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Next Challenge in CFRTP for Mass Production Automotive Application

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Nagoya University, Japan

HEADLINE

- COST ANALYSYS
- COMPOSITE DESIGN
- HIGH CYCLE MOLDING
- PROPERTIES OF DISCONTINUOUS PREPREG
- PROPERTIES OF RECYCLED PREPREG

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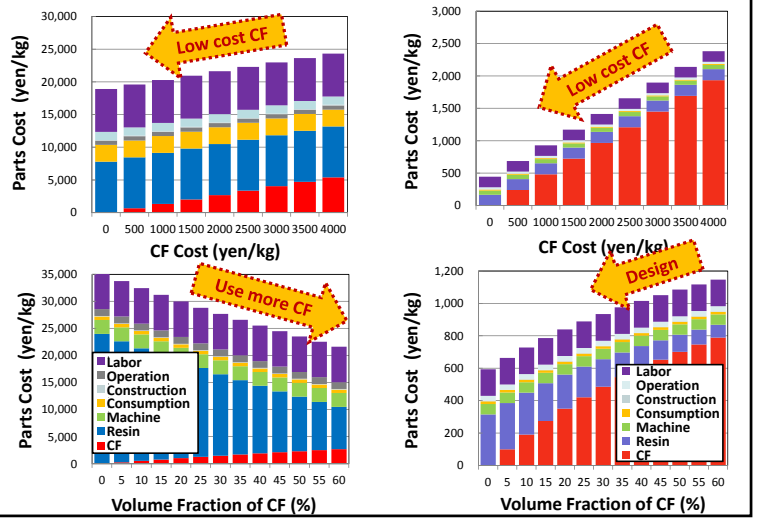
CF/PEEK Parts vs CF/PP Parts



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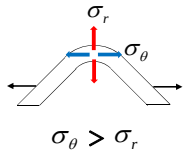
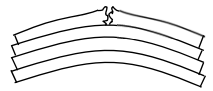
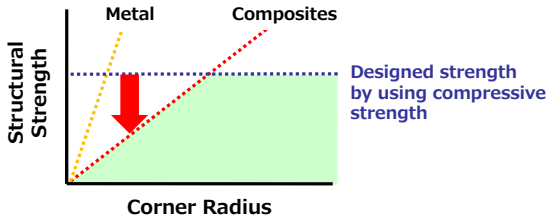
Importance of the curvature design in CFRP

	$\sigma_\theta >$ Compressive strength 	$\sigma_r >$ Interlaminar strength 
Domestic Failure Mode	Compressive failure	Delamination
Structural Strength	As designed	Unexpectedly low
Structural Failure Mode	Ductile	Brittle



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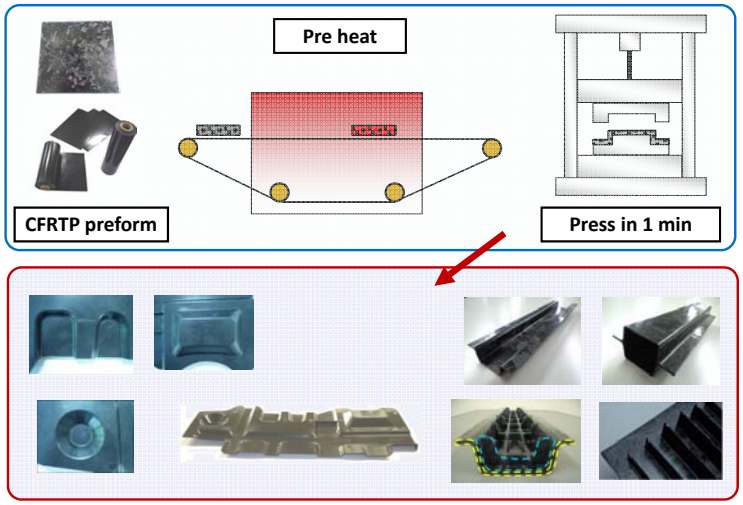
Continuous Compression Molding for Mass Production



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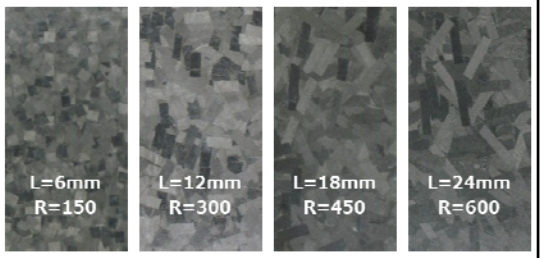
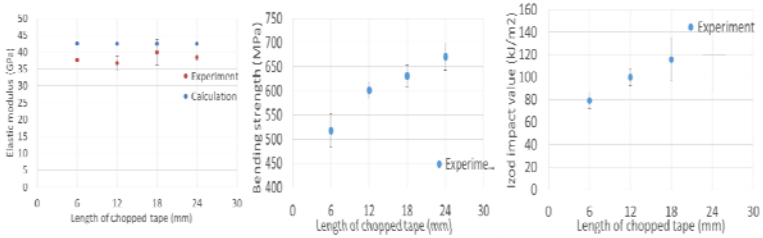
Properties of CTT: *CF Tape Reinforced Thermoplastics* (PA6)

CF Tape
Thickness: T=0.04mm
CF length: L=n*6mm
Aspect ratio: R=L/T





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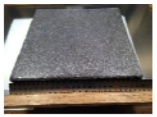
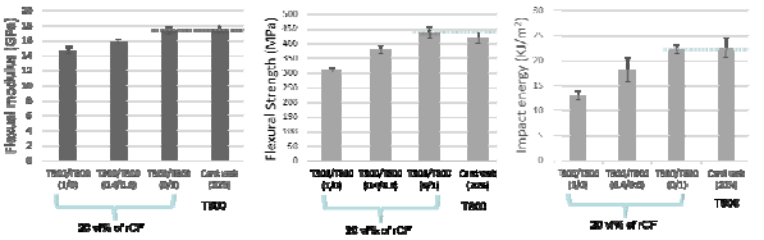
Mechanical Properties of Recycled CF/PA6

	Matrix	CF Length	Process	Advantage
Carbon Paper	PA6 Fibers	Concentrated around 6 mm	Paper Making Method	Short fiber can be used Small scatter
Card Web		Widely distributed up to several cm	Carding Machine	Very productive
CTT		As you wish	*Confidential*	High Vf and energy absorption

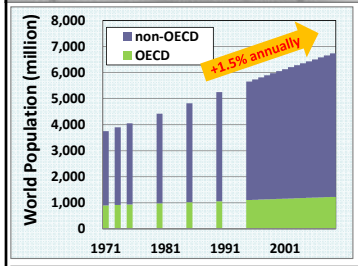


Carbon Paper

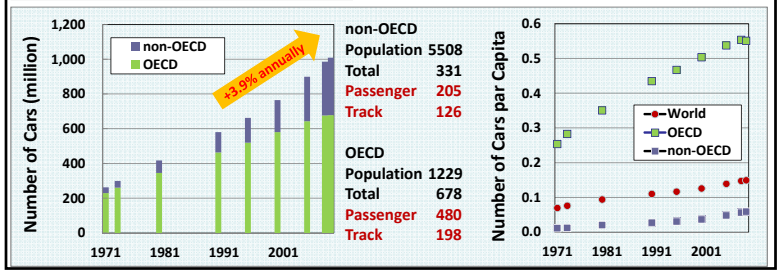
Card Webs



Growing World Population and Number of Cars

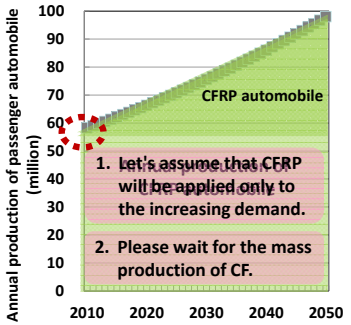


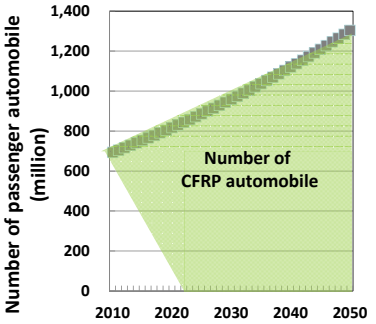
- Millions of cars are increasing annually.
- What's kind of cars should be produced in the future?
- How can we contribute this situation by drastic weight-lightening technology?



