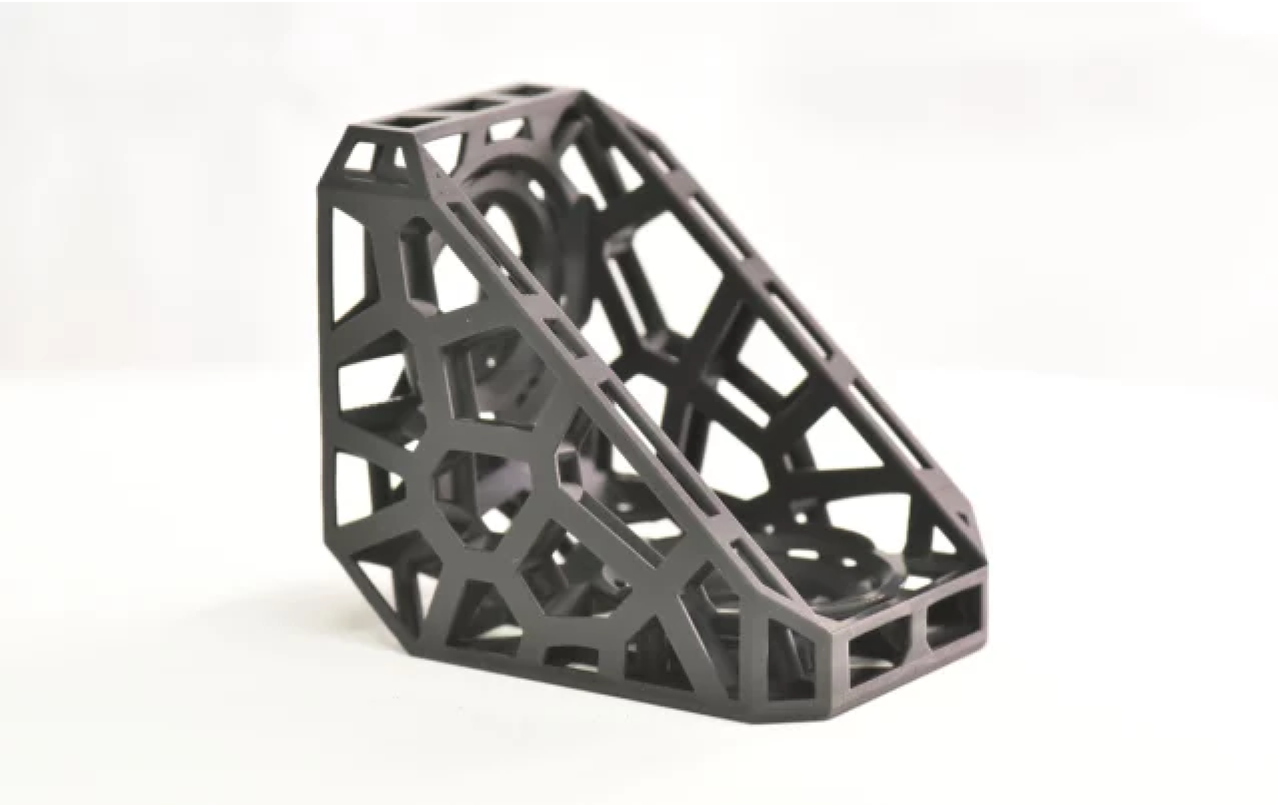
nTopology Breaks Generative Design into Its Elements

Follow ⁝

Now that manufacturing tools like 3D printing are capable of fabricating intricate geometries, generative design is all the rage in the world of CAD. There's one problem, though. Most professional CAD packages, with a couple of very recent or soon-to-be exceptions, aren't equipped to perform generative design functions.



High-performance isotropic plastic parts produced by Origin on a new process that will formally launch early next year. (Image courtesy of Origin.)

