3D Printer Using Continuous Carbon Fiber Composite Materials

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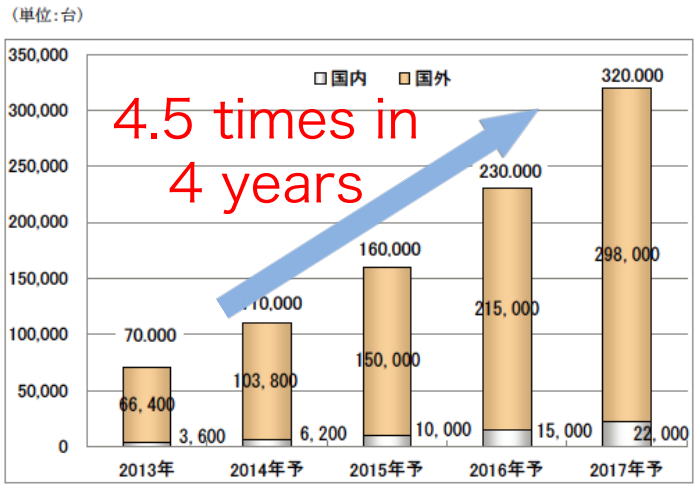
Background

3D printer for resin material

- Predicted to bring a“Revolution in Manufacturing” that will dramatically change manufacturing
- World 3D printer market to grow to 320,000 units in 2017
- Resin is not suitable for fabrication of structural members

➔ Primarily used for fabrication of prototypes and toys



Transition of scale of world 3D printer market
(Yano Research Institute Ltd., 2014)

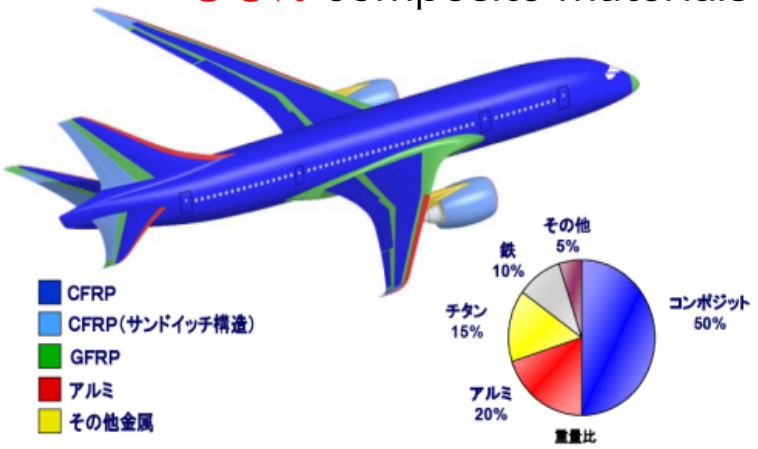
Engine block prototype
(METI Journal, 2013)

Background

Carbon fiber reinforced plastic (CFRP)

- Lighter, more rigid, and stronger than existing metallic materials
- Increasing application, widespread in airplanes and automobiles
- Molding of current composite materials is a very complicated process

50% composite materials

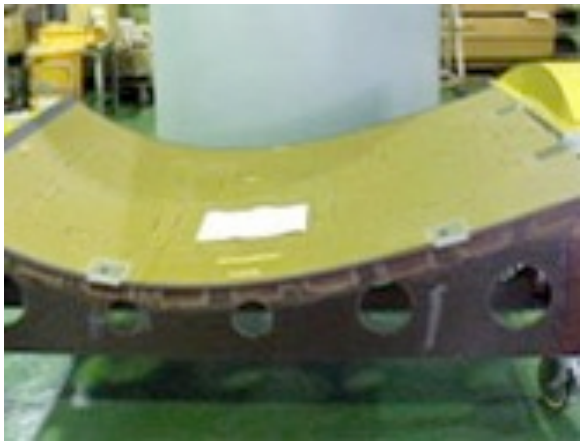


CFRP usage ratio in latest passenger plane (Boeing)

2D/3D designing → Laminating → Heating and hardening → Demolding → Single product machining → Sub-assembly → Assembly of all parts

