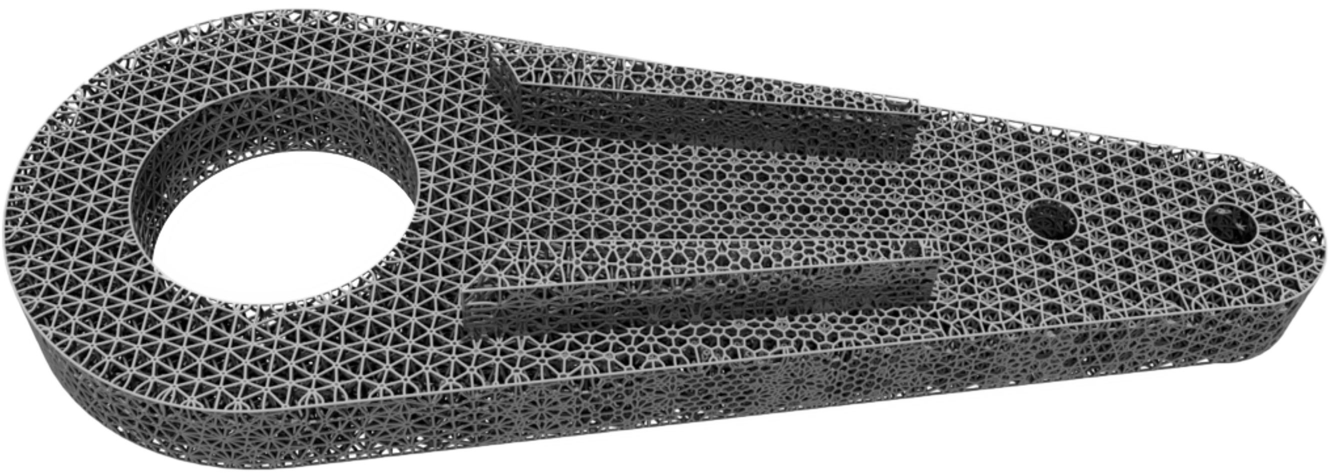
Carbon

How Lattices Revolutionize Product Development and Deliver Precision Performance



This lattice structure shows smooth transitions among three distinct lattice patterns all within a single part, demonstrating how different mechanical responses are achievable in one 3D-printed part using the same material. Smooth transitions would not be possible using three different materials.

The Design Power of Lattices

Lattices are commonly used in architecture and civil engineering to push the limits of design and build otherwise impossible structures. In the last few years, advances in 3D printing, materials science, and software have brought lattices to the attention of product designers and engineers, who can use them to develop novel, high-performance products quickly and efficiently.

Latticed designs possess many advantages. In a design process, lattices can be precisely tuned to accommodate specific environmental loading conditions and even to deliver multiple mechanical responses within a single part using the same material. Lattices can allow energy to be controlled in different ways throughout a part, and they can improve stress distribution over a surface. Part consolidation can also be achieved with the use of lattices in product design, as can the ability to create lighter weight parts. Moreover, implementing a lattice-driven design approach using software can provide speed-to-market advantages for products, as well as opportunities for mass customization.

A lattice-driven design approach with industrial 3D printing can change the way designers and engineers think about solving design challenges and creating products. Perfectly tuned lattices that meet specific mechanical, aesthetic, and other design requirements open new frontiers in product design and provide a new paradigm for innovation in design and performance.

However, the advantages of lattices for creating new and better performing products have remained largely untapped. The biggest reason for this is that product designers and engineers typically lack the design tools necessary to implement latticed designs for real products.

Making Lattice Design Tools More Accessible

To unlock the vast potential for lattice-driven design in 3D printing across different industries, designers and engineers need better access to design tools to stimulate more widespread adoption of the approach. At Carbon, we have taken on this challenge by developing the cloud-based Carbon Design Engine™ software to make lattice-driven design capabilities accessible to those looking to integrate this new type of design component into their product design and production plans.

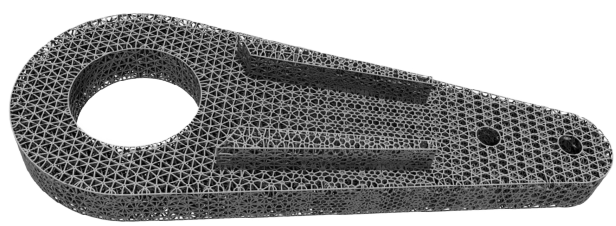
CARBON DESIGN ENGINE™: GENERATE CONFORMAL, PERFORMANCE-ORIENTED LATTICES

With Carbon Design Engine, you can generate conformal, performance-oriented lattice designs with a uniform lattice type, cell size, and strut diameter, also known as single-zone lattices. This robust, powerful tool helps product teams go from idea to functional lattice part in the field in just hours. Design Engine offers three different lattice types, each of which, like a material, has its own characteristics that will influence the performance of a lattice. The lattice structures designed by Carbon Design Engine fully adapt to the shape, filling every curve without breaking structural integrity. It's easy to learn for anyone familiar with CAD, regardless of if you've ever made a lattice before.