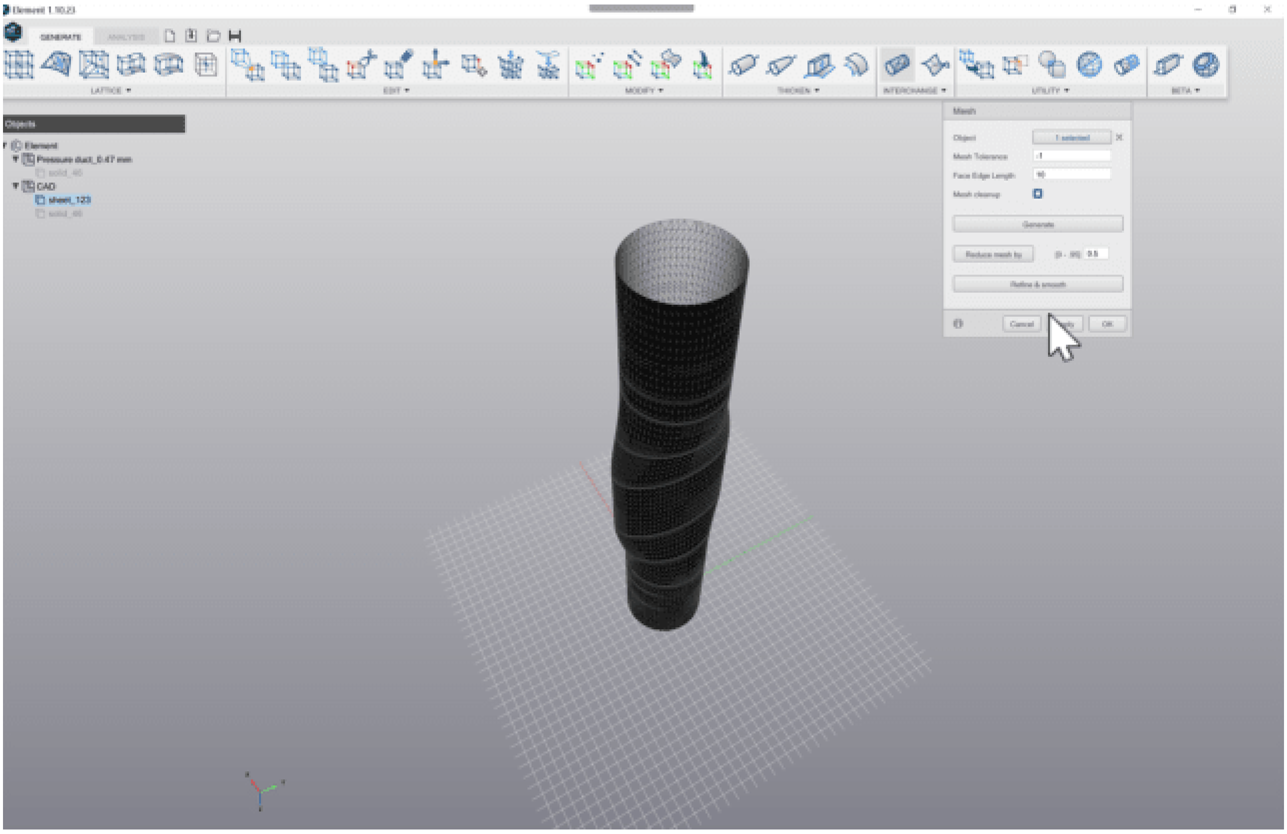
This may be a detriment to engineers, but it's a great opportunity for startups like nTopology, which released its generative design software, Element, earlier this year. ENGINEERING.com spoke to the company's cofounder and CEO, Bradley Rothenberg, and other team members to learn what sets Element apart from other CAD tools and how it could affect the future of design.

Doing What Hands Can't Do in CAD

Rothenberg explained that nTopology was founded with the goal of making "a more intelligent CAD system" for creating complex structures, such as lattices and cellular objects, that are nearly impossible or just really, really time consuming to create by hand in traditional CAD packages.

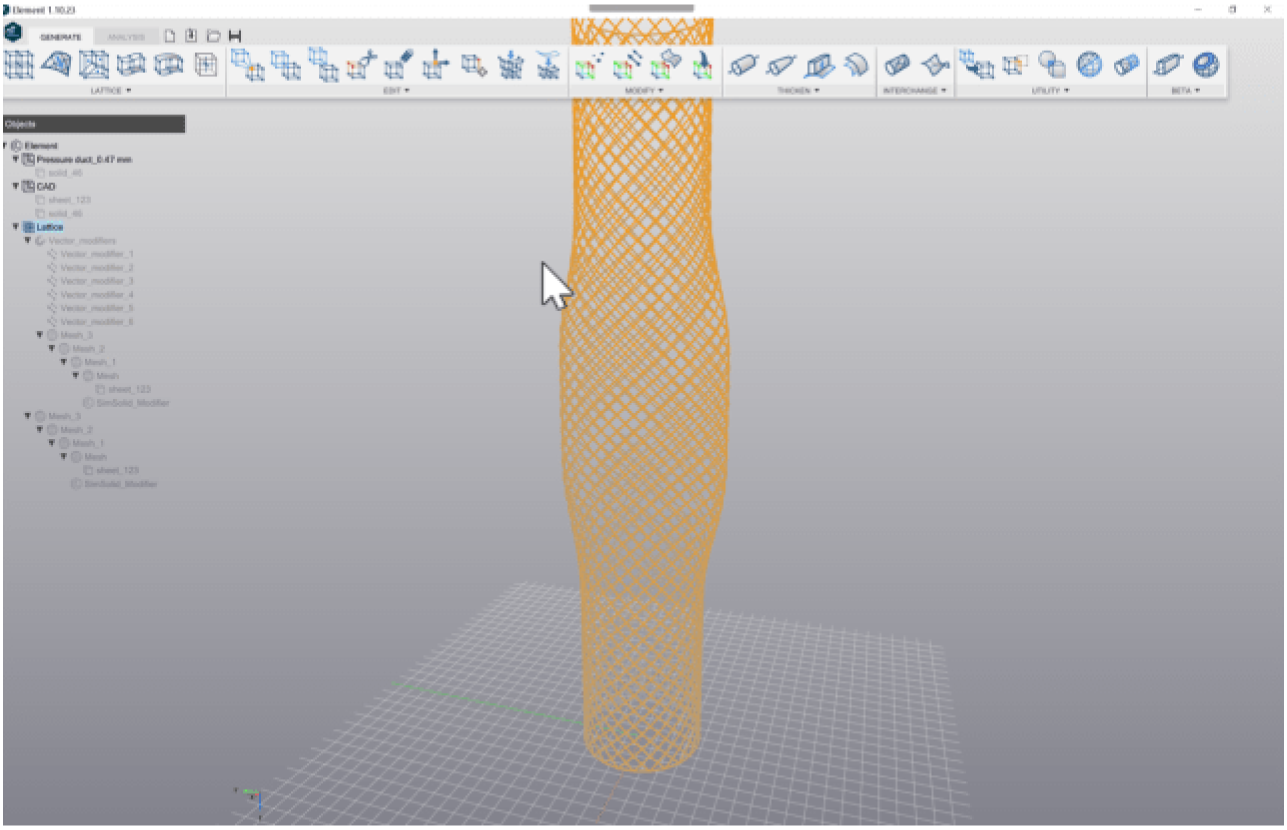
“The new paradigm in CAD is generative design, with computers helping you to design,” Rothenberg said. “Our goal long term is to be the new, dominant CAD system built with a generative methodology.”