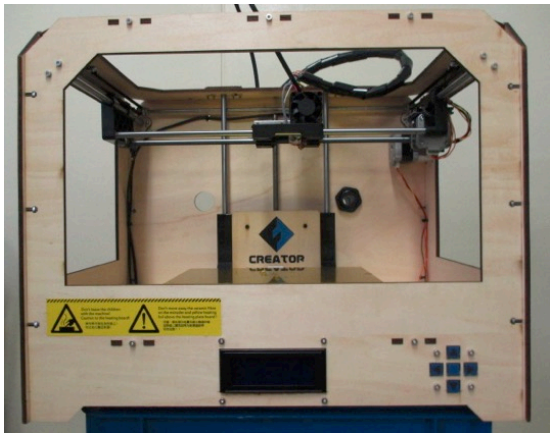
Conventional Technology and Its Issues

CFRP molding



Merits: High strength and rigidity
Demerits: Die is required, costly

3D printer



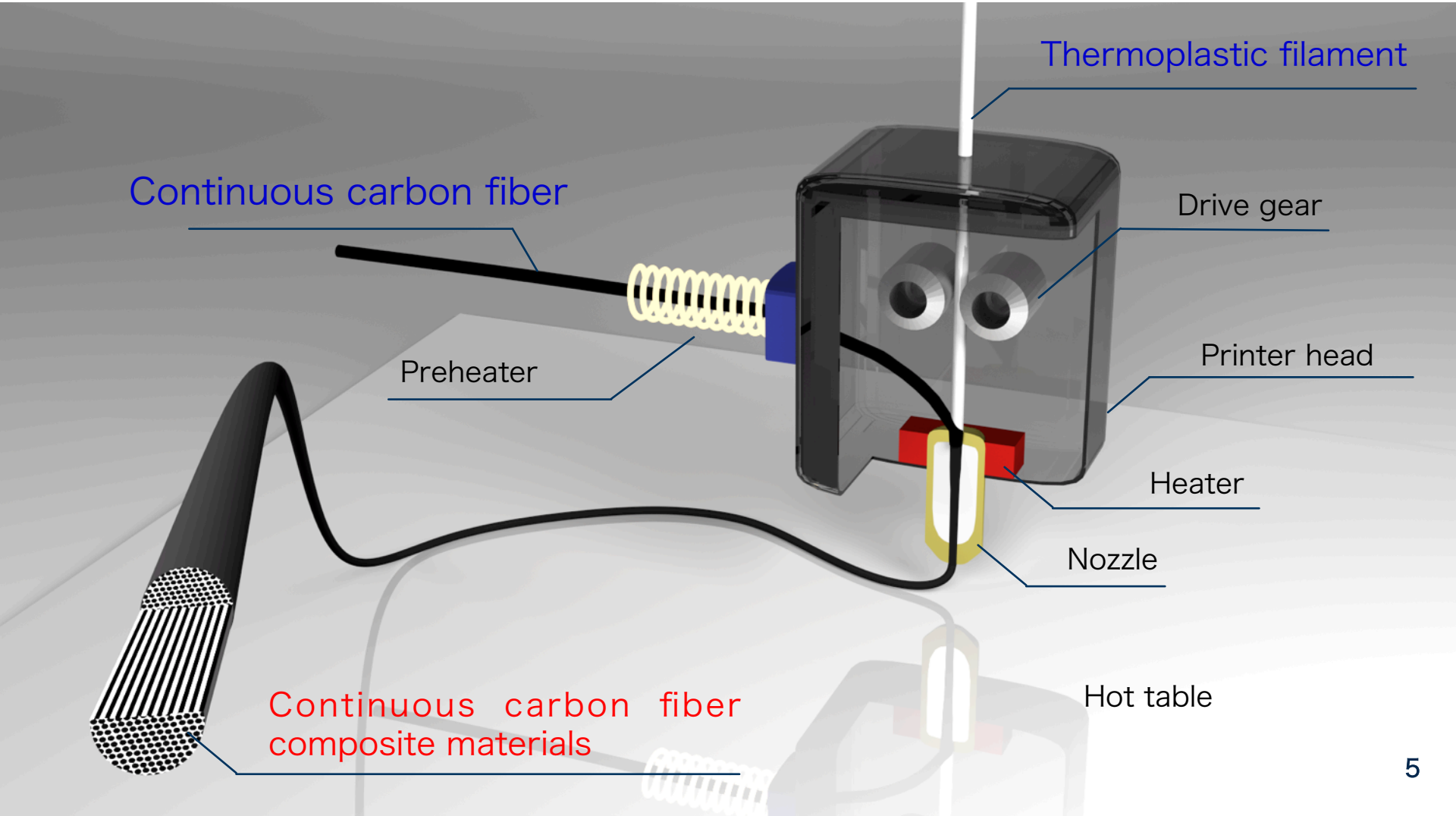
Merit: Automatic 3D molding
Demerits: Low strength and rigidity

High strength
continuous carbon fiber

Solution is a 3D printer that manufactures continuous carbon fiber composite materials

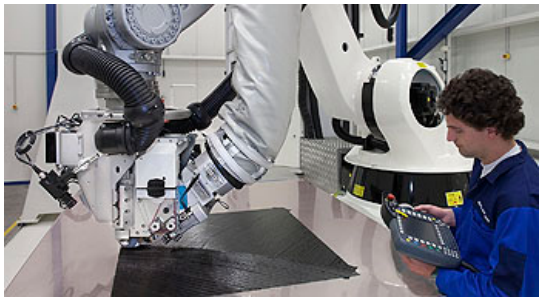
High Strength 3D Molding
by using Continuous Carbon Fiber 3D Printer

- The printer nozzle integrates continuous carbon fiber with thermoplastic resin



Characteristics of New Technology and Comparison with Conventional Technology

- Uses continuous carbon fiber, and “prints” highly rigid and strong materials three dimensionally
- Does not require a die and optimization is automatic, molding and machining (trimming) based on 3D CAD data
  - Suitable for multi-product production in small lots
  - Significantly reduces development period, manufacturing time, cost, and weight
- Low cost as the widespread 3D printer technology can be applied
  - Cost of a similar technology, automated fiber placement, is over 100,000 USD. Implementation of this technology is very rare in Japan.