non-OECD	
Population	5508
Total	331
Passenger	205
Track	126
OECD	
Population	1229
Total	678
Passenger	480
Track	198

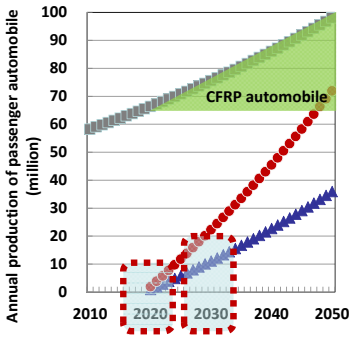
We Need a Proper Goal for Backcasting

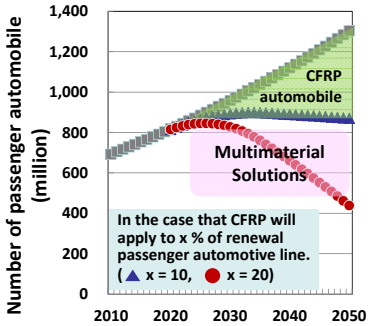




- If CFRP would be applied to all passenger automobile, annual CF demand is about 10 million tons.
- In the coming decades it's impossible to supply such amount of CF, hence we have to set a proper goal for backcasting.

One Idea of Our Common Future



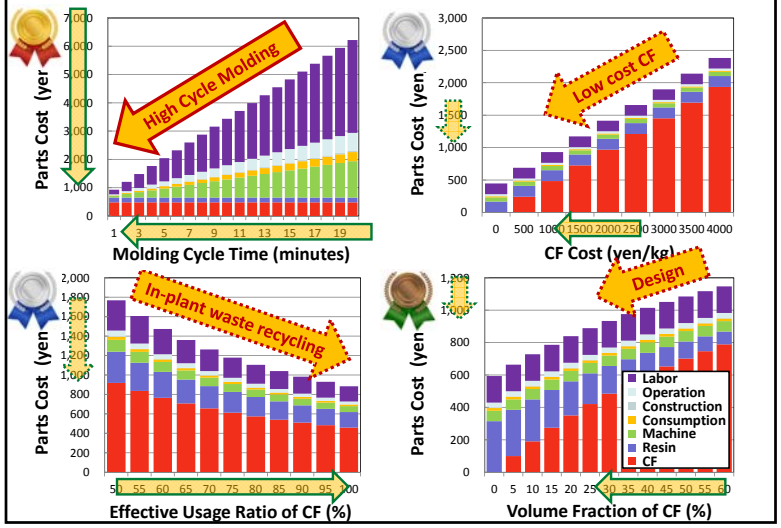


2020: Start mass production
2030: Annual production of CFRP automobile is 10 million
CF for them is 1 million tons

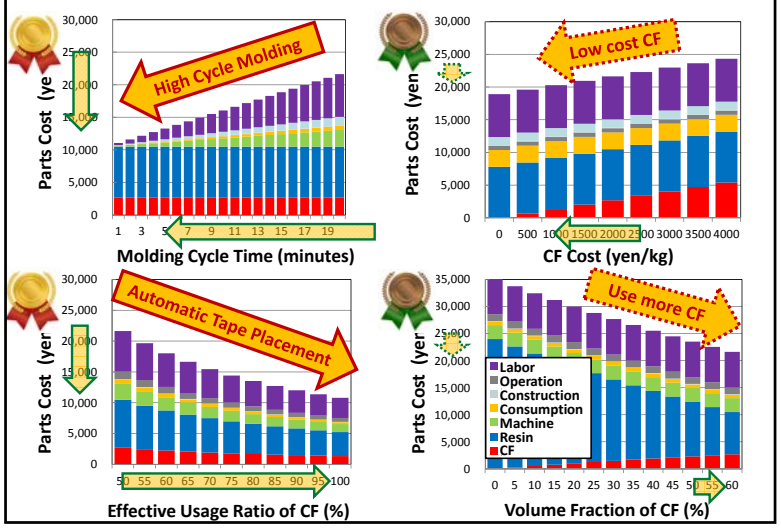
Consider respective goals to realize this future !
CF : cost, productivity, ...
CFRP : production cycle time, cost, recycling, ...
others : CAE, standardization, ...

First of all … standpoint of my presentation

Effective Cost Reduction Methods of CF/PP Parts



Effective Cost Reduction Methods of CF/PEEK Parts



Expectations for CFRTP

Common Difference

		Airplane	Automobile
Motivation		High oil price → tight national budget (including military budget) → low-cost CFRP (<50$/kg) and maintenance	High oil price and CO2 measures → weight lightening & early spread of EV (by battery reduction) → low-cost CFRP (<10$/kg) and recycling
Direction of technology development	Material & Preform	Low-cost engineering plastics	Low-cost & productive CF Low-cost general-purpose resin Low-cost impregnation
	Molding	Low-cost manufacturing → from hours to minutes → thermoforming/welding	Low-cost manufacturing → less than one minute → thermoforming/welding
		Yield improvement → automatic tape placement	Yield improvement → recycling of in-plant waste
		Measures for labor cost and intellectual property → automation	Measures for labor cost and intellectual property → automation
	Operation	Reparability Impact resistance Simplification of NDI	Reparability Recyclability of market waste New design for dynamic social demand

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	260,000@2010 380,000@2030	120@2010 1,000@2030	15@2010 30@2030
world annual production					
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)		65@2010	400@2010	5@2010	2@2010
CF demand per plant					

Drastic increase of carbon fiber production capacity is necessary

Japanese National Project 2011-2017

Drastic high cycle manufacturing technology of CFRP is necessary

Japanese National Project 2008-2022

Japanese National Projects For Mass Production CFRP Automobile

2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

CFRTP (material) Project *40M$*

- Parts replacement
- High cycle molding
- In-plant waste recycling

METI, NEDO, +5 (+5)
PL: Prof. Takahashi (LCIC)

LCIC, Mitsubishi Rayon, Toray, Toyobo, Takagi Seiko
(Kyoto Institute of Tech., Shizuoka Uni., Tohoku Uni., Toyama Uni., Yamagata Uni.)

CFRTP (structure) Project (2013-2022) *120M$*

- Composite design
- High cycle manufacturing
- Market waste recycling

METI, +25 (+9)
PL: Prof. Takahashi (LCIC), Prof. Ishikawa (N

LCIC, NCC, ICC, Tokyo Institute of Tech., Fukui Pre
NIMS, Mitsubishi Rayon, Toho Tenax, Toray, Toyo
Shimadzu, Aisin Seiki, Fukui Fibertech, KADO Corporation, Komatsu, Kyowa, Takagi Seiko, IHI, SHI, Honda, Mitsubishi Motors, Nissan, Suzuki, Toyota *(GCC, Tohoku Uni., Yamagata Uni., AIST, JAXA, DOME, Taiseiplas, Meiki, Toray Engineering)*

2020 Tokyo

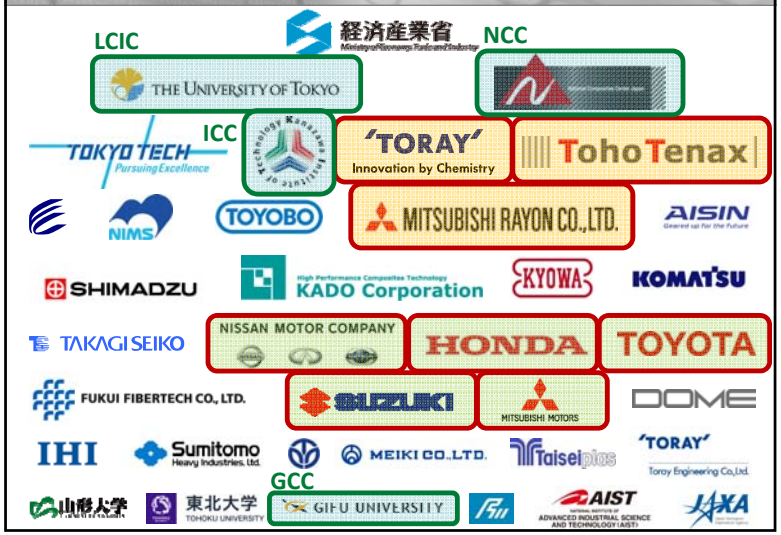
Innovative CF Project

- Productive & low cost

METI, +5
GM: Prof. Kageyama, PL: Prof. Hatori (LCIC)