Our efforts at Carbon to create a more accessible lattice design software tool are motivated by our own experiences working with partners in a wide range of industries to design and produce high-performance products that leverage new capabilities afforded via lattice-driven design.

ADVANCED LATTICING CAPABILITIES: LEVERAGE THE POWER OF INVERSE DESIGN

Our advanced latticing capabilities, include "inverse design." Engineers first input specific requirements—design constraints (e.g., size, shape, weight); material properties (e.g., modulus, toughness); and user-defined mechanical response (e.g., force vs. displacement, energy absorption capacity). Using this data, Carbon leverages an extensive library of lattice options to algorithmically generate design possibilities for a part or product, which can then be rapidly optimized and manufactured.



Inverse Design

INPUT

MATERIAL PROPERTIES + USER-DEFINED MECHANICAL REPONSE + DESIGN CONSTRAINTS

Resin viscosity
Final Material properties (e.g. modulus)

Force to be applied
Expected deformation

Length, width, height, weight, pore size, etc.

ADVANCED LATTICING CAPABILITIES
+
LATTICE LIBRARY

OUTPUT

= FINAL PART DESIGN

1. 3D Printing Ready
2. Multiple Functional Zones

Unit cell
Min/max size of cell
Cell gradients
Strut thickness
Printability

Examples of Lattice-Based Products

FOOTWEAR WITH ADIDAS

Several high-performance products that use elastomeric lattices have entered the market in the past three years. The adidas 4D line––including Futurecraft 4D, AlphaEdge 4D, and 4DFWD shoes––has well-known examples of elastomeric latticed designs that have advanced the state of the art in footwear and since become icons of design and manufacturing. Designed by adidas, the midsoles of the shoes, which are 3D printed using the Carbon Digital Light Synthesis™ (Carbon DLS™) process and an engineering-grade elastomeric polyurethane, control energy by employing a lattice that has multiple functional zones—**providing different mechanical responses within a single part, using the same material.**

adidas' latest invention, the 4DFWD midsole, uses Carbon's latest high-performance resin that is lighter and stiffer, optimized for forward motion and a smoother transition between strides. As the world's first 3D printed, anisotropic lattice midsole, the 4DFWD is mechanically designed to move a runner forward, transforming vertical pressure into forward motion. The 4DFWD lattice utilizes an entirely new 3D printed midsole design with adidas' proprietary FWD CELL shape, which incorporates a unique property of physics directly into this advanced running shoe.

The result is advanced cushioning with performance capabilities unachievable with ordinary foam, and has been ranked the #1 Best Running Shoe of 2021 by T3. The variation in functional zones within a single latticed part can create mechanical responses impossible to attain with foam or other materials. While adidas created their latticed midsole design in-house, the approach of using highly varied functional zones within a single part has also been demonstrated in other products using Carbon's advanced latticing capabilities, including in examples discussed below. With Carbon lattices, the ability to use different lattice patterns, along with techniques such as layering and gradual transitions between lattice types (for example, between triangular and hexagonal lattice patterns), can result in a stiffness-to-mass ratio that can be shifted by up to 3X within a single part. The cell shape, size, and strut diameter are some of the parameters that can be fine-tuned when building lattices, giving designers and engineers ultimate control when building high-performance products.

The 4DFWD lattice with adidas' proprietary FWD CELL shape, which incorporates a unique property of physics directly into this advanced running shoe

BIKE SADDLES WITH SPECIALIZED

Two high-performance, lattice-based bike saddles have also recently entered the market—the Specialized S-Works Power Saddle with Mirror technology and the fizik Adaptive bike saddle. In both cases, elastomeric lattice structures generated with Carbon's advanced latticing capabilities were implemented to promote comfort and performance. Lattice geometries were optimized for impact absorption, stress distribution, and lateral stability, with pressure mapping data informing the design processes to enable different mechanical responses in different saddle zones that improve the rider experience.

In both cases, condensed product development cycles were made possible by using Carbon latticing software and the Carbon DLS™ process. The Specialized team cut the overall product development timeline from the typical 18 to 24 months to just 10 months; the design process was condensed from 6 to 2 months, with design iterations that used to last for 2 to 3 weeks taking only 1 day.