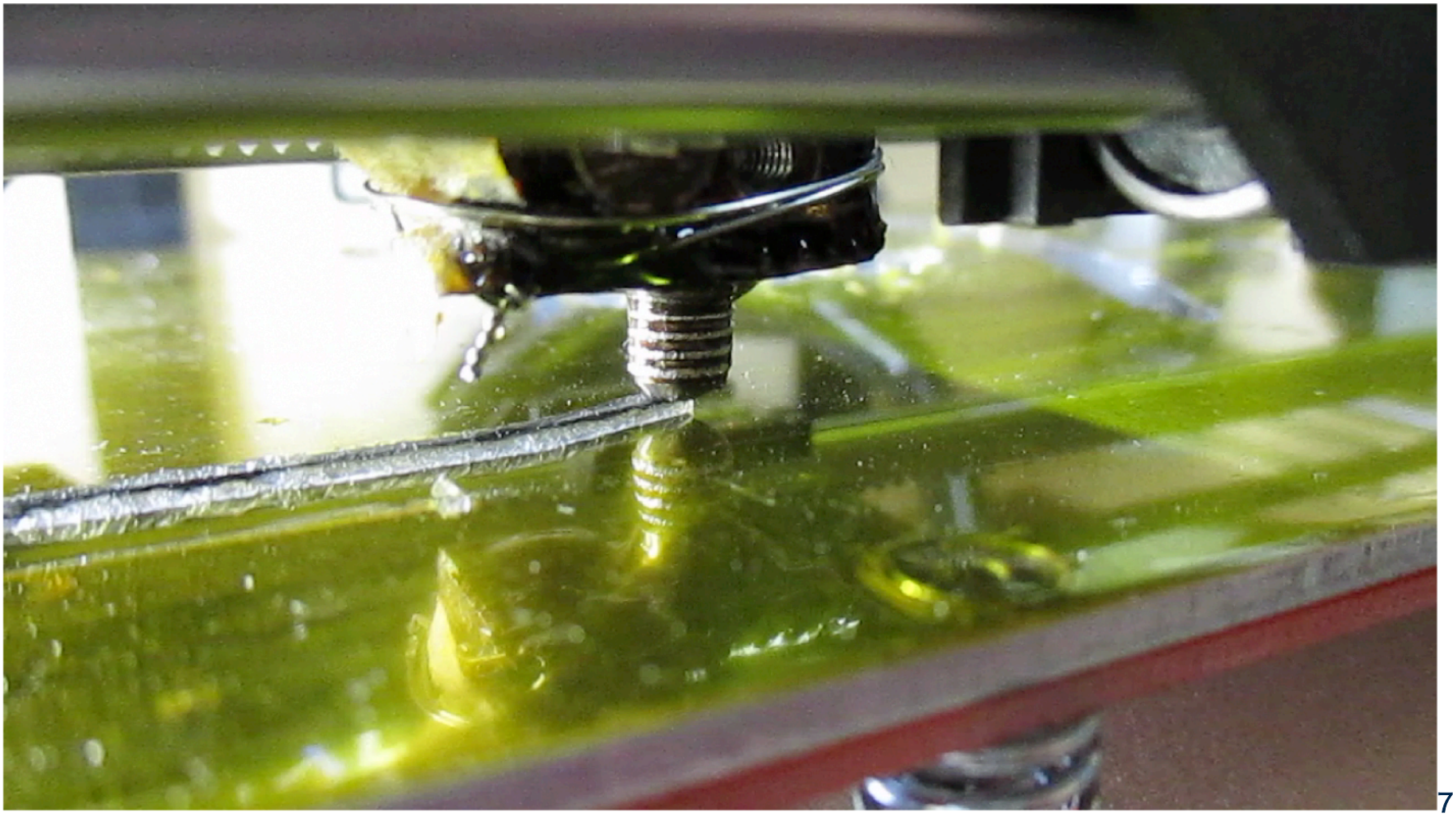


Automated Fiber Placement
(Netherlands Aerospace Centre)

- Because orientation and content of fiber are controllable, the advantage of CFRP is fully harnessed in combination with the optimization method

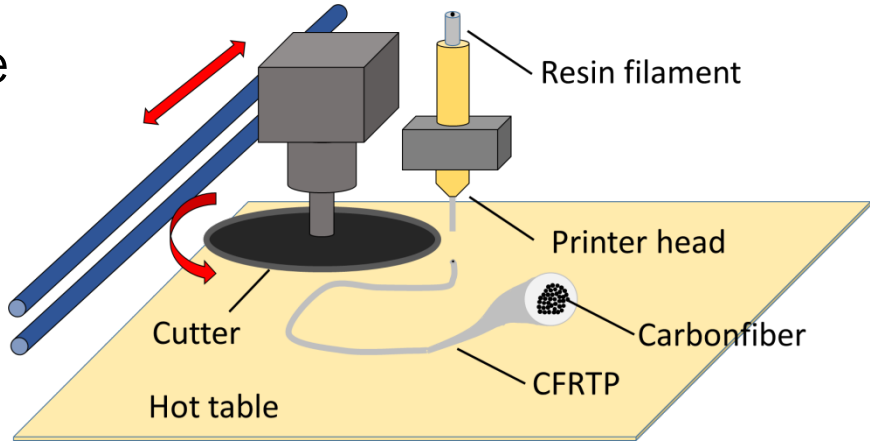
CFRTP 3D Printing

- 3D printing of composite materials (movie)