With a team of 15 engineers and software developers, nTopology has been working on this endeavor for several years, ultimately releasing Element. Designs are not made from scratch within Element; instead, traditional surface modeling tools can be used to create the initial object. Then, the design is imported into Element, where the user performs generative design through functional modeling.



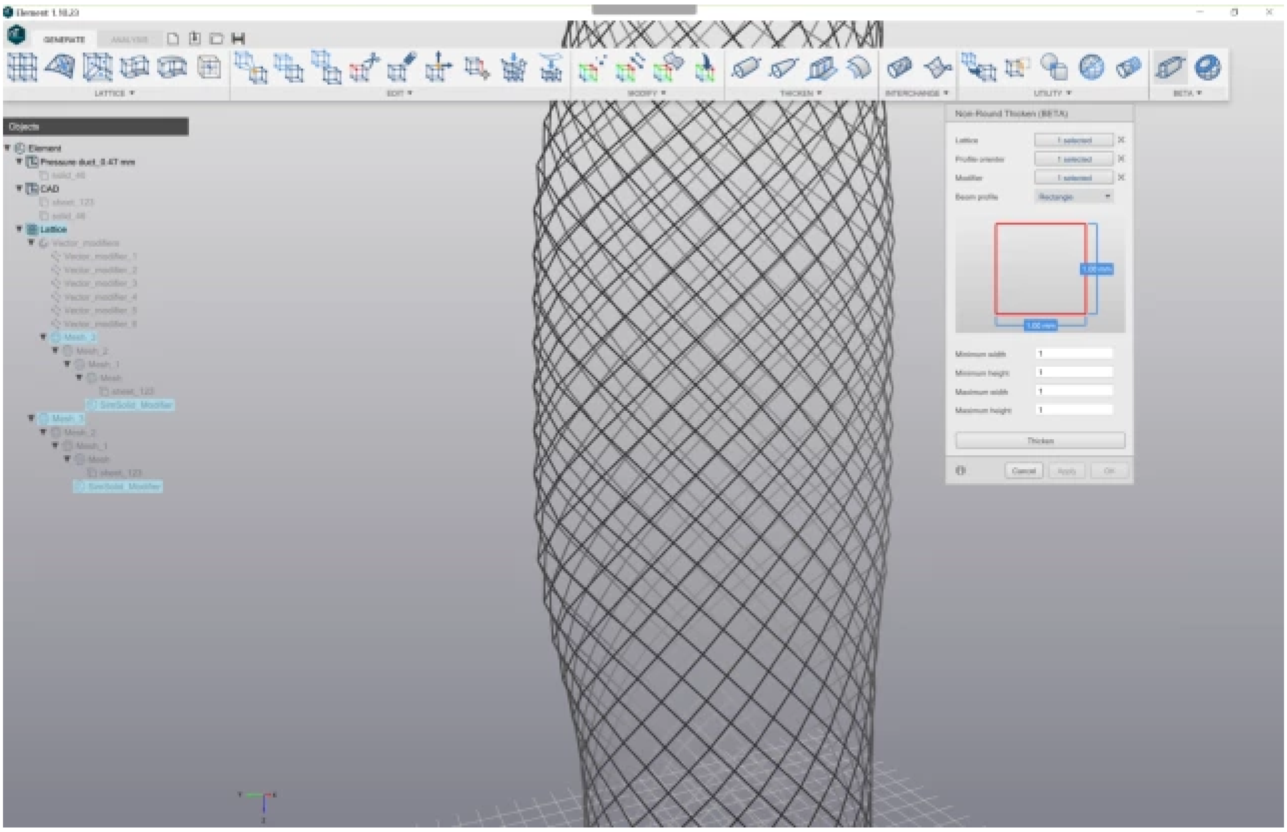
A mesh is created from an imported model.

Functional modeling involves the use of vector fields, which are driven by design rules and constraints with parameters that can be set by the user. For instance, it’s possible to create a lattice, rib or cellular structure by using a specific function that repeats a vector field along the surface of the mesh.