LCIC, AIST, Mitsubishi Rayon, Teijin, Toray

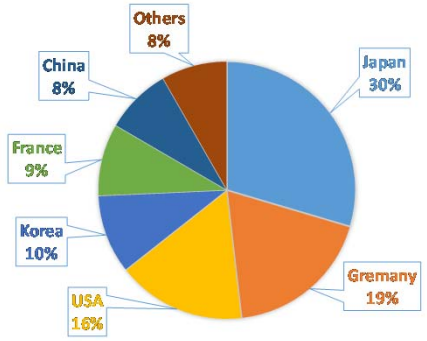
Consortium Members (34) of CFRTP Project



Recent Established Japanese Composite Research Centers

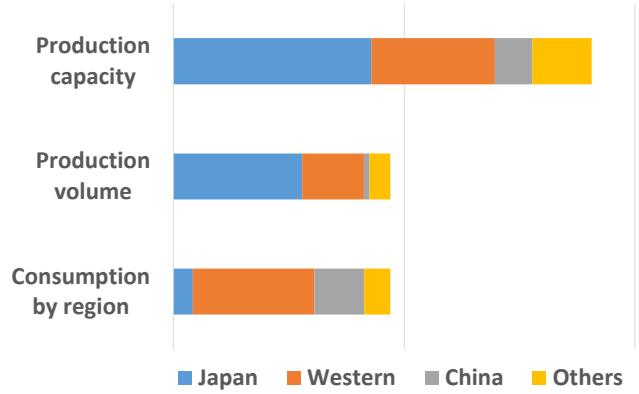
Since	Name	Full name	Location	Key persons	
2009 July	LCIC	Low Carbon Engineering Innovation Center	The University of Tokyo	Kazuro Kageyama Jun Takahashi	 
2012 April	NCC	National Composite Center	Nagoya University	Takashi Ishikawa	
2012 April	GCC	Gifu University Composite Materials Center	Gifu University	Takushi Miyake Asami Nakai	 
2012 August	ICC	Ishikawa Carbon Fiber Cluster	Kanazawa Institute of Technology	Isao Kimpara Kiyoshi Uzawa	 

World Passenger Automobile Production Share (2011)



World production share	
Toyota	11%
Nissan	6%
Honda	5%
Suzuki	4%
Mazda	2%
Mitsubishi	2%
Subaru	1%

World Carbon Fiber Share (2012)



The University of Tokyo
School of Engineering
Department of Systems Innovation

Research Equipments for CFRTP

Professor Jun Takahashi Laboratory

Molding Equipments

Equipment	Description	Equipment	Description
 Hydraulic double belt press	HELD (Germany) • Hydraulic pressure enables uniform pressure • Max. temp.: 380 ℃ Max. pressure: 8 MPa Max. speed: 15 m/min.	 Stamping press for molding	PEI (France) (THERMOPLASTIC LINE 500T) •Equipped with IR heater and material handling equipment automated process with a series of press-transport-heating • Output: 500 ton Board size: 800 x 800 mm Shut height: 300 mm Maximum speed: 400 mm/sec.
 Stamping press for molding	Kawasaki Hydromechanics (TMP2-300) • Equipped with IR heater and material handling equipment • Output: 300 ton Board size: 1200 x 1000 Shut height: 350 mm Max. speed: 300 mm/sec. Ejector: Hydraulic pressure, air Die clamper: Air Die lifter: Air	 Box type IR heater	NGK Insulators, LTD. • Infrared heater • Effective heating area: 1000 x 1000 mm Each of 8 points at the top or bottom can be controlled independently • 50.8 kW
 Heating and cooling auto press	PEI (France) • Auto double-acting heating and cooling press • Output: 30 ton • Board size: 500 x 500 mm • Heating and cooling with 1 platen • Temp. accuracy 200 ℃: R4.3 ℃ 400 ℃: R7.5 ℃ The heat plate divided into nine can be controlled independently • Automatic operation program	 Heating and cooling auto press	SINTO Metal Industries Corporation (AWFA-20) • Auto double-acting heating and cooling press • Output: 20 ton • Board size: 500 x 500 mm • Heating and cooling with 2 platen Equipped with a lifter for transporting the mold • Automatic operation program

Molding Equipments

Equipment	Description	Equipment	Description
 Heating and cooling hand press	SINTO Metal Industries Corporation (YSR-10 H/C) •Output: 10 ton •Board size: 225 x 225 mm •Heating and cooling with 2-platen	 Heating and cooling hand press	TOYO SEIKI Co., Ltd. (Mini TEST PRESS-10) •Output: 10 ton •Board size: 250 x 250 mm •Heating and cooling with 1 platen max. 300 ℃
 Rapid heating and cooling equipment(IH)	Hfn Co., Ltd. (High Frequency Nestle) •Output: 75 kW, 2 machines •Oscillating frequency: 30 kHz •Chiller unit: 37 kW •Rapid heating and cooling from room temperature to a temperature above the melting point of the resin	 Heating and cooling equipment (steam)	MATSUI MFG. Co., Ltd. / MIURA Co., Ltd. / Kaken Geneqs Inc. •Consist of boiler, coolant circulator system and temp. controller •Quick heating/ cooling from ambient to 150 ℃
 Autoclave	ASHIDA MFG. Co., Ltd. •Oven size: 1 m (D) x 1.5 m (L) •Max. operating temp.: 400 ℃ •Max. pressure: 2 MPa		

Molding Equipments

Equipment	Description	Equipment	Description
 Tape placement machine	FIBER FORGE Corporation (USA) •High speed plane lamination •Lamination of UD tape automatically •After lamination, spot welding by ultrasonic welding machine •Automatic feeding and cutting •Turntable is moved and rotated in the direction XY, and lamination •Laminated structure: Optional •It can handle the wide tape	 Tape placement machine	ADC (USA) •High speed three dimensional lamination •Lamination of UD tape automatically •Tape is wrapped around the mandrel while the resin is melted at high temperature nitrogen. •Closed section member can be produced in one step (Bonding process after lamination is unnecessary)
 Vibration welding machine	BRANSON (Germany) (M-624HRi) •Melting and joining thermoplastic resins by vibration •Max. size of molded products: 500 x 500 mm •Infrared heater enable us to heat joint surface in a non-contact (First introduced in Japan)	 Hot plate welding machine	Seidensha Electronics Co., Ltd. •Contact / Non-contact •Temp. range: Contact --260℃ Non-contact --600℃
 Ultrasonic welding machine	NIPPON FUTURE Co., Ltd. •Output: 1200 W •Frequency: 20 kHz •Oscillation method: Automatic tracking frequency system (ATHMOS) •Pressurization: Air cylinder •Max. applied pressure: 1500 N •Horn stroke: 70 mm		

Molding Equipments

Equipment	Description	Equipment	Description
 Laboplastmill	TOYO SEIKI Co., Ltd. (10C100) •Roller-type mixer for a thermoplastic resin •Rotation speed: 0.1—100 rpm •Max. torque: 1000 N/m •Max. 500 ℃ •2-axis low shear screw •Kneading chamber 90 cc	 Lab kneading injection unit	DSM (Holland) •Biaxial conical type •Small kneading machine (15ml) and injection molding machine •Temp. range: --350 ℃ •Shear rate: 4000/s
 Hand truder	TOYO SEIKI Co., Ltd. (Hand Truder PM-1) •Manual injection molding machine •Can make pellets •Furnace temperature: 20--400 ℃ •Cylinder size: ϕ12 x 130 mm •Sample capacity: 9 cc	 Wrap reel winder	Nishida MFG Co., Ltd. •Wind prepreg tape to reel frame of forming UD material •Amount of tape traverse: Any setting •Available Creel stand

