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4D Printing for Continuous Fibers Reinforced Composites

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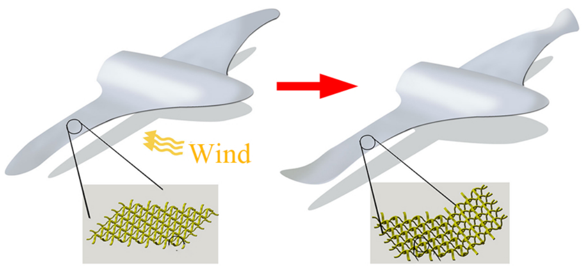
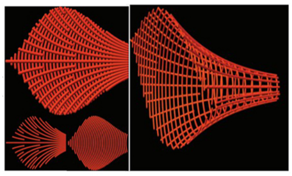
Application Background



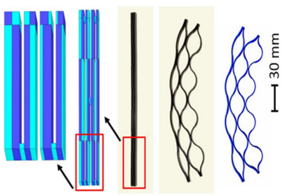
Structures that can produce large deformation and output external forces are required in the field of aeronautics and astronautics. A sketch of an airfoil that can deform spontaneously in response to external conditions

Application Background



Bilayer Composites?[1]

Although it can produce abundant deformation, , its bearing capacity is very poor.

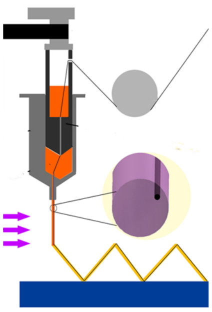


Shape Memory Polymers?[2]

Although it has actuation function, its deformation is discontinuous.

Direct writing + Fiber reinforced composites = ?

Direct Writing Process



Bicapillary structure

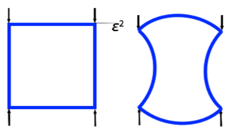
In order to obtain composites with excellent adhesion, continuous fibers need to pass through the monomer solution, and the bicapillary structure can achieve this goal without affecting the extrusion of the solution.

The fiber distribution in the matrix can be controlled.

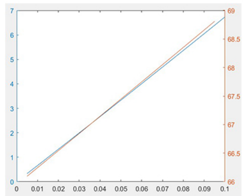
A hydrogel composite material is bent into S shape.

Truss Structure Design

Square cells

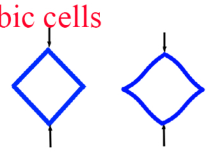


$$\theta = A\varepsilon \sin(\frac{\sqrt{C_0}}{L_0}s) + \frac{A^3\varepsilon^3}{64}[(1-\frac{A^2}{4})(1-\cos\sqrt{C_0})+2]\sin(\frac{\sqrt{C_0}}{L_0}s) + \frac{A^3\varepsilon^3}{192}\sin(\frac{3\sqrt{C_0}}{L_0}s)$$

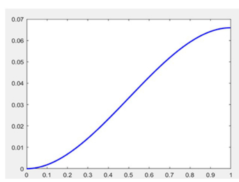


Bearing capacity curve of square cell

Rhombic cells

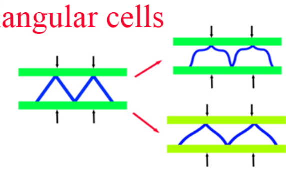


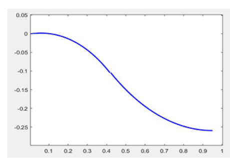
$$\beta(s) = \frac{\pi}{4} - 6\varepsilon[\frac{s}{L_0} - (\frac{s}{L_0})^2] + \varepsilon^2[\frac{6F_0}{F_1}(\frac{s}{L_0})^4 - \frac{12F_0}{F_1}(\frac{s}{L_0})^3 - \frac{9\pi F_1 - 36F_0}{5F_1}(\frac{s}{L_0})^2 + \frac{9\pi F_1 - 6F_0}{5F_1}\frac{s}{L_0}]$$



Deformation curve of rhombic cell

Triangular cells





Deformation curve of triangular cell

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1. Jennifer A. Lewis, et al. Biomimetic 4D printing. Nature Materials. 2016.
2. Chao Yuan, et al. Direct 4D printing via active composite materials. Science Advances. 2017.