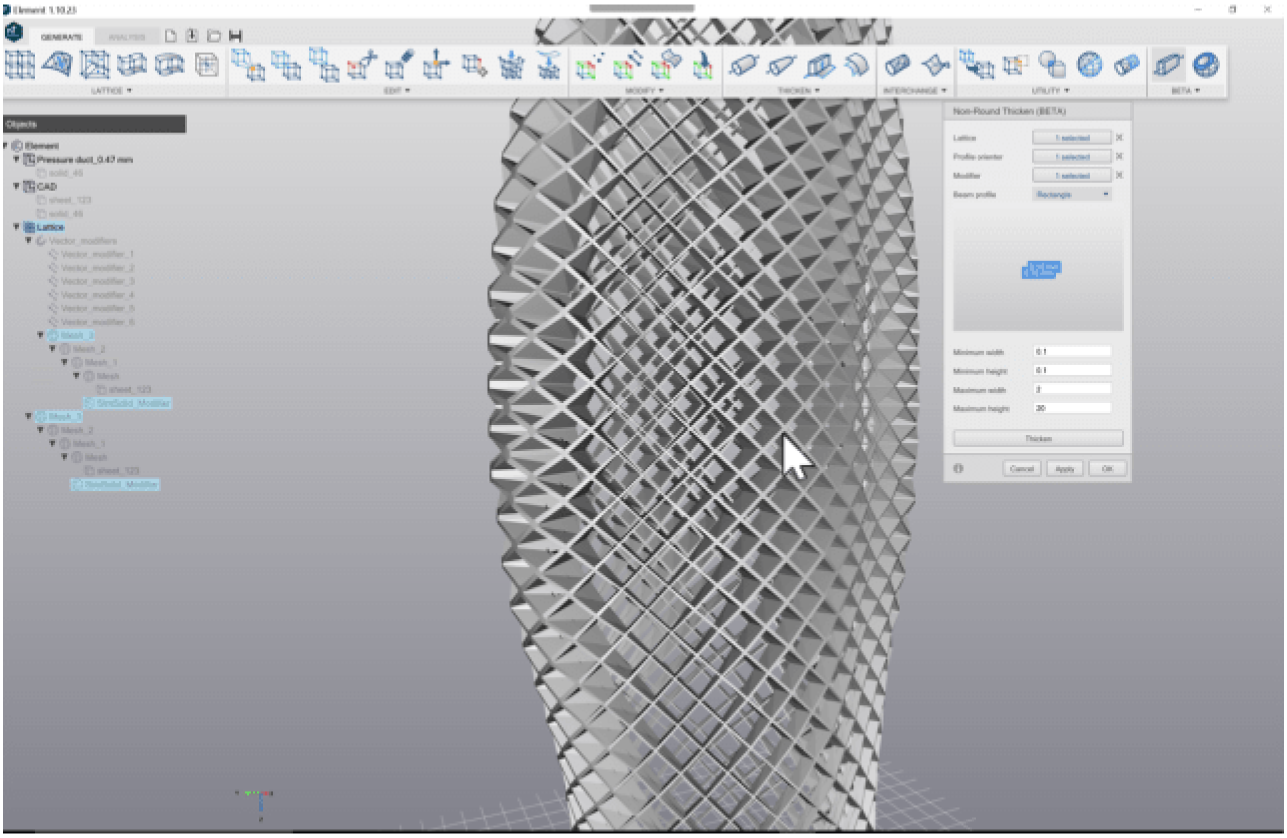
The geometry of the graph is dependent on the complexity of the design. In this case, the graph is a lattice.

This process is achieved by creating what Rothenberg referred to as a “graph” of the mesh, which represents the medial axis of the structure. The graph is made up of a series of nodes that are connected by linear beam elements and, if desired, shells for surfaces and facets.



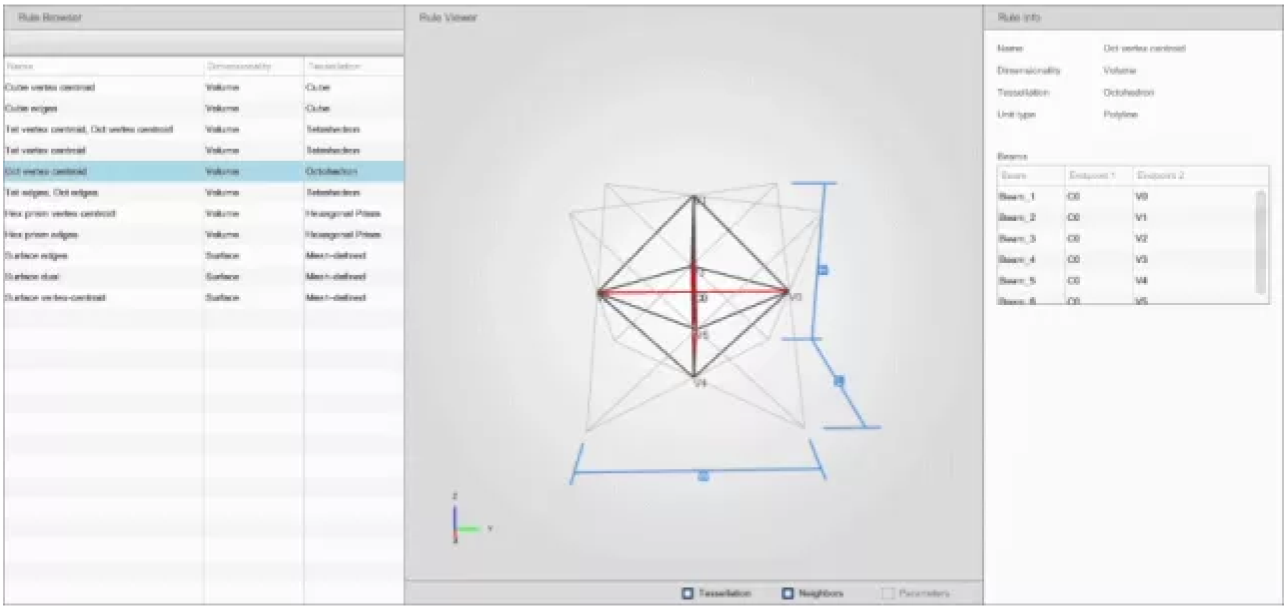
By applying a lattice function to the mesh, which generates squares at each node on the graph, a lattice mesh is created.