Evaluation and Analytical Equipments

Equipment	Description	Equipment	Description
 Universal testing machine	Shimadzu Corporation (AUTOGRAPH AG-X plus) ・Loading Capacity: 250 kN (25 ton) ・Loading Method: Direct high-precision constant speed strain control method via non-backlash ball screw drive ・Crosshead Speed Range: 0.0005—500 mm/min.	 Universal testing machine	Shimadzu Corporation (AUTOGRAPH AG-X plus) ・Loading Capacity: 100 kN (10 ton) ・Loading Method: Direct high-precision constant speed strain control method via non-backlash ball screw drive ・Crosshead Speed Range: 0.0005—1000 mm/min. ・Available thermostatic chamber
 Table-top precision universal tester	Shimadzu Corporation (AUTOGRAPH AGS-X) ・Loading Capacity: 5 kN (500 kg) ・Loading Method: Direct high-precision constant speed strain control method via non-backlash ball screw drive ・Crosshead Speed Range: 0.0001—1000 mm/min. (stepless)	 Hydraulic universal testing machine	Shimadzu Corporation (UH-500 kNI) ・Loading Capacity: 500 kN (50 ton) ・Loading Method: Servo program operation by electro-hydraulic servo valve ・Testing Speed(60 Hz): 0.5—80 mm/min. ・Ram Stroke: 250mm
 Drop-weight impact tester	INSTRON (dynatup9250HV) ・Max. Impact Velocity: 20 m/sec. ・Energy Range: 4.6—945 J	 Instrumented pendulum impact tester	INSTRON (POE2000e) ・Maximum capacity: 25.0 J ・Can obtain not only the energy absorption but also load-displacement curve

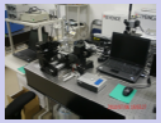
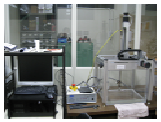
Evaluation and Analytical Equipments

Equipment	Description	Equipment	Description
 High-speed puncture impact tester	Shimadzu Corporation (Hydroshot HITS-P10) ・Testing machine capacity: 10 kN ・Hydraulic operation ・Max. speed: 20 m/s ・Available thermostatic chamber	 Fatigue Testing Machine	MTS Systems Corporation (Landmark) ・Loading capacity: 100 kN (10 ton) ・Shaker displacement: 150 mm (±75 mm) ・Hydraulic wedge grips
 Fatigue testing machine	MTS Systems Corporation (Landmark) ・Loading capacity: 50 kN (50 ton) ・Max. displacement: ±3 mm / more ・Hydraulic wedge grips	 Fatigue Testing Machine	Shimadzu Corporation (SERVOPULSER EHF-UB5-20L) ・Loading capacity: 50 kN (5 ton)
 Fatigue testing system	INSTRON Japan C., Ltd. (Model 8871) ・Maxi. load: ±10 kN ・Ram stroke: ±50 mm ・Repetition frequency: 20 Hz	 Creep Testing Machine	Shimadzu Access Corporation ・Max. load capacity: 1000 N ・Available thermostatic chamber

Evaluation and Analytical Equipments

Equipment	Description	Equipment	Description
 Differential scanning calorimeter (DSC)	NETZSCH (Germany) (DSC200 F3 Maia) ・Temp. range: -70—600 ℃ ・Available auto sampler	 Thermogravimetry-differential thermal analysis (TG-DTA)	Bruker AXS (Germany) (TG—DTA2020SA) ・Temp. range: --1550 ℃ ・Available auto sampler
 Dynamic mechanical analysis (DMA)	TA Instruments (RSA - G2) ・Dynamic force range: 0.001--35 N ・Temp. range: -150—600 ℃ ・Modulus range: 10^3 -- $3x10^{12}$ ・Distortion control method	 Microscope Raman spectroscopy	HORIBA Ltd. ・Equipped Laser : 457, 488, 514, 785 nm ・Spatial resolution: 1μm ・Large spectroscope: f=800mm ・Confocal optical system ・Available thermostat chamber and /or tensile tester
 3D X-ray microscopic CT scanner	Yamato Scientific Co., Ltd. •Spatial resolution: 0.75 μm •Max. scan range: 45 x 45 mm ・Available thermostat chamber and/or tensile tester	 Non-contact 3D scanner	KONICA MINOLTA Inc. RANGE 5 3D Laser Scanner ・Triangulation light block method ・Measurement distance: 450—800 mm ・Accuracy (Distance between balls): ±80μm

Evaluation and Analytical Equipments

Equipment	Description	Equipment	Description
 Micro droplet testing System	TOHEI SANGYO Co., Ltd. (HM410) ・Make resin micro droplet on monofilament ・Measure interfacial shear strength between resin and monofilament ・Testing Temperature: ambient to 400 ℃ ・Measuring Head Movement Speed: 0.06mm/min	 Automatic contact angle meters	Kyowa Interface Science Co., Ltd. ・Simultaneous shooting with X and Y-axis ・Hot stage and hot cylinder are available
 Acoustic emission system	Physical Acoustics Corporation ・Acoustic Emission system ・4-channel ・AE win analysis software ・18-bit A/D converter ・40 MHz high resolution ・Measure waveform and event simultaneously	 Ultrasonic flaw detector	Physical Acoustics Corporation ・A, B and C scopes ・Tank size: 340 (H) x 400 (W) x 40 (dep) mm ・5, 15, 20 MHz sensors
 3D ultrasonic inspection system	TOSHIBA POWER SYSTEMS INSPECTION SERVICE Co., Ltd. (Matrixeye EX™) ・Easy-to-carry portable system ・Sampling frequency: 10, 20, 40, 80, 100 MHz (12-bit) ・Frequency range: 2--15 MHz ・Gain setting: 0—80 dB	 Electron microscope (3D-SEM)	KEYENCE Corporation (VE-8800) ・3D real surface view microscope

Evaluation and Analytical Equipments

Equipment	Description	Equipment	Description
 High-speed video camera	Shimadzu Corporation (HPV-2) ・Recording speed: Max. 1 Mfps ・Frame rate: 100 frames ・Resolution: 312 (Horizontal) x 260 (Vertical)	 High-speed video camera	PHOTRON Limited. (FASTCAM SA-X) ・Resolution: 1024 x 1024 pixel, 12500 fps ・12-bit ADC ・Built-in data logger synchronous system (1MHz, 16-bit, 2 ch)
 Thermograph camera	Japan Laser Corporation ・Resolution: 640 x 512 pixel ・Built-in band pass filter	 Thermograph	FLIR Systems, Inc. (CPA-SC7500) ・Resolution: 320 x 256 pixel ・Maxi. digital frame speed: 20 kHz ・Thermal resolution: 0.02 ℃
 System industrial microscope	OLYMPUS Corporation (BX51M-33MB) ・Magnification: x50—x1000 ・Min. resolution: 0.37 μm ・Illumination: coaxial vertical	 Digital microscope	KEYENCE Corporation (VHX-1000) ・By synthesizing images taken at different distances, image that in focus overall can be displayed

Evaluation and Analytical Equipments

Equipment	Description	Equipment	Description
 Laser scanning microscope	KEYENCE CORPORATION (VK-8510) ・Height measurement: 7 mm ・Resolution of height : 0.01 μm ・Resolution of horizontal : 0.01 μm	 Polishing machine	Metkon Instruments Ltd. (TURKEY) (FORCIPOL 1V) ・Rotate speed: 50—600 rpm
 7.5-kW super Xenon weather meter	Suga Test Instruments Co., Ltd. (Super Xenon Weather Meter SX75) ・7.5 kW ・Radiation intensity: 180 W/m²	 Low temperature thermostat humidistat	Isuzu Seisakusho Co., Ltd. (A series Crystal) ・Inner dimension: 400 (H) x 500 (W) x 600 (dep) mm ・Temp. rising time: 20—120 ℃ 60 min. ・Temp. Precision: ±0.8 ℃ ±3.0 %RH
 Vacuum drying machine	ADVANTEC (Vacuum drying machine body: DRV320DA, COLD TRAP: DRT140FB) ・Inner dimension: 290 (H) x 300 (W) x 300 (dep) mm ・Temperature range: 50—250 ℃ ・Vacuum degree: 100—0.13 kPa	 Incubator	Isuzu Seisakusho Co., Ltd. (KOSUMOSU AT-S13) ・Inner dimension: 400 (H) x 450 (W) x 400 (dep) mm ・Temp. range: 40—300 ℃

