CARBON FIBER INNOVATION

K. Kageyama[1]
[1] School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan*
Corresponding author (kageyama@giso.t.u-tokyo.ac.jp)

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1 Introduction

Carbon fiber and carbon fiber reinforced plastics (CFRP) have excellent specific strength and modulus. They are also promising materials for extra lightweight structure. CFRP is being introduced in the aircraft industry, because it is counted on to sharply reduction of fuel consumption by reducing weight, while ensuring safety. But in order to apply carbon fiber and its composite material to mass-produced automobile, they should be friendlier to the environment and production and be more cost effective.

Now, most of PAN based carbon fiber is produced by Shindo process, which is invented by A. Shindo [1] in 1959. Critical element in Shindo process is the flame-resistant fiber, which is important as an intermediate raw material for obtaining carbon fiber. But this process has a limitation to the cost and the mass production. Post Shindo process should be introduced to carbon fiber industry to initiate a new production system which is friendly to the environment, energy saving and productive.

Thermoset resins, such as epoxy, are widely used as matrix of CFRP. Carbon/epoxy material system shows excellent mechanical properties. Now it is holding a leading place in the aircraft structure.

Certainly carbon fiber reinforced thermoset plastic (CFRTS) is conventionally used to structural members, but the use of CFRTS has been limited because of low productivity, poor workability, difficulty of material recycle and issue of cost.

On the other hand, carbon fiber reinforced thermoplastic resin (CFRTP) achieves the superior moldability, workability and recyclability, and it will come into the wide use in the automobile industry and the other industrial projects.

The key technologies, which will lead to carbon fiber innovation, might be post Shindo process of carbon fiber production, and the sustainable and high performance CFRTP. The recent research and development activities in Japan are introduced in the present paper.

2 Productive, Energy Conservative and Eco-friendly Carbon Fiber Production System

An industry-academia corporative research and development project has been proposed to develop the key technologies, which might lead the carbon fiber industry to the disruptive innovation. The research activity has been supported by METI. The purpose of the research project is to develop Post Shindo process of carbon fiber production system, which is productive, energy conservative and eco-friendly.

2.1 Post Shindo Process

The conventional process for making carbon fiber from PAN fiber, so called “Shindo Process” (Fig. 1), includes a oxidizing the fiber in order to stabilize polymer structure and resulting the oxidized-PAN fiber, has the flame-resistant property. The oxidation is the most important stage and the exothermic process. Its gradual heating ensures that a sudden release of heat does not occur.

So the manufacturing productivity of carbon fiber does not increase. It is necessary to improve the process of current carbon fiber manufacturing, so called “Post Shindo process”, and to produce a basic technology to achieve reducing the manufacturing energy and the amount of the CO2 exhaust.

2.2 Innovative Carbonization Process and Surface Treatment

The existing carbonization process is not so efficient due to its high-energy consumption and high CO2 emission. Hence the studies on the improvement of the efficiency should be necessary. In that sense, the studies and clarification on the transition process to carbon material are very important.

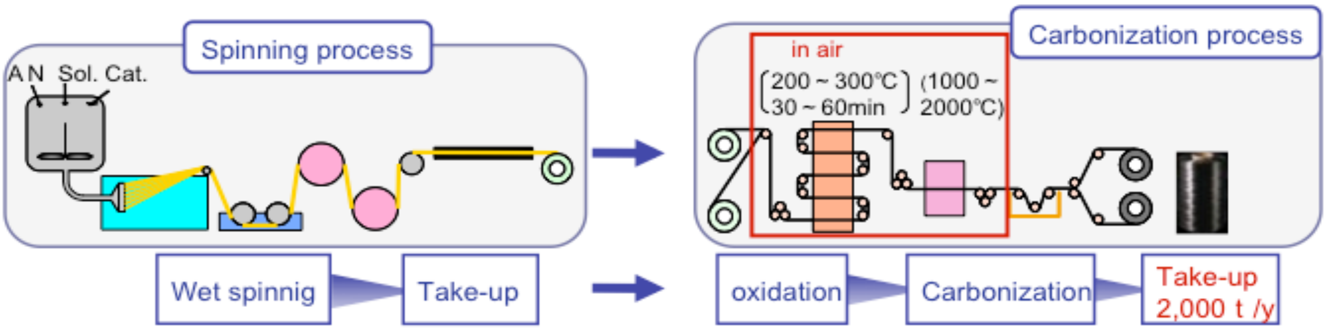

Fig. 1 Shindo Process (1959)