The function can then apply a given vector field to each node along the graph, resulting in a larger, unique design. In the case of a lattice, a function can be used to generate a square shape at each node that, when applied to every node, creates a lattice overall.



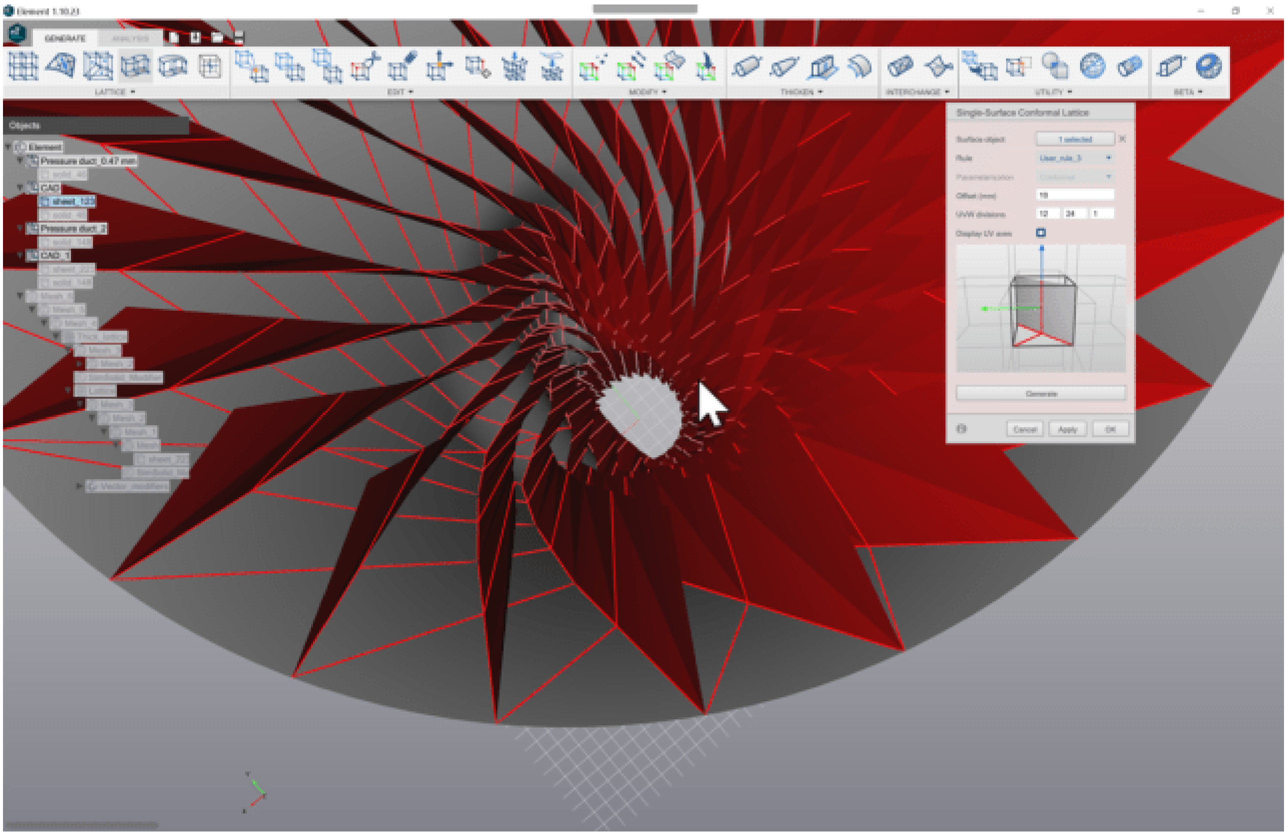
Variable thickness has been applied to the lattice, causing some areas of the mesh to extrude more than others.

Element has a number of predetermined functions that the user can manipulate depending on a given application, but users can also create their own vector fields and functions through the user-friendly Rule Builder tool.