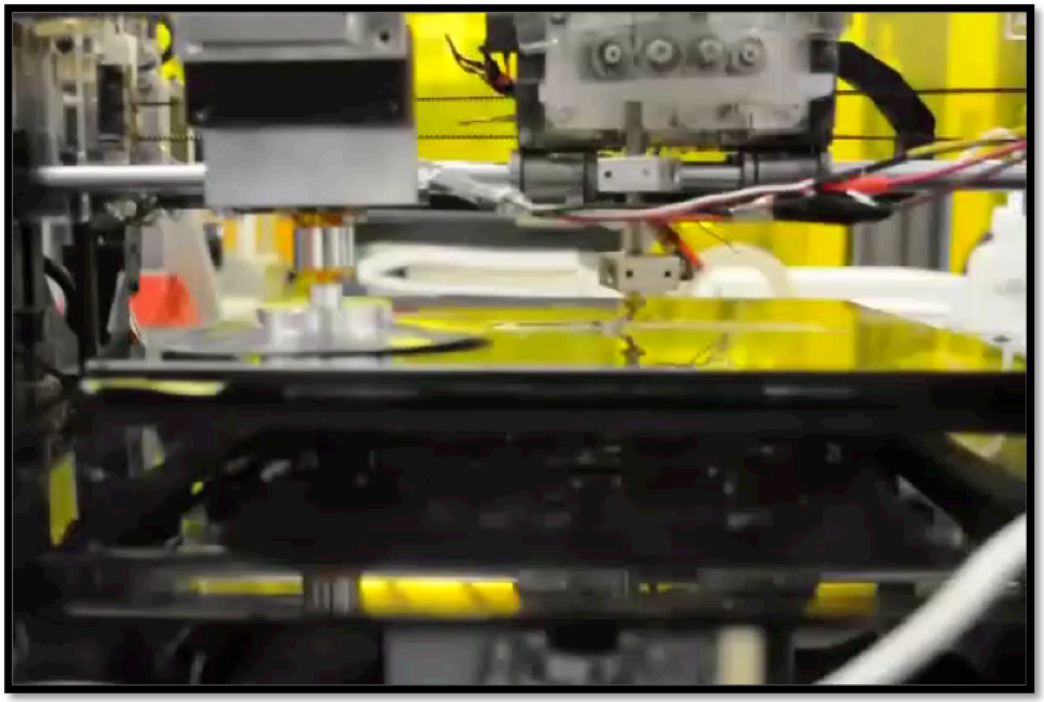


Fiber Cutting Mechanism

- Fiber is cut during printing, to realize free three-dimensional shaping



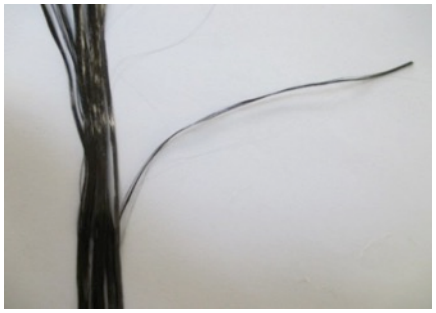
- Carbon fiber cutting (movie)

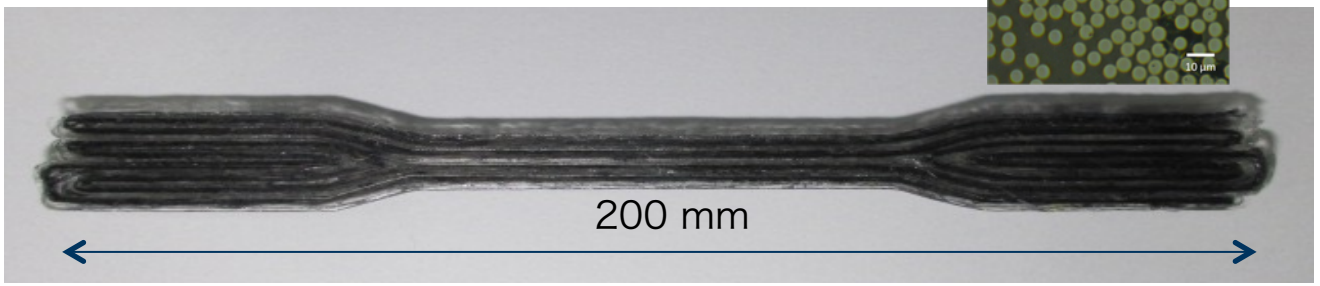


3D-Printed Test Piece in Dumbbell Shape

- PLA test piece
  (without reinforcing fiber)

