mileage in lifetime
- Go and stop many times

Bus is easy to introduce CFRP than private car.

Local circulation bus

- circular bus in local regions
- welfare vehicles for mainly senior person
- managed by Local Government Unit

The MOO bus managed by musashino city
source：the bus in TOKYO city

Method

To introduce CFRP to Bus

1.Calculate the effect by parts substitution

↓

2.Find out problems

↓

3.Propose new type of bus

Weight reduction effects by parts substitution → FEM

Reduction rate of environmental load → LCA

Design of thickness by FEM

Solver：MARC Pre-Post：Mentat

Design criterion of bus

Bend stiffness | **Torsion stiffness** | **Strength**

Thickness which clear all standard is determined

Stiffness standard is determined based on Large steel bus

Evaluation method of FEM (Bend stiffness)

Apply load around center of the wheelbase

Condition of FEM

W ：**Load**

L ：**wheelbase**

b ：**position of load**

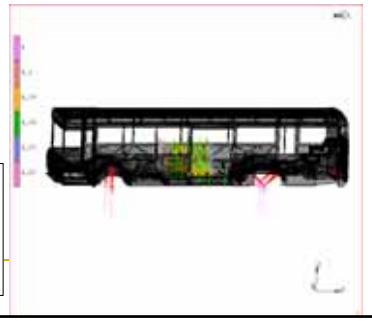
↓ **FEM**

FEM result

δ ：**maximum flexure**

x ：**position of above point**

$$\frac{EI}{L^3} = \frac{Wbx}{6L^4\delta}(L^2 - b^2 - x^2)$$



Evaluation method of FEM (Torsion stiffness)

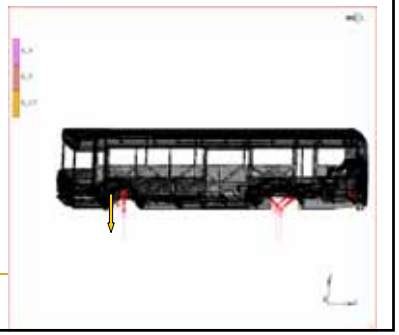
Apply load around front accelerator

$$\frac{GJ}{L^3} = \frac{WR^2}{L^2\delta}$$

Condition of FEM
W : **Load**
L : **wheelbase**
b : **Distance between position of load and tire**

FEM

FEM result
δ : maximum flexure

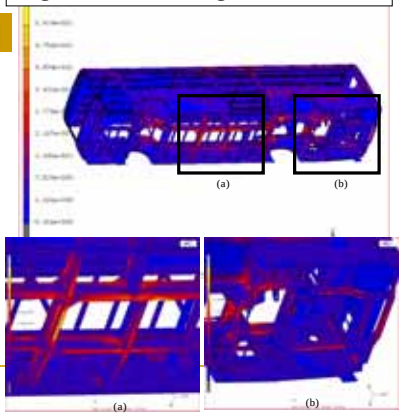


Evaluation method of FEM (Strength)

Apply load of overall body weight on the whole floor

The safety factor is fixed 4.5 times larger than each strength.

FEM



~Design criterion~
Steel : yield stress CFRP : Strength

	Steel	CFRP
Critical stress (MPa)	225	500

Evaluation method of LCA

•Goal of study

compare life cycle energy consumption between steel bus and CFRP bus

•Functional unit

rider ship is 30%, lifetime mileage is 430,000km

•System boundaries

material production, vehicle production and use stages

•Item of environmental loads

energy consumption

•Energy intensity of each materials

•Fuel efficiency

Steel-large bus : 2.34km/L

Fuel efficiency of other bus is calculated by the proportional relationship of weight

	Energy intensity(MJ/kg)
Steel	33
CFRP	232

Size investigation by weight reduction efficiencies (Analytical conditions)

Large bus 88 seater

Small bus 20 seater

Middle bus 55 seater

Micro bus 15 seater

Investigate which size is the most efficient to apply CFRP

Material properties

	Steel	CFRP
Density(g/cm^3)	7.8	1.58
Young's modulus(GPa)	206	54

Point : ・Substitution parts are frame and panel
・Use previous shape and change only size and thickness
・Investigate four different size buses

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Size investigation by weight reduction efficiencies (Analytical result)

Size	Material	Structural member(kg)	Total(kg)	Rate(%)	Criterion
Large	Steel	2719	9980	-	All
	CFRP	1760	9021	-9.6	Torsional rigidity
Middle	Steel	1459	6371	-	Strength
	CFRP	599	5511	-13.5	Flexural rigidity
Small	Steel	1072	2700	-	Flexural rigidity
	CFRP	493	2121	-21.4	Flexural rigidity
Micro	Steel	609	1630	-	Flexural rigidity
	CFRP	306	1327	-18.6	Flexural rigidity

Small and micro buses show high efficiencies

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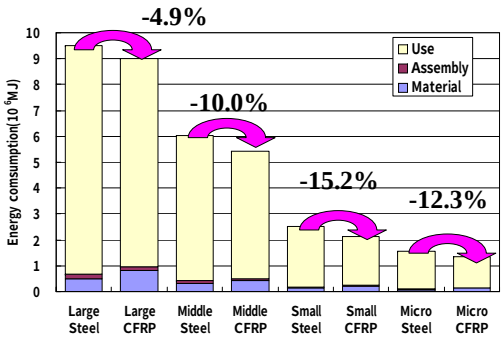
Size investigation by LCA (Result)



- Small bus show high efficiencies
- Aging society particularly in countryside. Narrow road and small population

Target: small bus

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Proposal of *new type* bus

①Efficient structure and shape
②Ensuring impact safety
③Kindness to aged people

Difficult to reform from *previous shape* of bus

The new type bus is designed from the beginning to solve these problems

NAME **JUN-KAN BUS**

This name is from “JUNKAN” in Japanese, this word means circulation in English.