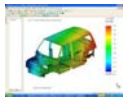
Cutters and Others

Equipment	Description	Equipment	Description
 Abrasive waterjet cutter	FLOW JAPAN Co. (MACH3) ・MACH3 Waterjet mix ultra high pressure water with abrasive	 Composite material cutting machine	MARUTO Testing Machine Company (AC-500CF) ・Cutting size: 500 mm ・Auto-sending/ returning system ・Clamp mechanism by air cylinder
 Micro cutting machine	MEIWAFOSIS Co., Ltd. (BS-310 CP) ・Max. Cutting Surface: 190 x 150 mm ・Max. Thickness: 0.04 x 40 mm ・Min. Thickness: 2 μm ・CP method (Contact Point method) ・Band speed: 10--800 m/min. ・Band type: Diamond chip	 Cutting RP machine	Roland DG Corporation (MODELA Pro MDX-500) ・Rapid prototyping machine ・Processing machine for manufacturing to realize easily by representing from 2D to 3D
 Small precision cutting machine	MARUTO Testing Machine Company (TS-40) ・Max. cutting surface : round 30 x random length (mm) square 60 (w) x random length x 25 (H) mm	 Contour machine	LUXO Co. (U-300) ・General cutting machine with an endless saw blade (large band saw)

Cutters and Others

Equipment	Description	Equipment	Description
 Notching machine	YASUDA SEIKI SEISAKUSHO Ltd. (189-PN) ・Notching tool for notch-process to Charpy-izod impact test specimen ・Cutter rotational speed: approx. 500 rpm (50 Hz)	 Bench drilling machine	YOSHIDA TEKKOJO Inc. (YBCD-420)
 Small high voltage power supply・CR electrode	Green-Techno (GT 100P) ・Experiment instrument of lightning resistance ・Max. output voltage: 10 kV	 Mold racks	Transcale ・Store and manage large molds
 Overhead traveling crane	NIPPON HOIST Co., Ltd. (NHEY2.8THA) ・Max. lifting capacity: 2.8 ton		

CAD/CAE Software

Software Name	Description	Software Name	Description
 HyperWorks	Altair •HyperMesh Interactive high function Preprocessor •RADIOSS Linear/Non-linear finite element solver •HyperForm Synthesis press molding framework	 CATIA/ DASSAULT TASSAUL SYSTEMS	NTT Data •3D CAD software •Capable of any shapes and structural models (parts, surfaces and assemblies)
 PAM-FORM	ESI •Resin/Compound material molding analytical software •A package: mesh creating function, preprocessor, solver and postprocessor ・High precision and high-speed explicit dynamic solver capability	 DIGMAT	ues software asia •Calculator software for linear/Non-linear composite material •By multi-scale structural analysis technique, grasp the behavior and mechanism of composite materials
 LS-DYNA	JSOL •Shock analytical software of dynamic explicit method •JVISION (Pre-and post-processor having high affinity with LS-DYNA)	 Marc/ Nastran/ Patran	MSC Software •Marc Non-linear structural analysis solver •Nastran Analytical program available for basic to complicated structures •Patran Pre-and post-processor: integrate solver and various CAD environments
 Abaqus	SIMULIA •General finite element program; heat transfer analysis and structural analysis of advanced contents •Preprocessor (AbaqusCAE) capable of modeling, job management, monitoring of analysis, display of result		

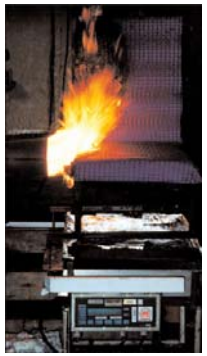
National Composites Center Japan

3500 ton Press Facilities

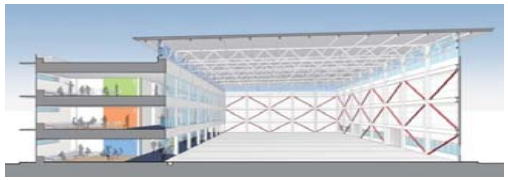
National Composites Center Japan

Lightning test device

Heat and Flame Resistance Devices



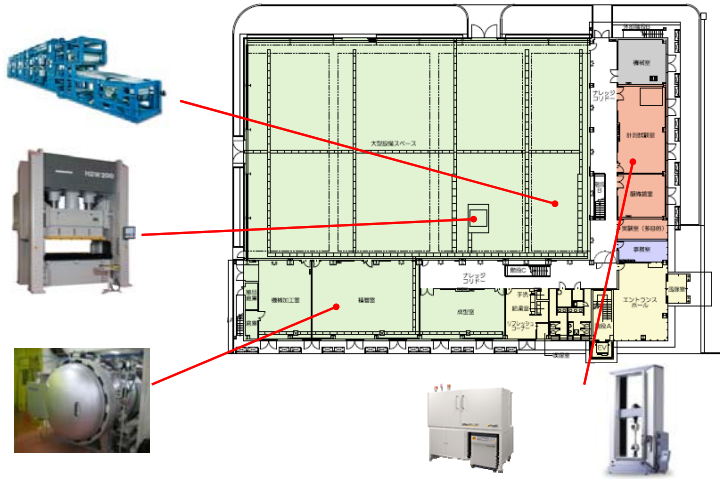
Ishikawa Innovative Composite materials research & development Center



4,400m² Total
2,500m² Working Area

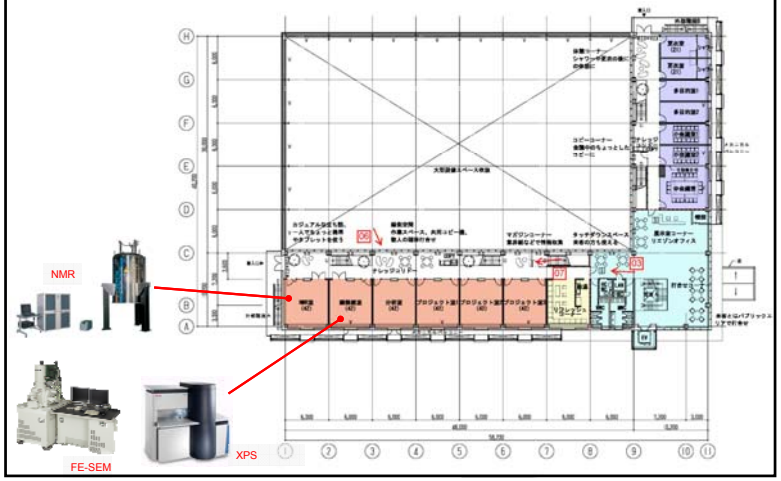
Ishikawa Innovative Composite materials research & development Center

1F Manufacturing and Mechanical Testing Facilities



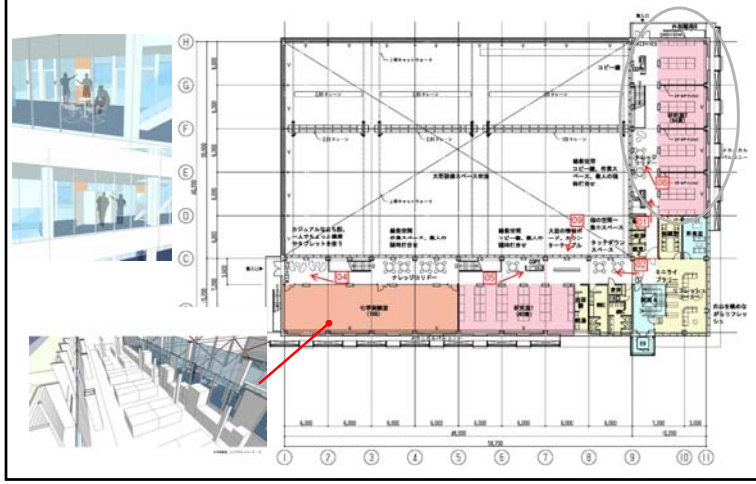
Ishikawa Innovative Composite materials research & development Center

2F Analytical Facilities and Laboratories



Ishikawa Innovative Composite materials research & development Center

3F Chemical Facilities and Laboratories



Japanese National Projects For Mass Production CFRP Automobile

2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

CFRTP (material) Project

- Parts replacement
- High cycle molding
- In-plant waste recycling

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Innovative CF Project

- Productive & low cost

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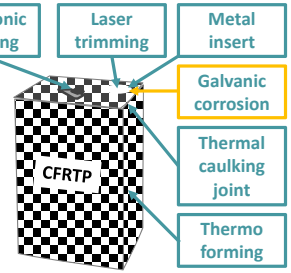
LCIC, AIST, Mitsubishi Rayon, Teijin, Toray

How to make Oil Can by CFRTP ?

