

Making Cars with CFRTP: Cheap, and Ready for Volume Production

Motohiko Hamada
Nikkei Automotive Technology

Abstract:

Carbon Fiber Reinforced ThermoPlastics are looking promising in vehicular manufacturing. Conventional Carbon-Fiber Reinforced Plastic uses a thermosetting plastic such as epoxy for the matrix, but CFRTP has switched to polypropylene and other thermoplastic materials. While CFRP technology was adapted from aircraft, CFRTP was developed for vehicles right from the start, making it is cheap and suitable for volume manufacturing applications.

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The development of Carbon Fiber Reinforced ThermoPlastic (CFRTP) for automotive frames has accelerated sharply, with four research facilities active in Japan. The first to open was the University of Tokyo's Low-Carbon Research Network Japan, established in 2009. In 2012, it was followed by three more institutions: the National Composite Center at Nagoya University, the Composite Materials Center of Gifu University, and the Ishikawa Carbon Fiber Cluster at Kanazawa Institute of Technology. With all four engaged in full-scale research now, the development of CFRTP is forging ahead.

How soon the material is ready for widespread adoption depends on these institutes. Even though it is said to be "low cost," CFRTP requires considerably more capital investment into production facilities than existing Carbon-Fiber Reinforced Plastic (CFRP) technology. While the equipment investment is steep, large-scale manufacturing would pay that off and make low prices possible. It would be a sort of process industry.

Until the two components of epoxy are mixed for reaction, they are liquids with low molecular weights and low viscosity. The liquid seeps into carbon fiber smoothly, making manual fabrication straightforward.

The viscosity of polypropylene (PP), however, is about a thousand times higher than unset epoxy, which means forming large components such as automobile frames would require presses wielding forces on the mega-Newton (MN) order. Components with minor concavities could be formed with pressing force of 10 MPa, and significant hollows would demand 20 MPa, so a piece with an area of a square meter would require about 10 MN (1000 tf). The roof or front hood, at about two square meters, would be 20 MN (2000 tf), and for pieces with significant topology double that, or 40 MN (4000 tf).

Unlike CFRP, which is also useful in small-lot production, CFRTP is intended for use with large-capacity equipment. Researching the material itself requires a major capital investment, a bit beyond the reach of most universities or small pressed-component manufacturers. The result was collaborative research facilities. As none of the major automotive manufacturers has announced full-scale in-house investment into the field, development will rely on these four active R&D institutions.

Creating Isotropic Matrix with Short Carbon Fibers

At present, the group leading CFRTP development is the Development of Sustainable Hyper Composite Materials Technology Project running under the auspices of Japan's New Energy and Industrial Technology Development Organization (NEDO). The group includes the University of Tokyo, as well as Toray Industries, Inc. of Japan, Mitsubishi Rayon Co., Ltd. of Japan, TOYOBO Co., Ltd. of Japan, and Takagi Seiko Corp. of Japan. The group's promotion committee lists members including Toyota Motor Corp. of Japan, Nissan Motor Co., Ltd. of Japan, and Honda R&D Co., Ltd. of Japan. Prototypes have already been made and evaluated, with results announced. The constituent technologies developed are the intermediate matrix, forming, bonding, and recycling.

The NEDO group envisions a lightweight car, with a body weight of 1380 kg. Aggressive utilization of CFRTP components would replace 584 kg of steel with only 174 kg of CFRTP (**Fig. 1**), yielding a 30% reduction in the total 970 kg body weight. Fuel consumption would be cut by 22.5%, and assuming that a total of 3.38 million vehicles can be fielded by 2030, it would represent an annual savings of 507,000 kL (about 3.18 million barrels) in crude equivalent.

These calculations do not take vehicle cost into account, and of course the 3.38 million units assumes that they can be manufactured cheaply enough. CFRP technology was originally developed for use in aircraft, and suffers from long fabrication times and high cost. CFRTP, on the other hand, can be fabricated rapidly, which means lower cost.