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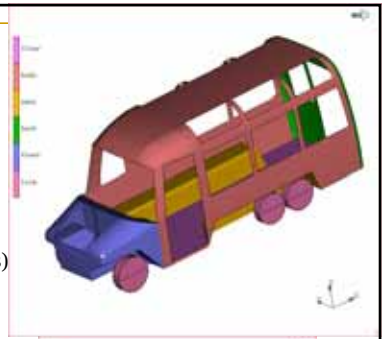
JUN-KAN BUS

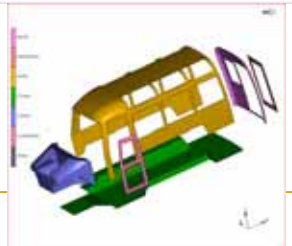
Bonnet

- Bonnet to absorb impact energy in front of bus
- All drive system in bonnet (ultra low floor, non-step and non-stairs)



Monocoque structure

CFRP is suitable for monocoque structure



Passenger cabin

- Large space inside of bus by optimization
- Open-plan space by the window above

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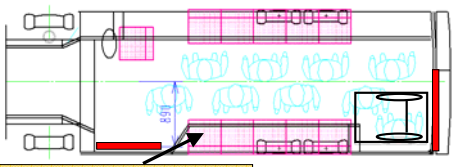
Layout of the JUN-KAN BUS

Comfortable space for 20 passengers

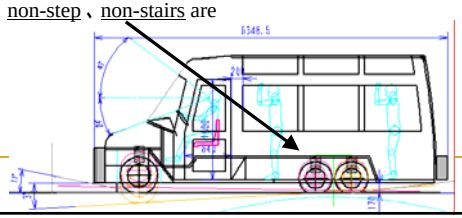


・Back door for wheel-chair

・Ensuring wheel chair space

Seats set above the tire cover

Ultra low floor、non-step 、non-stairs are realized



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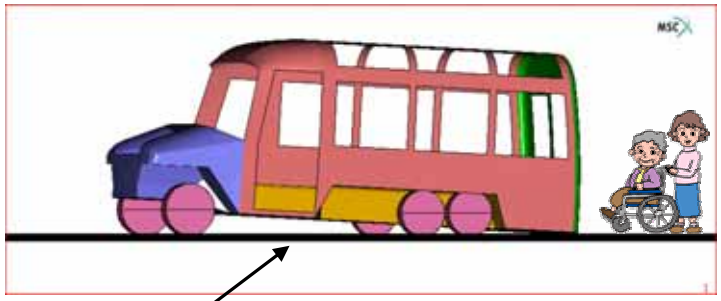
Getting on and off



Usually, kneeling side of the bus
For the wheel chair, kneeling back side of the bus

The height of the floor is 160mm, lowest all over the world

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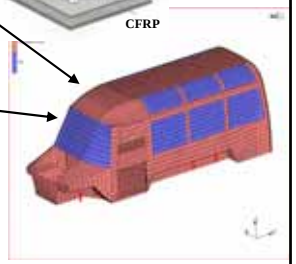
Material selection

CFRP/aluminum-honeycomb-core/CFRP composite

Super light weight material、adequate for monocoque

Windows by poly carbonate

High transparency, contribute for stiffness



FEM

	Sandwitch(CFRP/Core/CFRP)	PC
Floor	74 (2/70/2)	
Others	32 (1/30/1)	
Window		4

Unit : mm

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Results of JUN-KAN BUS

Body weight become only 221kg!

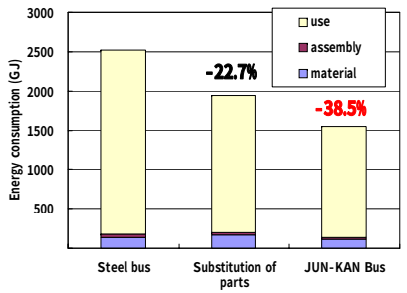
The weight reduction rate of body is -79.4%

The interior boards are unnecessary because the panel is flat!

→a great lightening of the interior can be expected

Weight of the bus: 1,500kg

(Weight reduction ratio: -44.5%



Reduction rate of lifecycle energy consumption is also improved

Conclusion

Applying CFRP to bus

Parts substitution → **New type structure**

- More effective application of CFRP

  →improve weight reduction ratio and reduction environmental load

- Reduce assembly cost by integrated structure

  →Cost down

- Ultra low floor、non-step 、non-stairs are realized

  →more convenient

It is important to design from the beginning in order to apply CFRP to the bus.

In case of a car, it is also important to re-design the structure from the beginning.