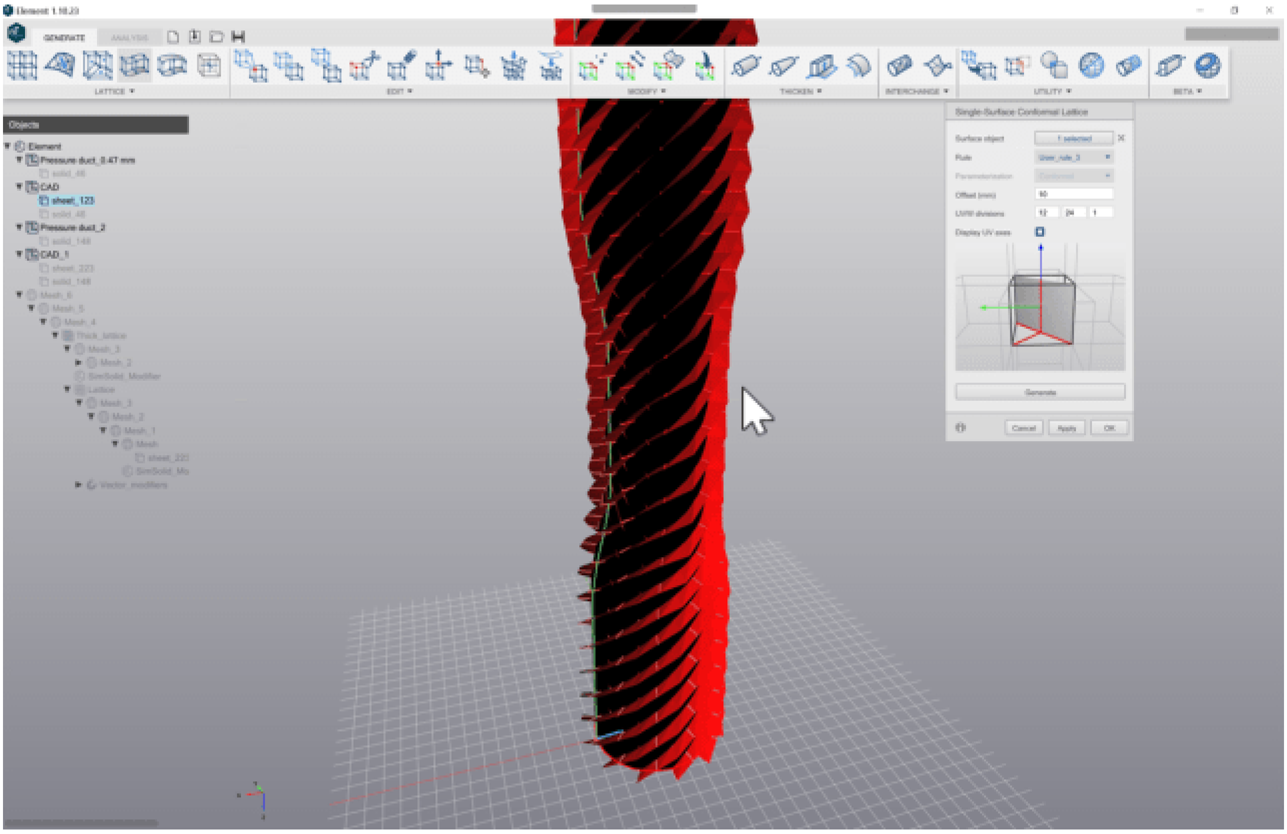


The Rule Builder tool makes it possible to draw beams and faces to create a shape that will be generated all along the graph.

The graphical tool makes it possible to draw beam elements, faces or shells to create vector fields that can be generated all along the graph and used to create unique topologies. Every time a tool or function is used, a node is added to the outliner on the left, so that a user can go back and make changes that will propagate through the last child of the chain.



In this case, a number of beams and faces have been arranged to create a simple wall shape that, when applied to every node, creates a spiral in the overall graph.