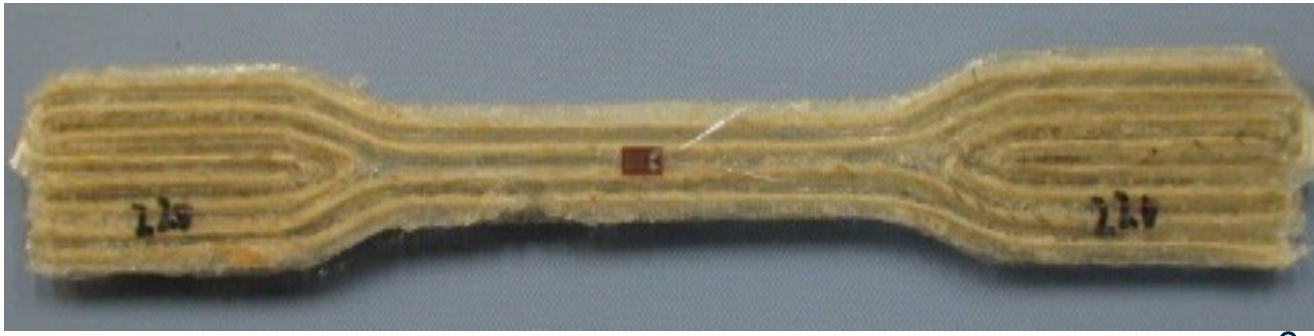
- CFRP for 3D printing





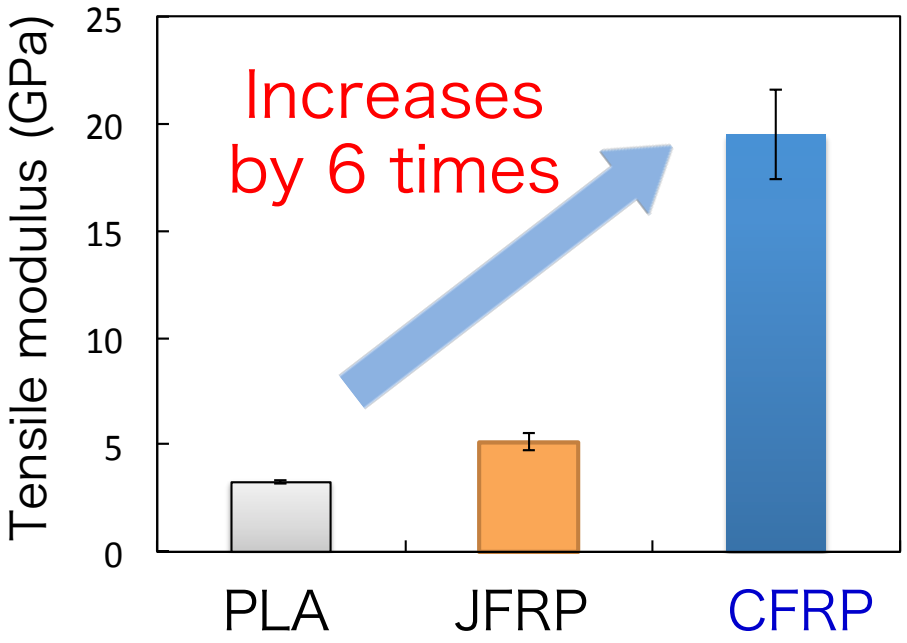
t : 4 mm

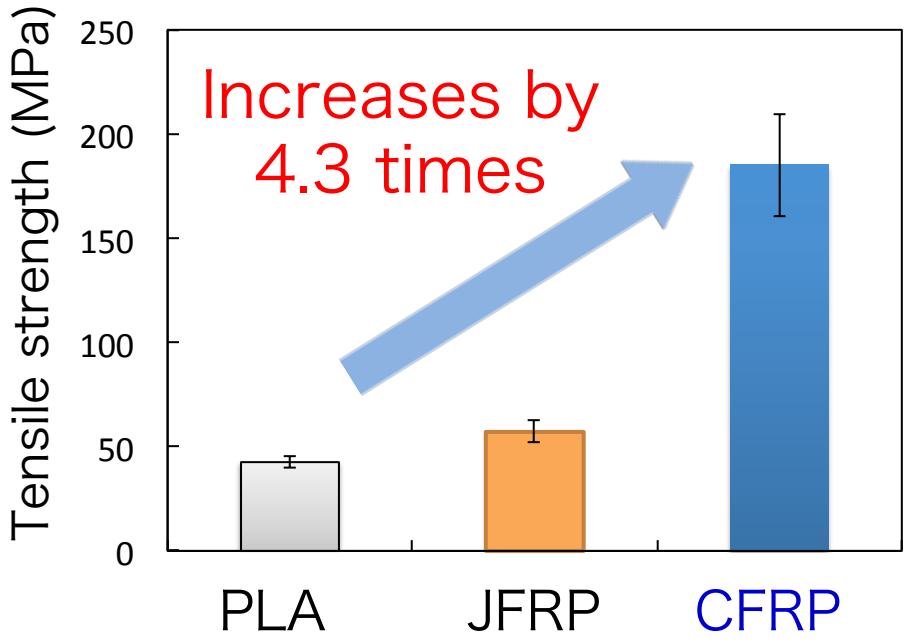
- JFRP for 3D printing
  ➔ Green composite combining jute fiber and PLA



Material Characteristics of 3D Printing Composite Materials

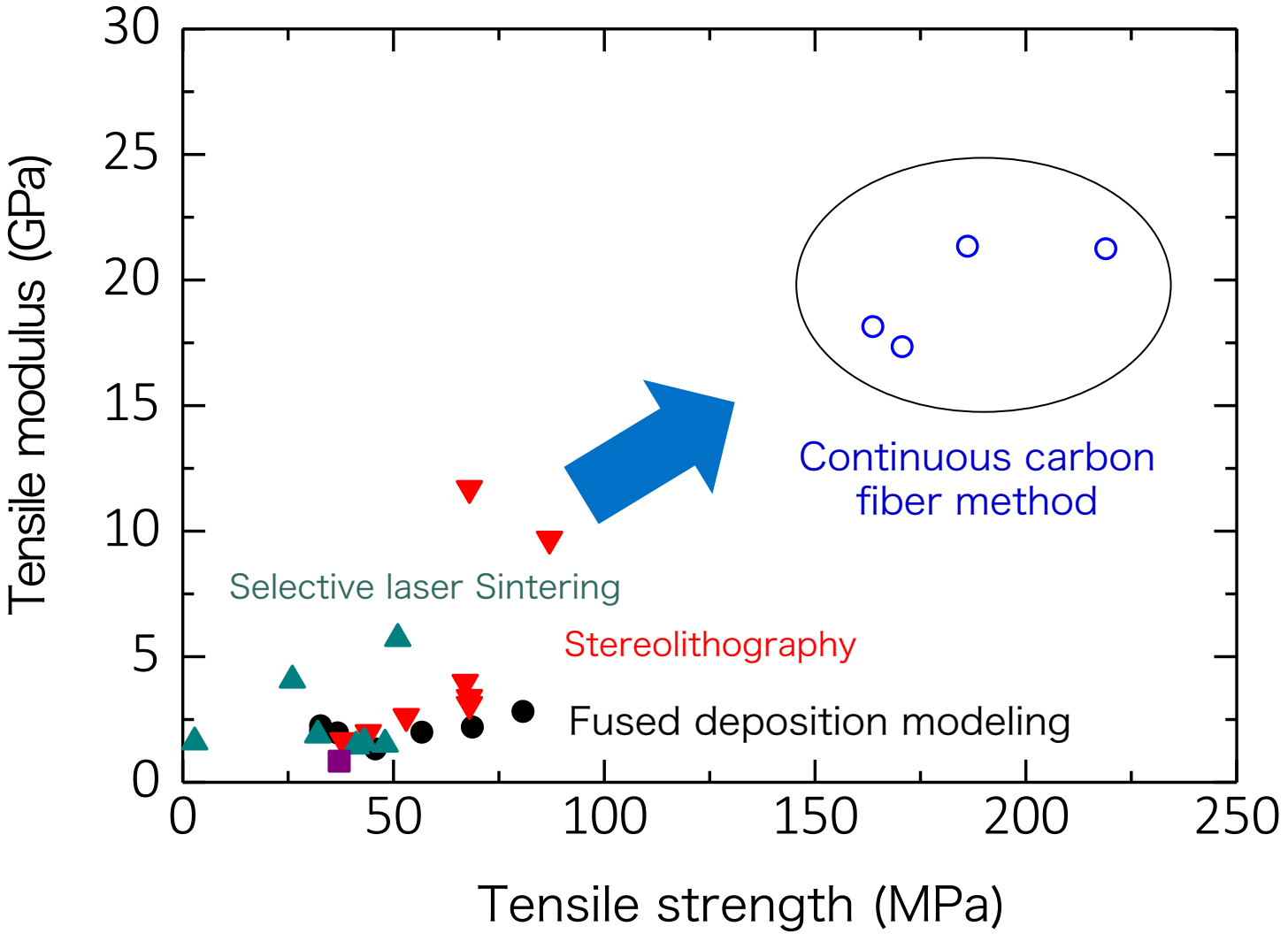
- Introducing continuous carbon fiber increases the modulus and strength by 4 to 6 times