Furthermore, the existing method for the surface treatment of carbon fiber leads the high-energy consumption and the inefficient process because of its chemical electrolytic treatment and its waste disposal. In addition, the treatment ability is limited due to fluid resistance. In order to reduce energy consumption and increase production speed, the studies of novel and efficient method for the surface treatment is also important.
In order to solve these issues, the following investigations are expected to establish fundamental technologies for the innovative carbonization and the surface treatment: to clarify the structural transition mechanism during its carbonization process; to establish microwave based carbonization technologies as an innovative and eco-friendly technology for carbon fiber production in future.

3 Sustainable Hyper Composite Technology

Development of sustainable and high performance CFRTP has been implemented in "Sustainable hyper composite technology", a NEDO nanotechnology and material technology development project [2]. This project will develop an easy-to-process intermediate base material, which can be molded in a short time as a fundamental technology for realizing easy-to-process high-strength carbon fiber composite material. Using this intermediate base material, high-speed molding technology, bonding technology and recycling technology will also be developed to enable further weight reduction of automobiles, etc..
To adopt various parts of automotive body, two types of materials are developed. Isotropic discontinuous CFRTP is for panel elements including complex shaped structures. Unidirectional continuous CFRTP is for structural elements requiring high mechanical properties. By using these materials, this project is also developing a high-speed molding, joining and recycling technology (Fig. 2).

3.1 CFRTP Intermediate Base Materials

The project included a development focused on two themes, carbon fiber and thermoplastic resin. Regarding carbon fiber, surface treatment technology, which simultaneously provides adhesiveness with thermoplastic resin and dispersiveness within the resin, was developed. Thermoplastic resin, which simultaneously achieves carbon fiber the impregnability and the physical properties, was developed. CFRTP intermediate base materials with the superior productivity and workability are now being developed.
Discontinuous FRP (i.e. SMC, GMT) can be used for complex shaped components. But it often suffers from low mechanical properties and varying quality due to anisotropic and heterogeneous dispersion of carbon fiber. From this point of view, new isotropic and high strength CFRTP stampable sheet is designed in this project. This sheet is based on new material and processing technologies including matrix resin, interface adhesion, fiber dispersion, and resin impregnation. Although still under development, this new stampable sheet already indicates 3.2 times as specific modulus, and 6.2 times as specific strength compared to steel. This property is of comparative with continuous CFRTP and about 60% of less weight from steel parts is expected.
Unidirectional continuous CFRTP exhibits excellent mechanical properties. Final target value of the flexural strength of unidirectional continuous CFRTP is 1600 MPa.