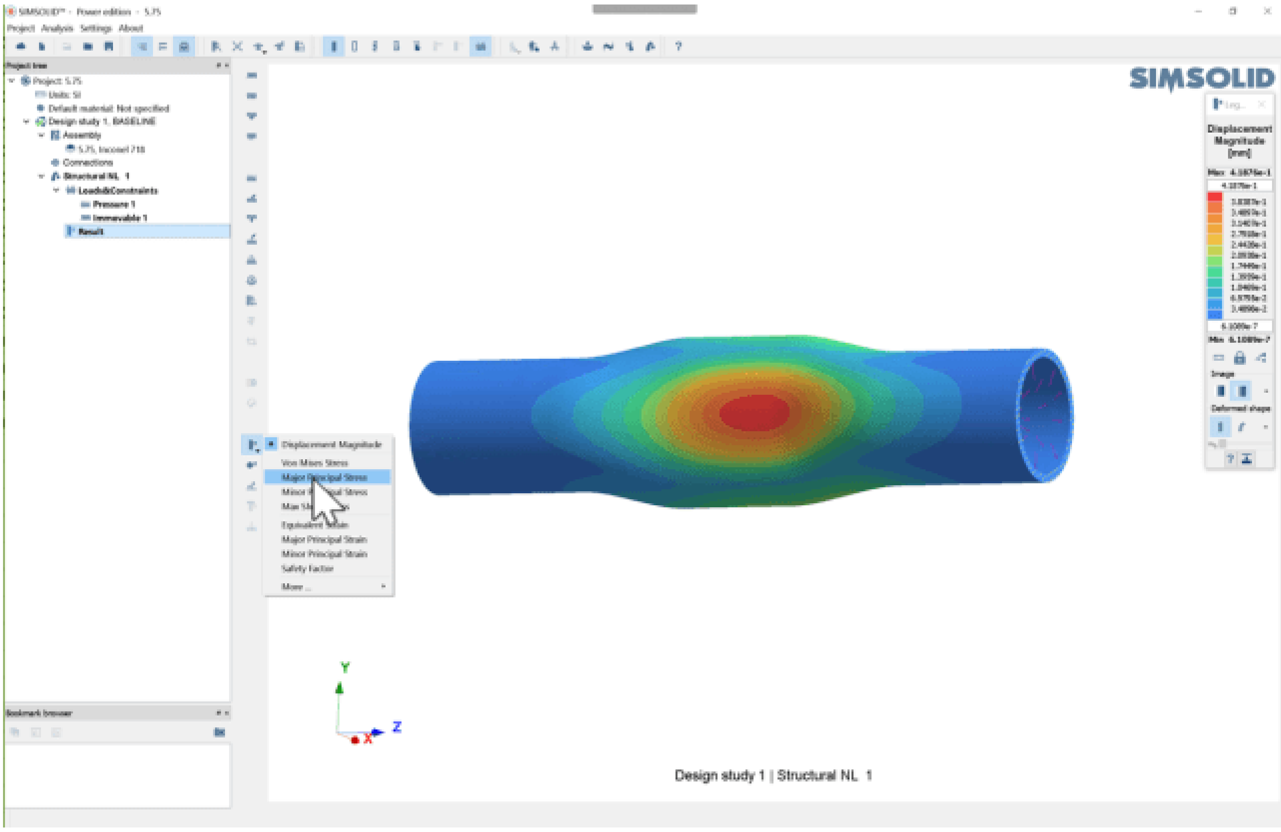


By flipping the simple wall shape in the rule, it is possible to reverse the direction of the spirals.

“Essentially, instead of manually going in and drawing everything, you as an engineer operate on a higher level of control and abstraction of the geometry kernel,” Rothenberg said.