Rectangular Steel Oil Can

Replacement of individual parts

Is this really the right way to reduce weight ?



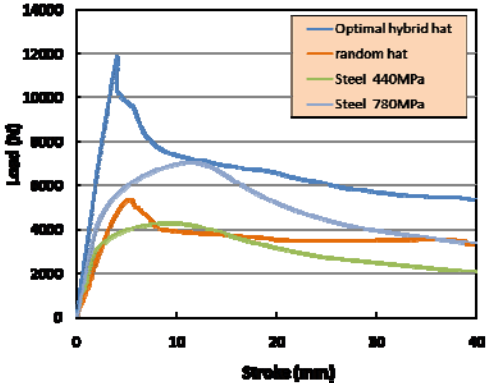
Design by composites

More Flexible !

More Functional !

More Cute !

Comparison between CFRTP and Steel Hollow Beam



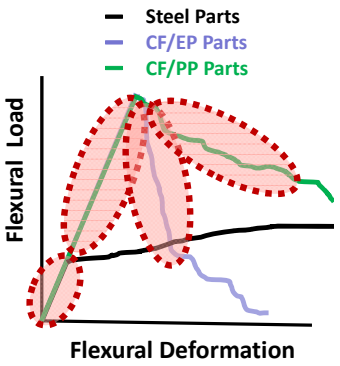
- Weight is 50%
- Energy absorption capacity is
  2.0 times of 440MPa grade steel
  1.5 times of 780MPa grade steel

Comparison of Fracture Process

CF/EP

CF/PP

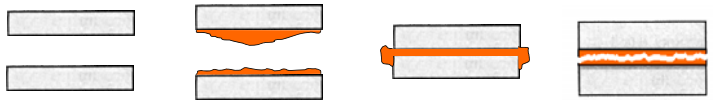
Comparison of Steel, CF/EP, and CF/PP Parts



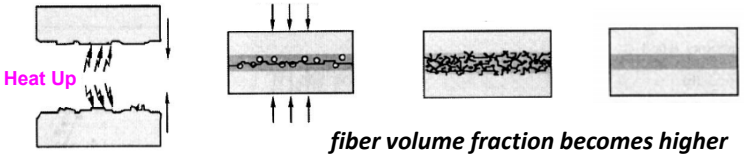
1. Compared to steel parts, the weight of CFRP parts is from 1/3 (plate) to 1/2 (beam).
2. Elastic strain range of CFRP is larger, hence less likely to dent.
3. CF/EP shows sudden load fall due to the delamination, hence is weak in hole, notch and corner.
4. CF/PP not only shows high energy absorption capacity but is stronger in hole, notch and corner.
5. Additionally, CF/PP can easily bond, repair and recycling by using thermoplasticity.
6. By using these features of CF/PP, new structures and manufacturing methods can be developed.

Difference in Adhesion between CFRTS and CFRTP

CFRTS: Bolted or adhesive joint --- weaker than base material



CFRTP: Welding joint --- the same or stronger than base material



fiber volume fraction becomes higher and fiber tangles at the welded section !

Joint between CFRTP and Metal

・LAMBORGHINI Aventador

・McLaren MP4-12C

・TOYOTA LFA

CFRTP don't hesitate bolted joint.

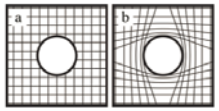
Nut insert and drilling to CFRTP member

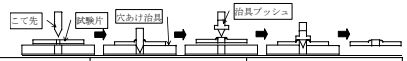
■ Nut insert

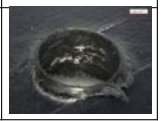
- Creep of thickness direction by the clamping pressure is worried.
- Simultaneous nut insert press molding is possible by discontinuous CFRTP.

■ Hole drilling

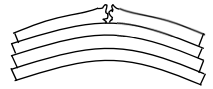
- Delamination hardly occurs by hole drilling.

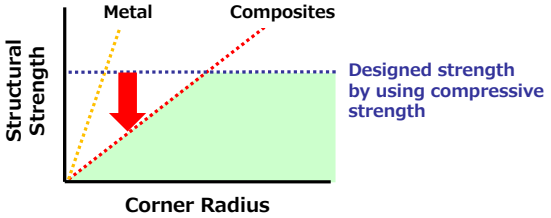




	Mechanical	Thermal
CF Mat with properly modified PP Vf=20		
CF Mat with too much modified PP Vf=20		

Importance of the curvature design in CFRP

	$\sigma_\theta >$ Compressive strength	$\sigma_r >$ Interlaminar strength
		
Domestic Failure Mode	Compressive failure	Delamination
Structural Strength	As designed	Unexpectedly low
Structural Failure Mode	Ductile	Brittle



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- ~~Parts replacement~~
- High cycle molding
- ~~In-plant waste recycling~~

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Innovative CF Project

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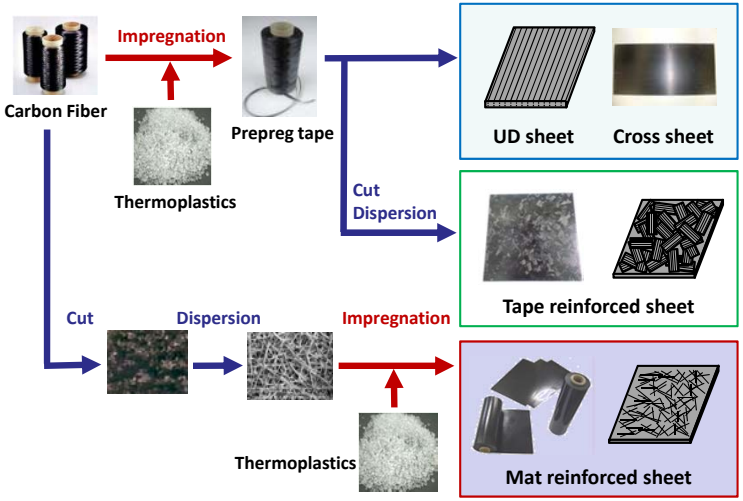
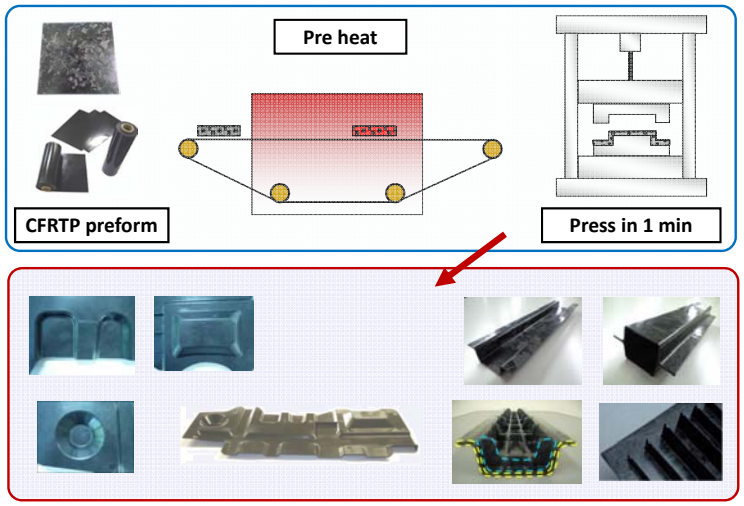
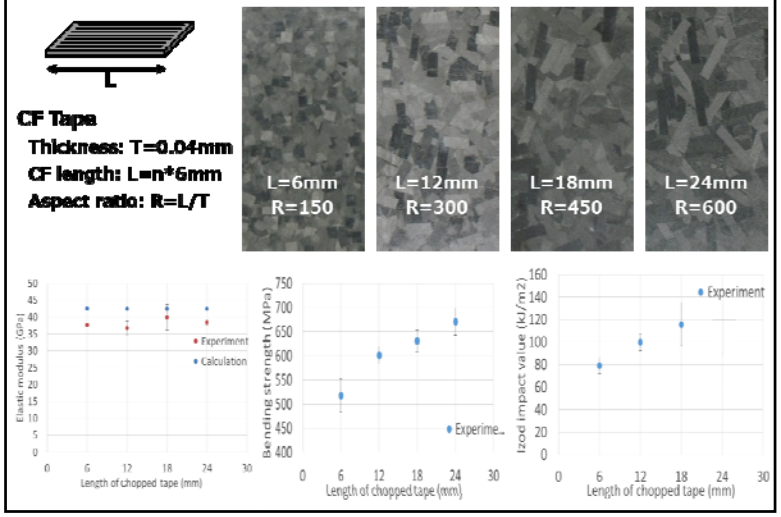
Thermoplastic Prepreg Sheets