Material Characteristics Comparison with Commercially Available Industrial 3D Printers

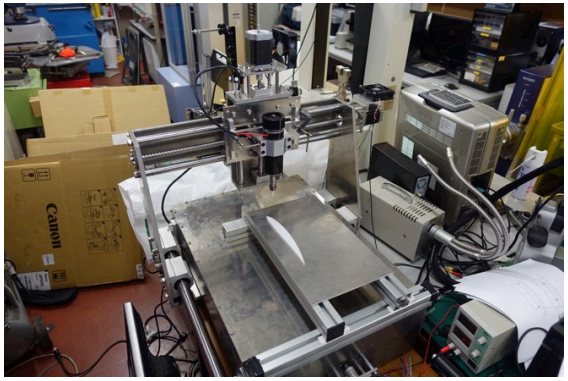
The characteristics are dramatically improved compared to commercially available industrial 3D printers



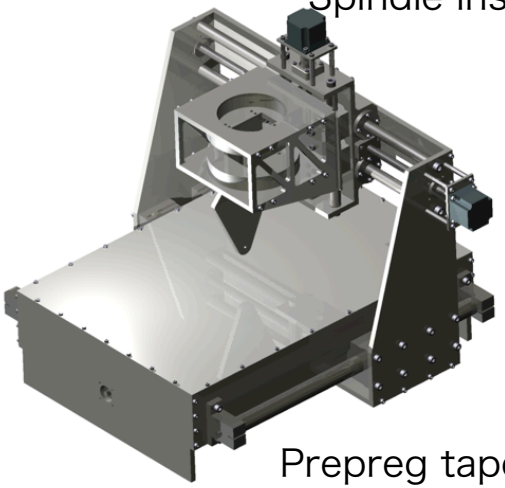
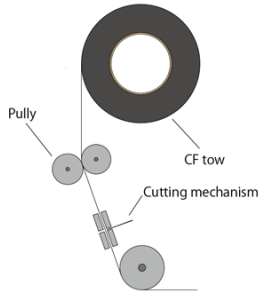
Device Image

- Desktop Composite Material 3D Printer
  - Optimizes fiber orientation from 3D CAD data
  - 3D printing of high strength carbon fiber composite materials on desktop
  - Can also machine and trim by changing the head

- Structure
  - Highly rigid base
    - Compatible with heavy head for molding composite materials
    - Compatible with 3D CNC
  - Multiple head types
    - Spindle CNC machining
    - Prepreg tape layup
    - In-situ impregnated CFRTP
  - Software
    - Optimization of fiber orientation



Spindle installed (3D CNC)

