

# New optimization approach helps design lighter carbon fiber composite materials

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Researchers from Tokyo University of Science adopt a design approach for carbon fibers that optimizes fiber orientation and thickness to enhance the strength of fiber reinforced plastic, producing lighter plastic in the process that can help build lighter airplanes and automobiles. Credit: Robert Bye on Unsplash

Carbon is vital to the existence of all living organisms, since it forms the basis of all organic molecules that, in turn, form the basis of all living beings. While that alone is pretty impressive, it has recently found surprisingly novel applications in disciplines such as aerospace and civil engineering with the development of carbon fibers that are stronger, stiffer, and lighter than steel. Consequently, carbon fibers have taken over steel in high-performance products like aircrafts, racecars, and sports equipment.

Carbon fibers are usually combined with other materials to form a composite. One such composite material is the [carbon fiber](#) reinforced plastic (CFRP), which is well-known for its [tensile strength](#), rigidity, and [high strength](#)-to-weight ratio. Owing to its high demand, researchers have carried out several studies to improve the strength of CFRPs, and most of these have focused on a particular technique called "fiber-steered design," which optimizes fiber orientation to enhance strength.

However, the fiber-steered design approach is not without its drawbacks. "Fiber-steered design only optimizes orientation and keeps the thickness of the fibers fixed, preventing full utilization of the mechanical properties of CFRP. A weight reduction approach, which allows optimization of fiber thickness as well, has been rarely considered," explains Dr. Ryosuke Matsuzaki from Tokyo University of Science (TUS), Japan, whose research is focused on composite materials.

Against this backdrop, Dr. Matsuzaki—along with his colleagues at TUS, Yuto Mori and Naoya Kumekawa—proposed a new design method for optimizing the fiber orientation and thickness simultaneously depending on the location in the composite structure, which allowed them to reduce the weight of the CFRP compared to that of a constant thickness linear lamination model without compromising its strength. Their findings can be read in a new study published in *Composite Structures*.

Their method consisted of three steps: the preparatory, iterative, and modification processes. In the preparatory process, an initial analysis was performed using the finite element method (FEM) to determine the number of layers, enabling a qualitative weight evaluation by a linear lamination model and a fiber-steered design with a thickness variation model. The iterative process was used to determine the fiber orientation by the principal stress direction and iteratively calculate the thickness using maximum stress theory. Finally, the modification process was used to make modifications accounting for manufacturability by first creating a reference base fiber bundle in a region requiring strength improvement and then determining the final orientation and thickness by arranging the fiber bundles such that they spread on both sides of the reference bundle.

The method of simultaneous optimization led to a weight reduction greater than 5% while enabling higher load transfer efficiency than that achieved with fiber orientation alone.

The researchers are excited by these results and look forward to the future implementation of their method for further weight reduction of conventional CFRP parts. "Our design method goes beyond the conventional wisdom of composite design, making for lighter aircraft and automobiles, which can contribute to energy conservation and reduction of CO<sub>2</sub> emissions," observes Dr. Matsuzaki.

**More information:** Yuto Mori et al, Variable thickness design for composite materials using curvilinear fiber paths, *Composite Structures* (2021). [DOI: 10.1016/j.compstruct.2021.113723](https://doi.org/10.1016/j.compstruct.2021.113723)

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