Patterned Continuous Fiber Reinforced Elastomer Composite for Stretchable Characteristic

Patterned fiber elastomer composite retains stretchability while tuning tensile strength and elongation via fiber geometry.

Elastomers are a type of polymer that exhibit special elastic qualities, allowing them to return to their original shape after being stretched. Elastomers and elastomer composites have become ubiquitous in materials manufacturing for industries as diverse as apparel, aeronautics, robotics, and more. On their own, most elastomers have relatively weak tensile strength, meaning that they can easily snap when stretched too far. This has led manufacturers to add fibers to elastomers to make reinforced composites with greater strength. Normally, these fibers are placed straight along the direction that requires high strength, but once straight fiber is placed in elastomer composite, it is no longer stretchable since the embedded fiber is not stretchable. Therefore, most currently available fiber-reinforced elastomer composites have only flexible characteristics, with limited to no stretchability, negating the foundational use of elastomer as a material.

To overcome this limitation, researchers at Purdue University have developed a novel pattern of laying fibers to maintain the essential stretchability of their unique elastomer composite. When tensile load is applied to the composite, it stretches like an elastomer, but the rigid fibers impose a limit that prevents the composite from stretching so far that it breaks. The deformed shape and degree of elongation can be controlled by manipulating the pattern of the fiber, allowing this material to be adapted to fit the needs of specific applications. Manufacturing can be accomplished easily, effectively, and inexpensively through the use of advanced 3D printing technology.

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Authors
Garam Kim

Further information
Parag Vasekar
psvasekar@prf.org

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Sample manufacturing and tensile testing were performed. In the fabrication of the wavy-patterned fiber-reinforced elastomer composite, carbon fiber tow and elastomer matrix were used. The fabrication of the wavy-patterned fiber-reinforced elastomer composite involved casting the coupon in a mold comprising bottom, side, and top sections. Following the trials to place the patterned fiber in the mold, it became evident that the impregnated fiber needed to be securely held in shape until the elastomer cured sufficiently to maintain the fiber's position. To achieve it, a top cover with needle holes was designed and fabricated. As a result of this improved fabrication process, the wavy-patterned fiber was positioned approximately in the middle of the coupon's thickness, and the absence of visible air bubbles or voids inside the coupon was confirmed.

The behavior and failure mechanism of the wavy-patterned fiber reinforced elastomer composite under tensile loading conditions were investigated via tensile tests with roller grip test fixture. Various test specimens with different fiber patterns compared in a series of tests including traditional tensile testing and pre-cracked testing. For the tensile test, the MTS universal testing system was used. The tensile test results showed the default wavy-patterned fiber reinforced elastomer composite showed 249% higher maximum tensile stress with 46% lower elongation compared to the pure elastomer test specimen. Different wavy patterns showed different elongation range and amount of fiber changes the stiffness and strength of the elastomer composites, validating the composite's ability to be fine-tuned to specific needs. It validated that the desired stiffness and elongation of the elastomeric structure can be achieved by adjusting the amount of fiber and the wavy pattern design. In the pre-cracked tensile tests, the wavy-patterned fiber-reinforced elastomer composite showed reduced sensitivity to pre-existing cracks, unlike the premature failure observed in the pure elastomer test specimen.

Advantages:

-Increased tensile strength compared to elastomer alone

-Tensile properties can be customized by manipulating amount of patterned fiber

-Maintains the stretchable quality of elastomer

-Deformed shape and stretch limits can be customized by manipulating fiber pattern

-Can utilize 3D printing for efficient, precise manufacturing

Applications:

-Apparel

-Sporting goods

-Aerospace technology

-Maritime equipment

-Robotics

-Biomedical devices

Publications:

Manufacturing of Stretchable Wavy-Patterned Fiber-Reinforced Elastomer Composites and Its Behaviors Under Tensile Loading Conditions. G Kim, R Su, H Lee, D Tackett, E Barocio, TD Ropp, RB Pipes. SAMPE Journal 60 (5)

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