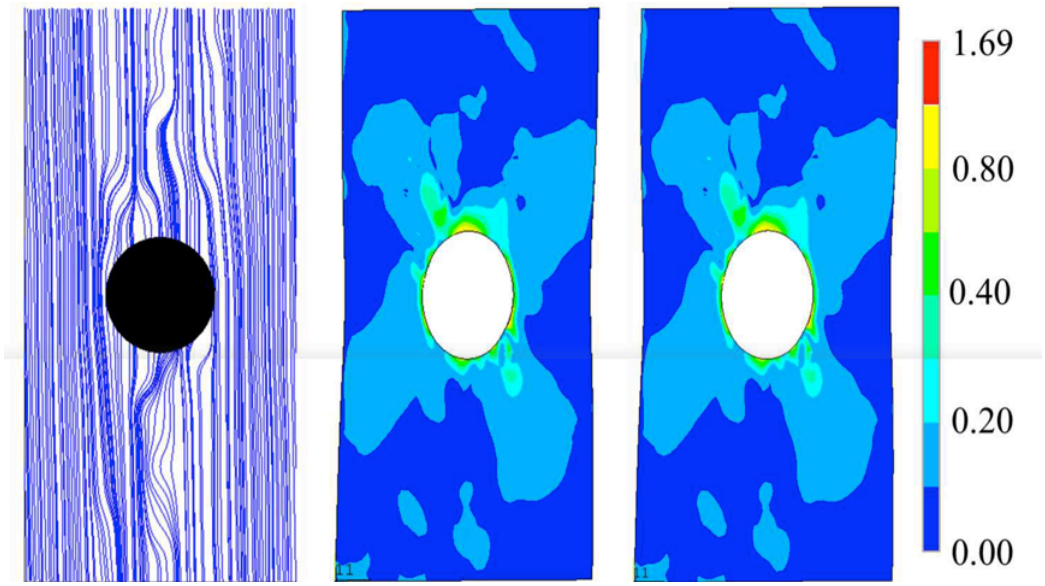



Prepreg tape layup head

New Design Concept Leads to New Products

- Not bound by conventional linear fiber orientation, and degree of design freedom is significantly improved, including curvature fiber orientation
- New design concept allows creation of new products
- Same 3D CAD data yields different products, indicating that the performance of the optimizer determines product performance.

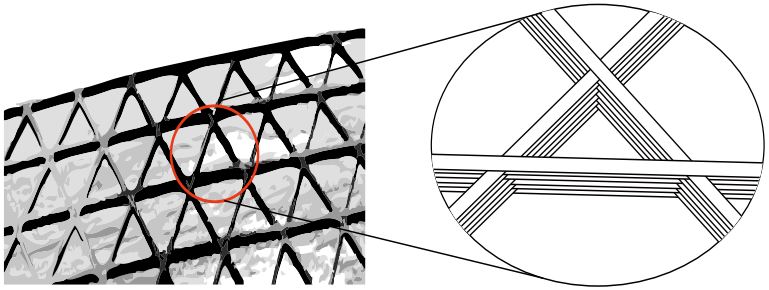
➔ Accumulated knowledge on optimization including curvature orientation.



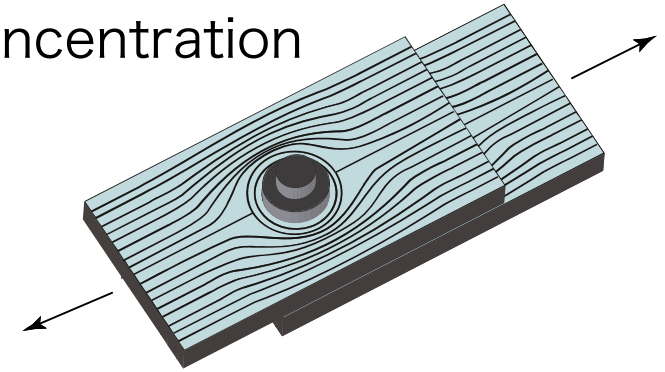
Continuous fiber orientation Stress distribution Fiber content considered