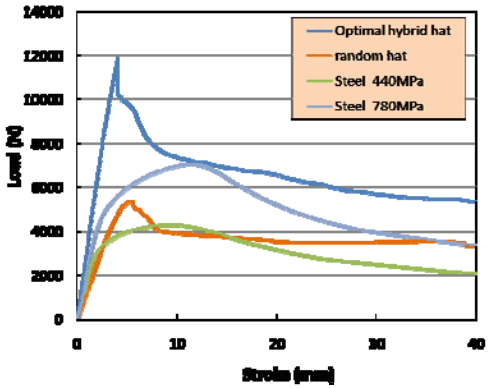
Continuous Compression Molding for Mass Production



Properties of CTT: *CF Tape Reinforced Thermoplastics* (PA6)

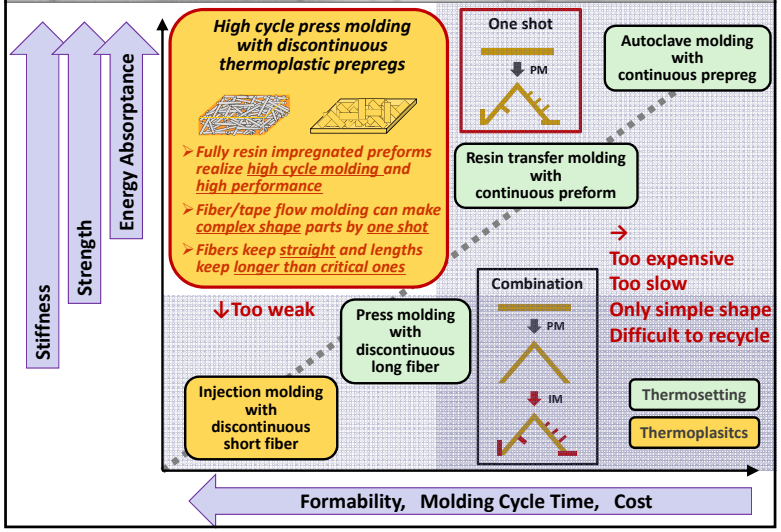


Comparison between CFRTP and Steel Hollow Beam

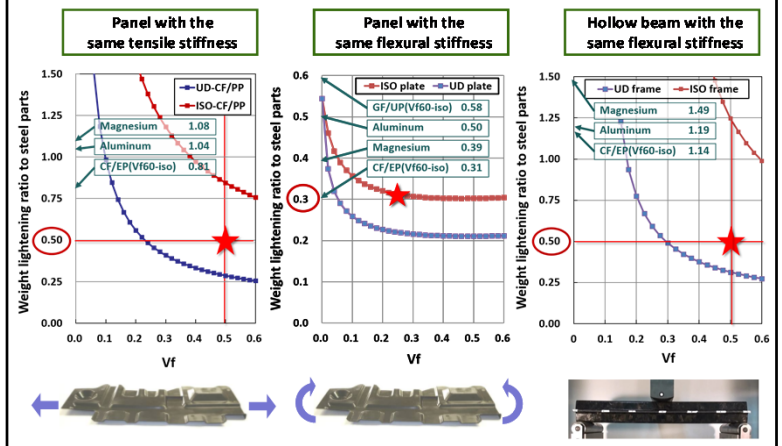


- Weight is 50%
- Energy absorption capacity is
  2.0 times of 440MPa grade steel
  1.5 times of 780MPa grade steel

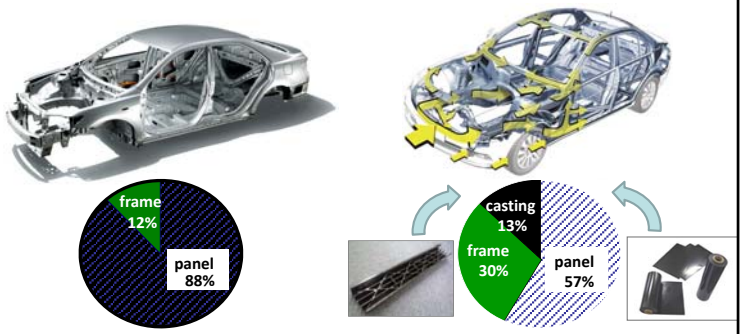
Developing Direction of CFRTP for Mass Production



Comparison of Weight Lightening Ratio between CF/PP and Steel Parts



Automotive Materials and Structures

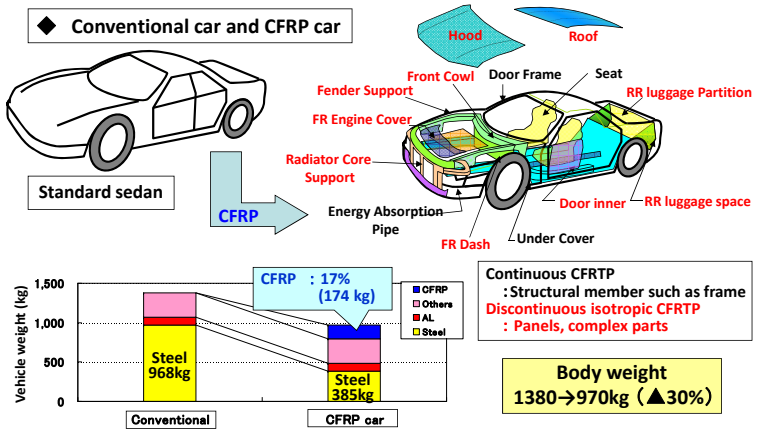


< Monocoque body >
Better structure for lightweight

< Frame monocoque hybrid body >
Better for safety and recyclability

- Automobile parts are mostly composed of plates.
- Flexural properties are dominant in the case of automotive materials and structures.