The Specialized S-Works Power Saddle with Mirror

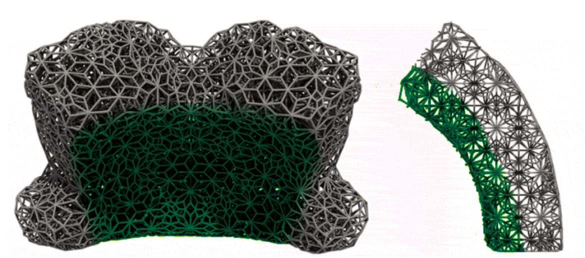
fizik's Antares Versus Evo 00 Adaptive bike saddle

HELMETS WITH RIDDELL

Riddell's SpeedFlex Precision Diamond helmet performs better than any other on the market. In place of foam, the helmet utilizes elastomeric lattices, with over 140,000 struts, to compose the helmet liner. The approach helps control linear and rotational forces during impacts. Varying functional zones in the lattices generated with Carbon's advanced latticing capabilities also resulted in a 65% reduction in the number of parts. This part consolidation, which involved going from 20 discrete helmet liner pieces to just seven, translated to a more compact design and fewer product assembly steps.

Riddell also harnessed speed-to-market advantages, going from the first design file to the NFL field within only 6 months. Extremely fast design cycles were enabled by the ability to rapidly refine lattice designs with Carbon's advanced latticing capabilities and then 3D print them immediately using the Carbon DLS process. The result is an advanced cushioning system that achieves superior fit and function for athletes.

Finally, used with Riddell's head scanning technology, these helmets demonstrate opportunities for mass customization, with finely tuned lattice structures printed to match the precise contours of an individual athlete's head, promoting both comfort and performance. This lattice-driven design approach now underlies both customized professional helmets for NFL players, as well as stock helmets for youth and varsity players.

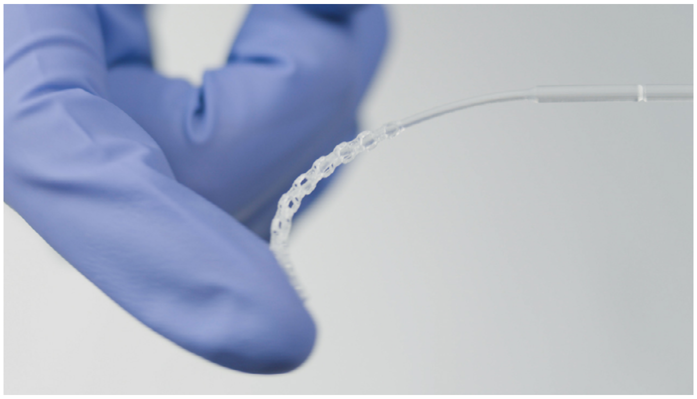


Lattice structures created with Carbon's advanced latticing capabilities compose a complex cushioning system for the Riddell SpeedFlex Precision Diamond helmet. Color shading indicates a higher level of compression.

DIAGNOSTIC MEDICAL DEVICE WITH RESOLUTION MEDICAL

The Resolution Medical Lattice Swab, made with the Carbon DLS process, employs a latticed design using an FDA-approved dental material, an approach that allowed for rapid refinement and immediate production to help address the shortage of nasopharyngeal swabs for COVID-19 testing. Within days, informed by real-time clinical feedback, the swab head design created using Carbon Design Engine was optimized for biospecimen collection efficiency, patient comfort, and compatibility with PCR test systems for COVID-19. The product went from concept to market in less than 3 weeks, including with a thorough clinical assessment.

In addition to rapid design and development, Carbon Design Engine allowed for a highly inventive design—the first example of a lattice-based design for a diagnostic testing swab. A conformal lattice structure surrounds a helical stem with tapered thickness to provide varying degrees of flexibility all in one part. Further, in contrast to standard flocked swabs that rely on a patient sample sticking to the surface, the Lattice Swab design facilitates the gentle accumulation of a biological specimen within the cage to aid collection efficacy.



Flexibility of the swab head and stem shown with minimal pressure applied with one fingertip; flexibility is more pronounced closer to the swab head tip as a function of the soft lattice cage structure and tapered nature of the helical stem design. This promotes comfort, ease-of-use, and sample collection efficiency.

The Infinite Capabilities of Lattices

At Carbon, we sometimes refer to the "infinite" capabilities of lattices. While not literally infinite, our Carbon Design Engine software hosts so many lattice options for different functions that we have yet to truly map the total number of unique structures (though we estimate it's about 10^16).

What if you could unlock over a quadrillion new product design possibilities and then produce your product immediately, with an optimized design that meets your exact specifications before your first prototype? And then scale production into the thousands, tens of thousands, or millions, depending on your needs?

That's our vision for Carbon Design Engine and our advanced latticing capabilities: we aim to give product creators in every industry the ability to unlock high-performance designs that advance the state of their art. We hope Carbon's latticing capabilities inspire your mind and provide a path forward for innovation in design, rapid development, better product performance, and dependable production.

We look forward to making this possible and embarking on this lattice journey with you. Please stay tuned this summer and fall for updates.

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The Resolution Medical Lattice Swab