Additional Capacity for Automatic Manufacturing of New Structure

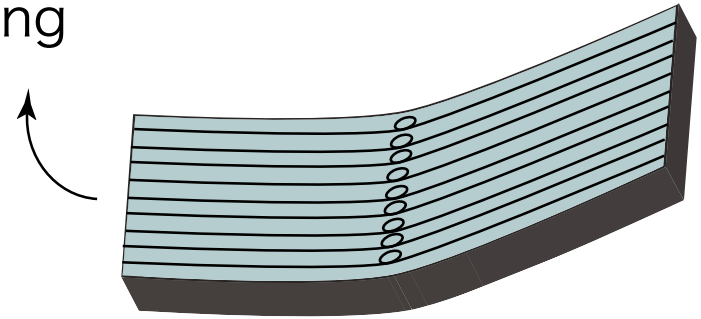
- Automatic isogrid molding



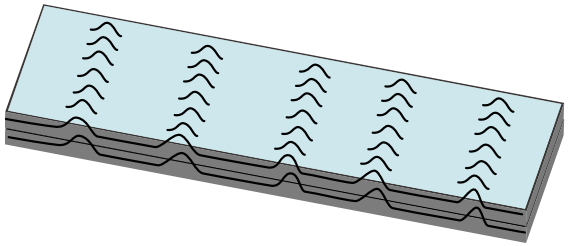
- Reduction of stress concentration



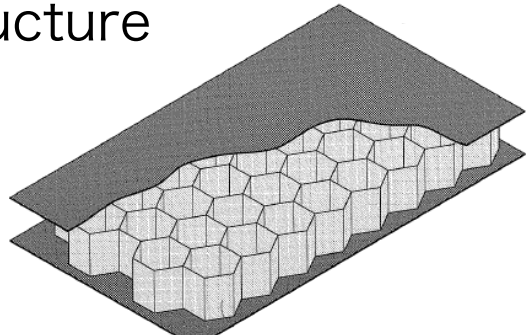
- Bending



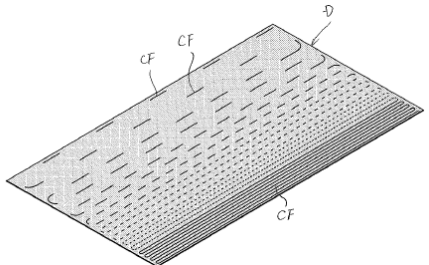
- Prevention of delamination



- Sandwich structure

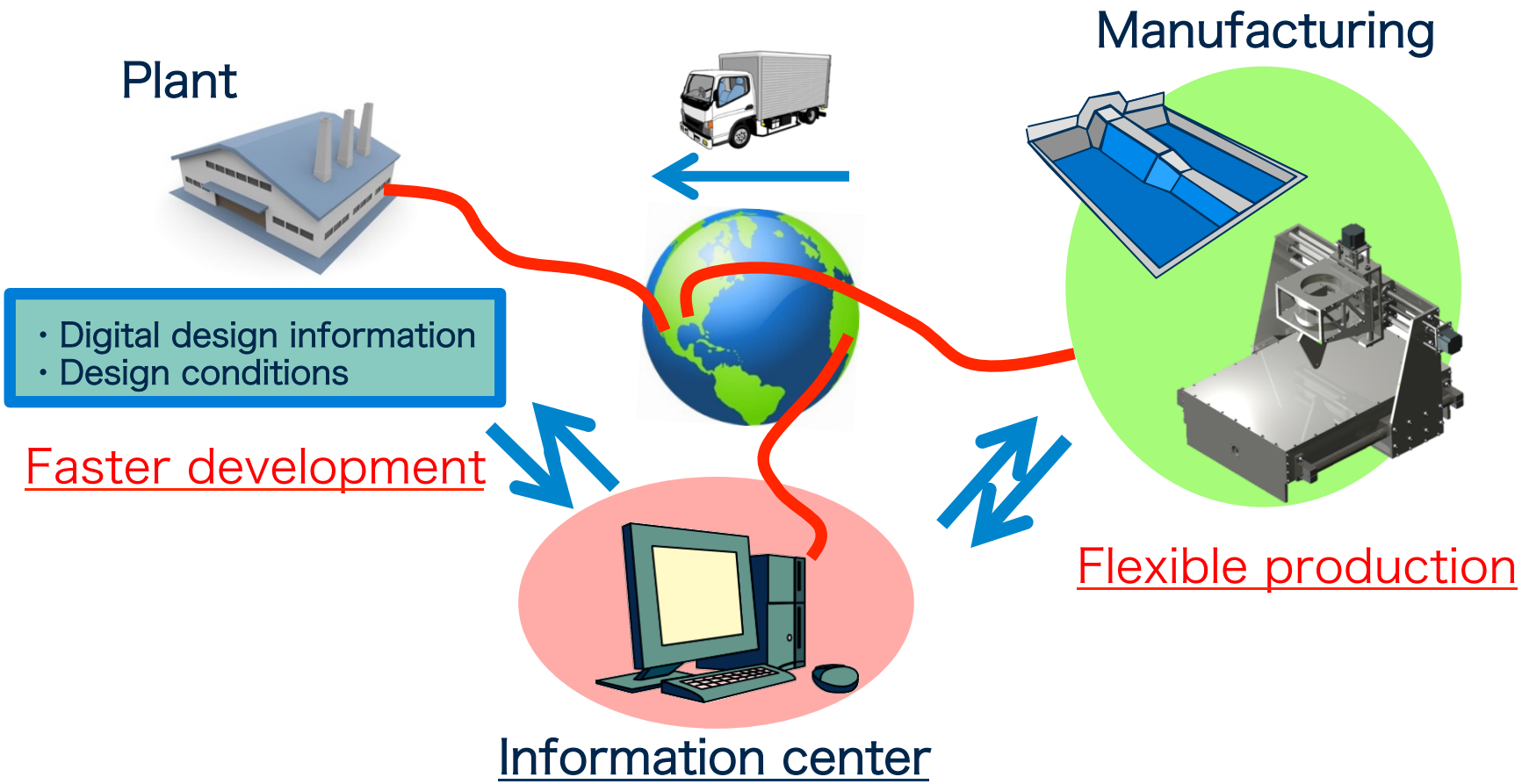


- Modulus/strength/ tailoring



Software-controlled Manufacturing

- Key to optimizing fiber orientation and strength database.
- Manufacturing will be software-controlled, and information will be centralized in Japan; thus, replicating the technology will be difficult.



Potential Applications

Application

- Suitable for manufacturing a variety of components requiring structural strength in small lots, and substantially reduces development period, manufacturing time, cost and weight
- Aviation, automobile, medical, and general work equipment sectors. Particularly, machining jigs and medical care devices such as prosthetic legs and assist suits
- Possibility of application to batch manufacturing by combining 3D printer and an assembly robot for metal parts

Other developments

- High-level amateurs
- Post secondary and corporate research institutions
  - Education: prototyping, designing, and optimizing
  - Research: Adaptable to diverse requirements

Challenges for Practical Applications

- Technology required for fiber orientation optimization, continuous carbon fiber 3D printing, and fiber cutting has already been developed.
- The fiber volume fraction needs to be increased to the level of existing CFRP products.
- Future scope of this study is to develop nozzles and filaments to achieve a high volume fraction of fiber.
- It is also necessary to establish a technology to improve the accuracy of three-dimensional molding to the level of existing 3D printers for practical applications.

Expectation to Businesses

- Introduction of this technology is expected to be effective for businesses that require (manufacturing of) various strength components in small lots.
- Joint study with companies having the technology to manufacture this printer as a complete device
- Joint study with companies considering developing a new business in the 3D printer area
- Assistance in establishing a venture business

Intellectual Property Right of This Technology

PCT Application

Title of invention:
Three-dimensional Printing System, Three-dimensional Printing Method, Molding Device, Fiber-containing Object, and Production Method

Application No.: PCT/JP2015/ 65300

Filing date: May 27, 2015

History of Industry-Academia Collaboration

- 2014:　Selected for Support Industry Program under Strategic Core Technology Advancement Program (Supporting Industry Program)
- 2015:　Selected for NEDO Next Generation Structural Member Manufacturing and Machining Technology Development

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