Weight Reduction Concept by using CFRTP



Continuous CFRTP
: Structural member such as frame
Discontinuous isotropic CFRTP
: Panels, complex parts

Body weight
1380→970kg（▲30%）

Body weight can be reduced by 30% with CFRTP application

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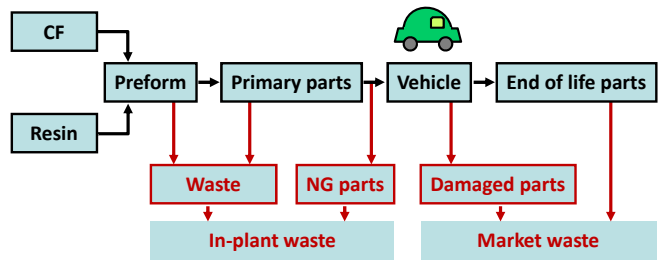
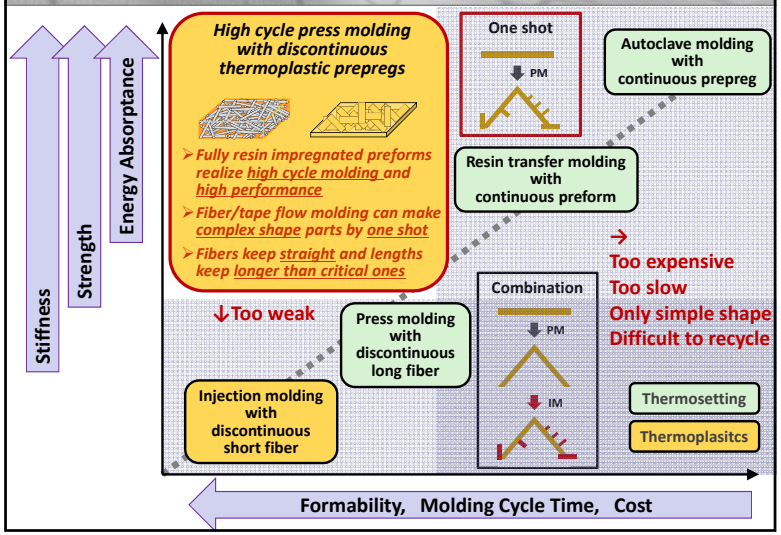
“in-plant waste” and “market waste”



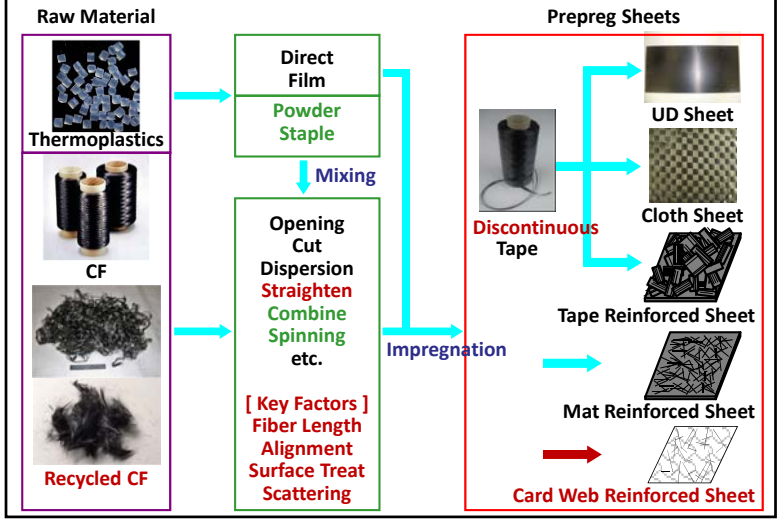
“in-plant waste” : identity of the material is clear
no environmental degradation ⇨ high quality recycled materials

“market waste” : identity of the material is not clear
with environmental degradation

Developing Direction of CFRTP for Mass Production



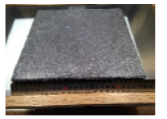
Thermoplastic Prepreg Sheets by Waste CFRP



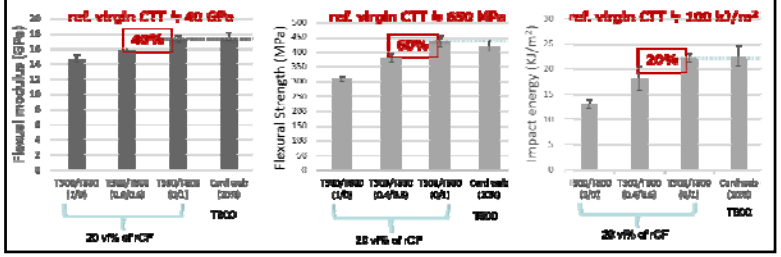
Mechanical Properties of Recycled CF/PA6

	Matrix	CF Length	Process	Advantage
Carbon Paper	PA6 Fibers	Concentrated around 6 mm	Paper Making Method	Short fiber can be used Small scatter
Card Web		Widely distributed up to several cm	Carding Machine	Very productive
CTT		As you wish	*Confidential*	High Vf and energy absorption

CTT: carbon fiber tape reinforced thermoplastics

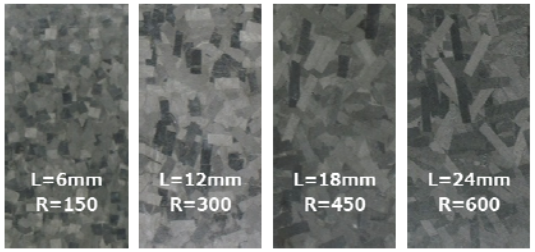

Carbon Paper

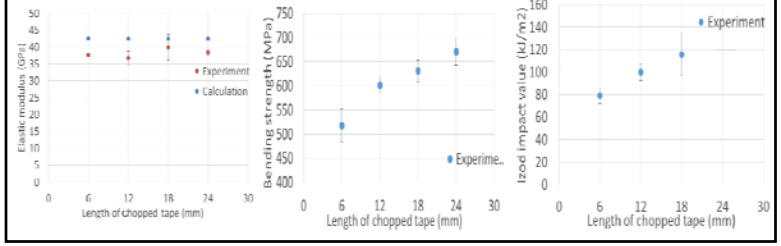

Card Webs



Properties of CTT: *CF Tape Reinforced Thermoplastics* (PA6)

CF Tape
Thickness: T=0.04mm
CF length: L=n*6mm
Aspect ratio: R=L/T





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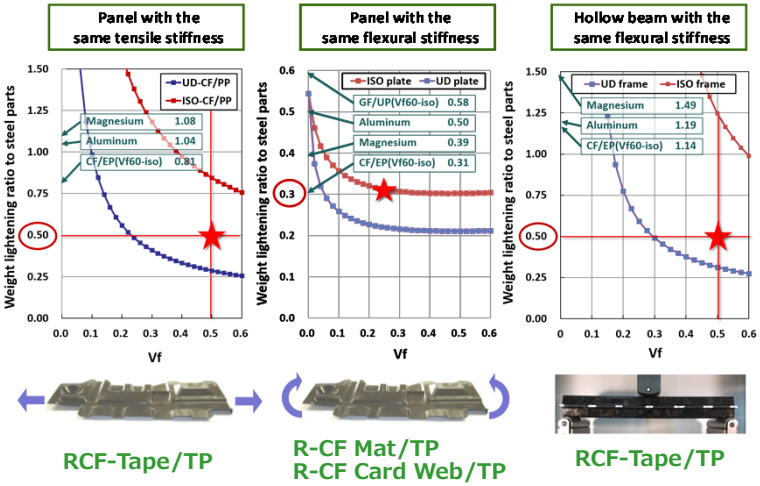
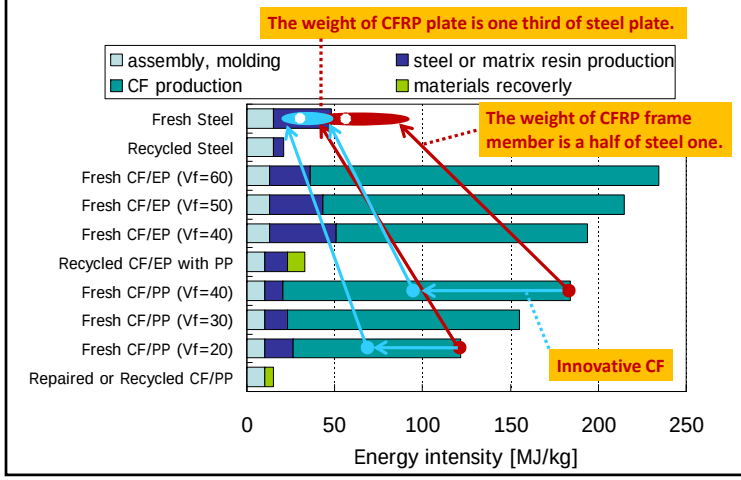


Energy Consumption for Parts Production

Energy Consumption [MJ/parts] ≠ Energy Intensity [MJ/kg]



Thank you for your kind attention.

INNOVATION