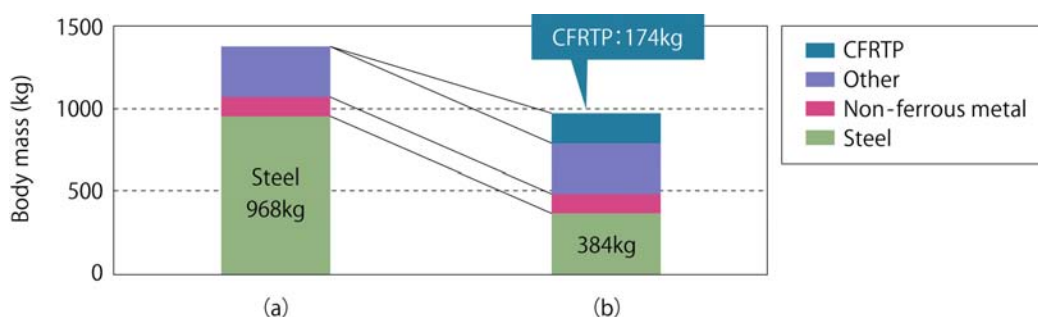


Fig. 1 Effects of lower CFRTP mass

(a) A body made primarily with steel, (b) The body using 174 kg of CFRTP.

Blanc for sample

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Products via Stamping

The resulting isotropic matrix material is stamped into structural components for automotive use. Formability is important in material utility. Researchers crushed a cylinder of the material in the axial direction and measured the increase in diameter, defining results as the elastic modulus. The larger the elastic modulus the higher the fluidity, and the more shapes can be formed.

Elastic modulus drops as fiber length increases (**Fig. 8**) or Vf rises (**Fig. 9**). In other words, adding a lot of long fibers to the mix in hopes of increasing strength makes forming harder. The qualitative difference was clear, but determining quantitative data is

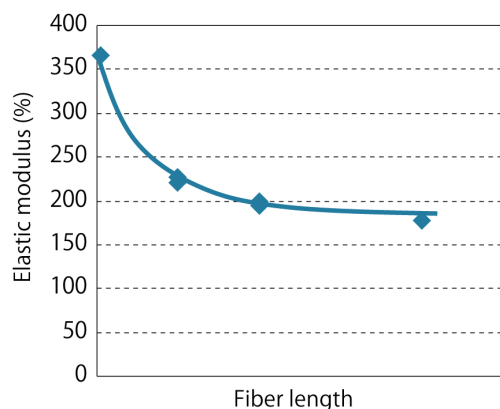


Fig. 8 Relationship of fiber length to elastic modulus

The elastic modulus decreases as fiber length increases.

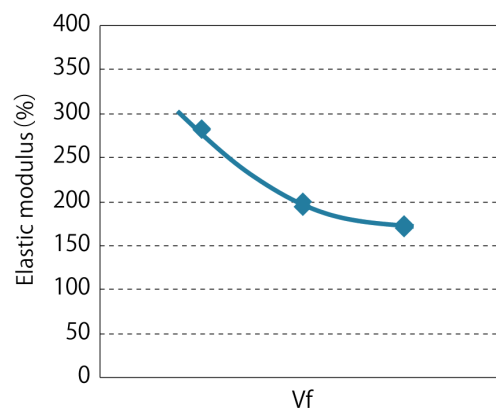


Fig. 9 Relationship of Vf to elastic modulus

The elastic modulus decreases as Vf increases.

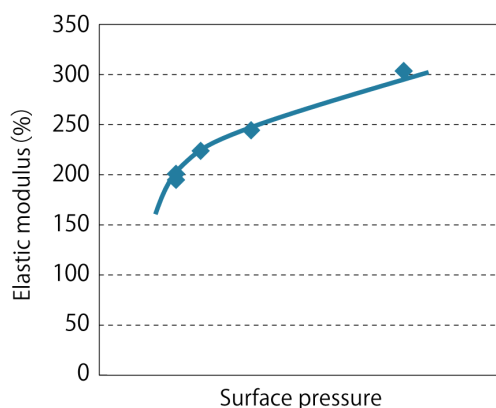


Fig. 10 Relationship of surface pressure to elastic modulus

The elastic modulus increases as surface pressure increases.