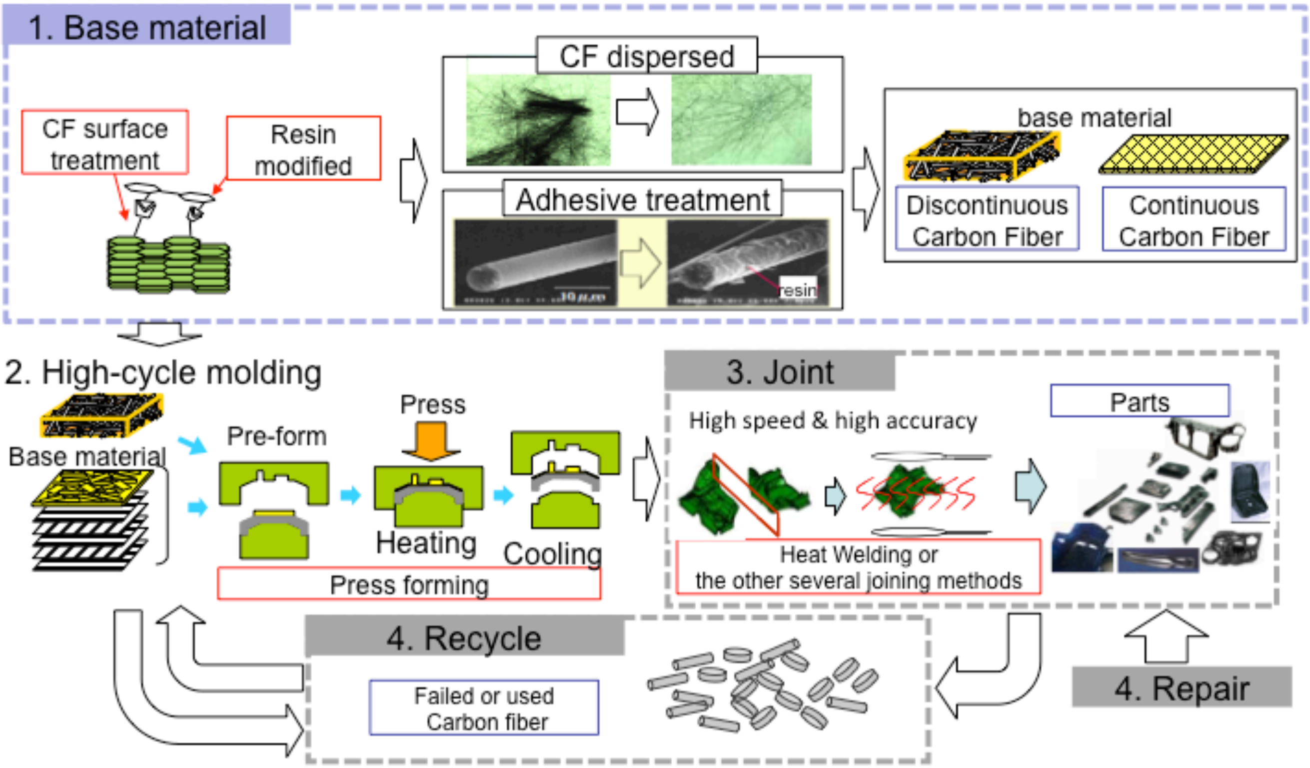

Fig. 2 Sustainable Hyper Composite Technology [3]

3.2 CFRTP Molding Technology

Fabrication technology will be developed in order to apply CFRTP intermediate base materials to automobile structural members. High-cycle stamping molding method and high-cycle internal pressure molding method become available through the use of CFRTP.

High-cycle stamping method for the CFRTP base material has been developed. Elemental members, such as rib, drawing parts and curved panels, can be successfully molded within 1 minute of cycle time. Molding process of car component will be developed in this project.

3.3 CFRTP Joint Technology

Welding technology can be applicable to CFRTP when the matrix resin is heated up to the melting temperature. The methods of connecting CFRTP members with other CFRTP members or with metal members are being developed. It will be possible to manufacture CFRTP products of various sizes and shapes, permitting the use of CFRTP not only in the auto industry but also in a variety of fields of applications.

3.4 CFRTP Recycling Technology

CFRTS has technical concerns about material recycling: (1) separation of thermoset resin from carbon fiber by chemical and/or thermal process, and (2) surface treatment of recycled carbon fiber in order to obtain sufficient interfacial bonding strength. Use of thermoplastic resin as matrix material can solve the recycle problems. Recycling method and evaluation of recycled materials have been carried out in the project. These results will improve the 3R properties at each stage of the life cycle.

An environmental impact evaluation (LCA) of the developing technology will be conducted. This will quantify the degree of contribution to environmental impact reduction during the life cycle of products manufactured by using the CFRTP.

4 Conclusions

A disruptive innovation will be brought to carbon fiber industry by development of productive, energy conservative and eco-friendly carbon fiber production system. Sustainable, easy-to-process and high performance CFRTP materials make the mass production of structural members possible, and the developed manufacturing system might have increasing impact on automobile industry.

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