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strength per unit weight and elastic modulus per unit weight (**Fig. 15**). The ribless random prototype won in strength, while the ribbed hybrid design was best in rigidity. While not shown, researchers confirmed that switching from PP to PA matrix further boosted strength.

Intertwining Fibers between Adjacent Sheets

Bonding was another target for research. CFRTP is formed in a high-temperature, high-pressure environment, so large components will require extremely large manufacturing equipment and long cycle times. It would be ideal if larger pieces could be made by joining together a number of smaller, easier-to-manufacture parts.

Research looked into thermoplastic material bonding technologies capable of delivering speed and strength comparable to those of steel welding. There is no appropriate adhesive agent for PP, so welding was chosen instead. It was confirmed that hot pressing on layered sheets could be used with intermediate matrix material, including methods such as hot plate welding, vibration welding, and ultrasonic welding. Test results showed that welding produced an integral structure with a higher fiber content, and bonding strength of at least 90% of the matrix itself.

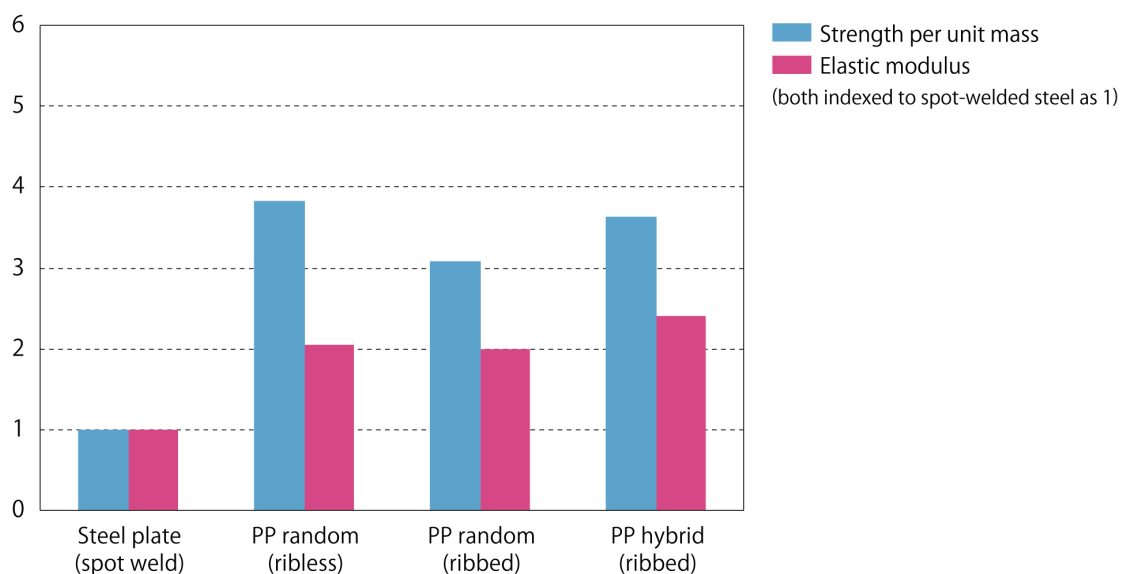


Fig. 15 Weight reduction effect of PP random and hybrid hat channels

The mechanisms of bond surface destruction was also probed. When two sheets of long-fiber CFRP are heat-bonded together, it is difficult to obtain the full strength of CFRP with just bonding between the two matrices. With short fibers, however, there is no clear bond interface, and interlocking fibers increase toughness, thereby boosting bond strength.

European institutions are also researching CFRTP, but aircraft technology appears to be involved, as is the case with CFRP. In contrast, says Jun Takahashi, Professor, Department of Systems Innovation, School of Engineering, University of Tokyo, “Japanese CFRTP was designed for automotive use from the start.” While the manufacturing facility would be massive, volume production would bring the unit price down fast. If NEDO’s hope of 3.38 million vehicles on the road by 2030 is realized, the technology will have proven itself as appropriate for volume roduction.

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