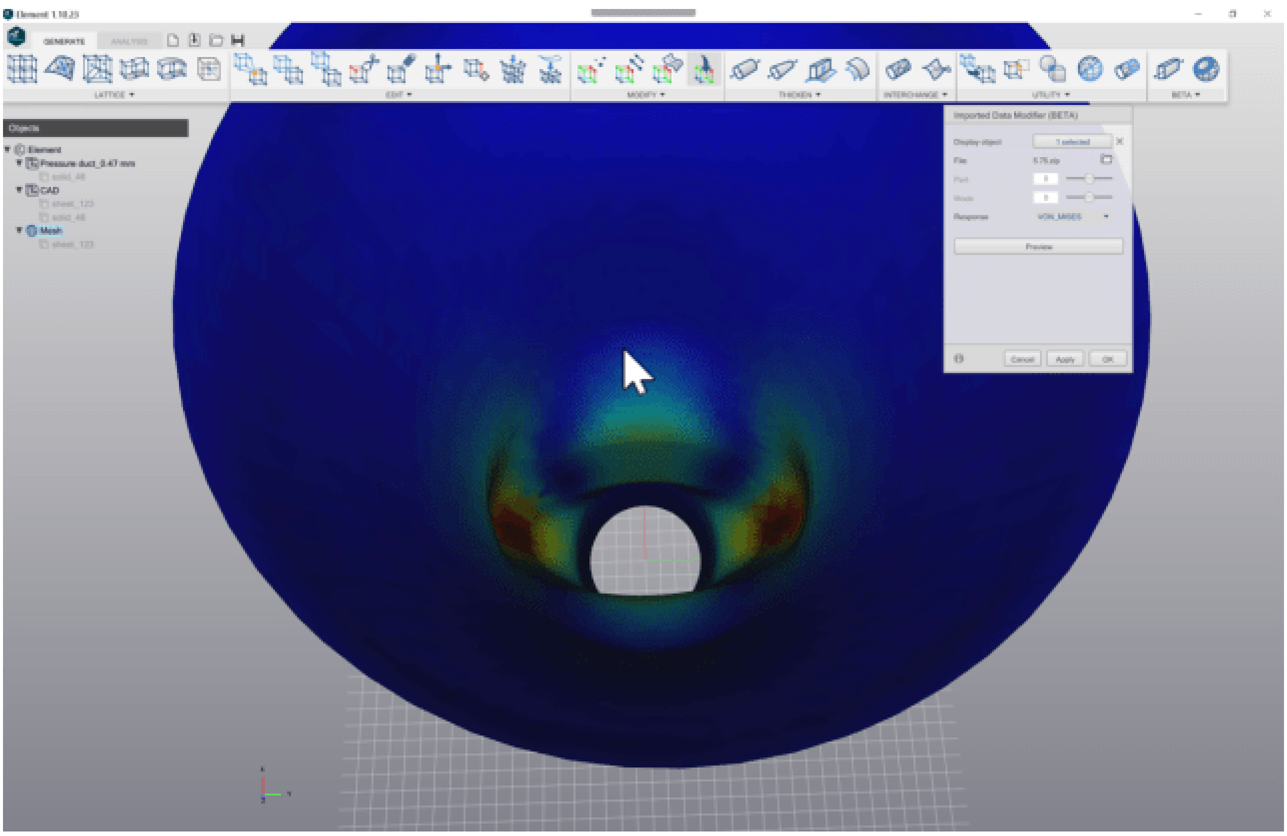
Practical Applications of Element

To demonstrate how these techniques can be implemented more practically, nTopology employee Andrey Shlokov introduced some finite element analysis (FEA) to the workflow. Although nTopology plans to introduce its own analytics tools to Element, using SIMSOLID or Abaqus FEA, it’s possible to import FEA data directly into Element.



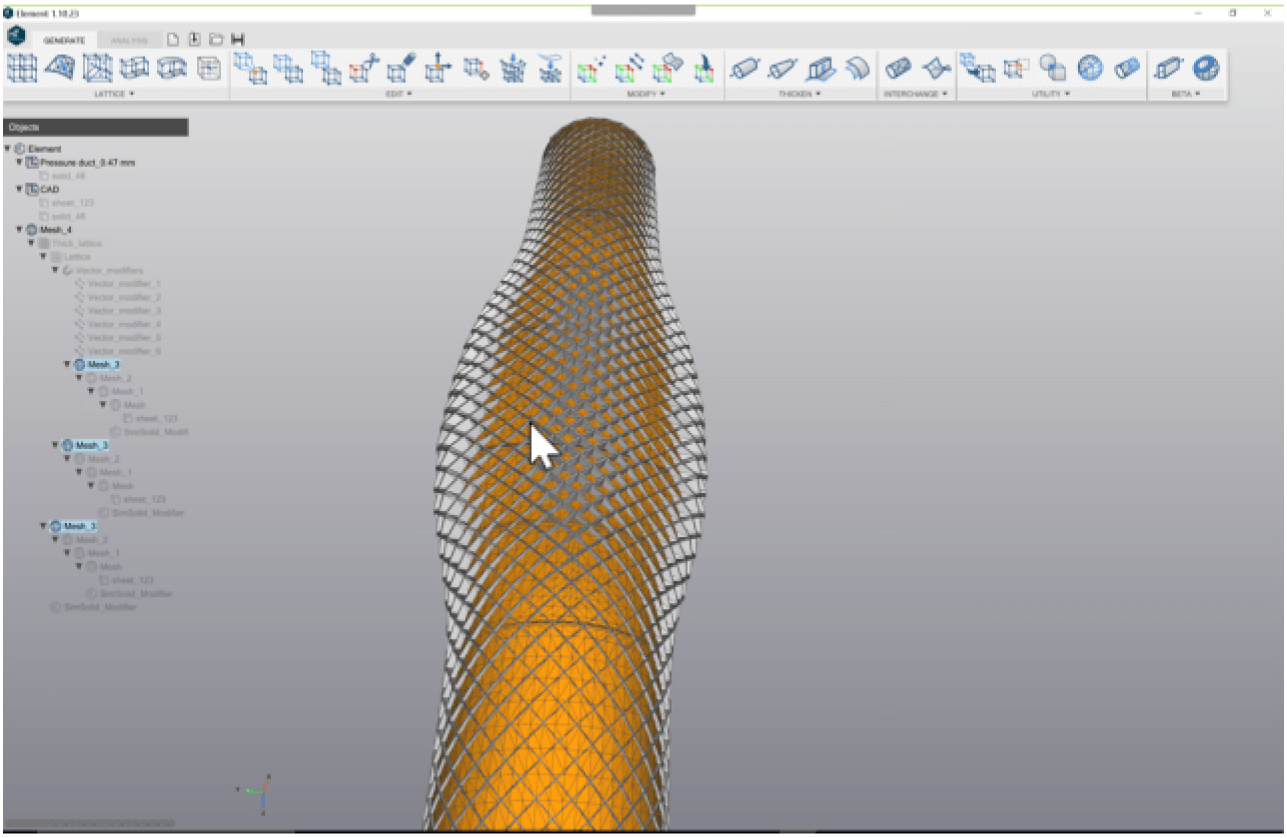
Internal stress is applied to the pressure vessel in SIMSOLID.

Shlokov first generated an FEA of stress that would be caused by air running through the inside of an Inconel 718 pressure vessel, a sort of specialty exhaust pipe, in SIMSOLID. The data was then imported into Element and applied to the existing mesh discussed earlier in this article.



The stress data is then imported and applied to the interior geometry of the part.

Using this data, Shlokov was able to generate variable thickness throughout the pipe in a way that would compensate for the stress the part would undergo in the real world. By offsetting the original mesh, the part is made thicker where there are higher stress values and thinner where there are lower stress values.



The lattice is made thicker toward the center of the part, where it will experience the most stress.

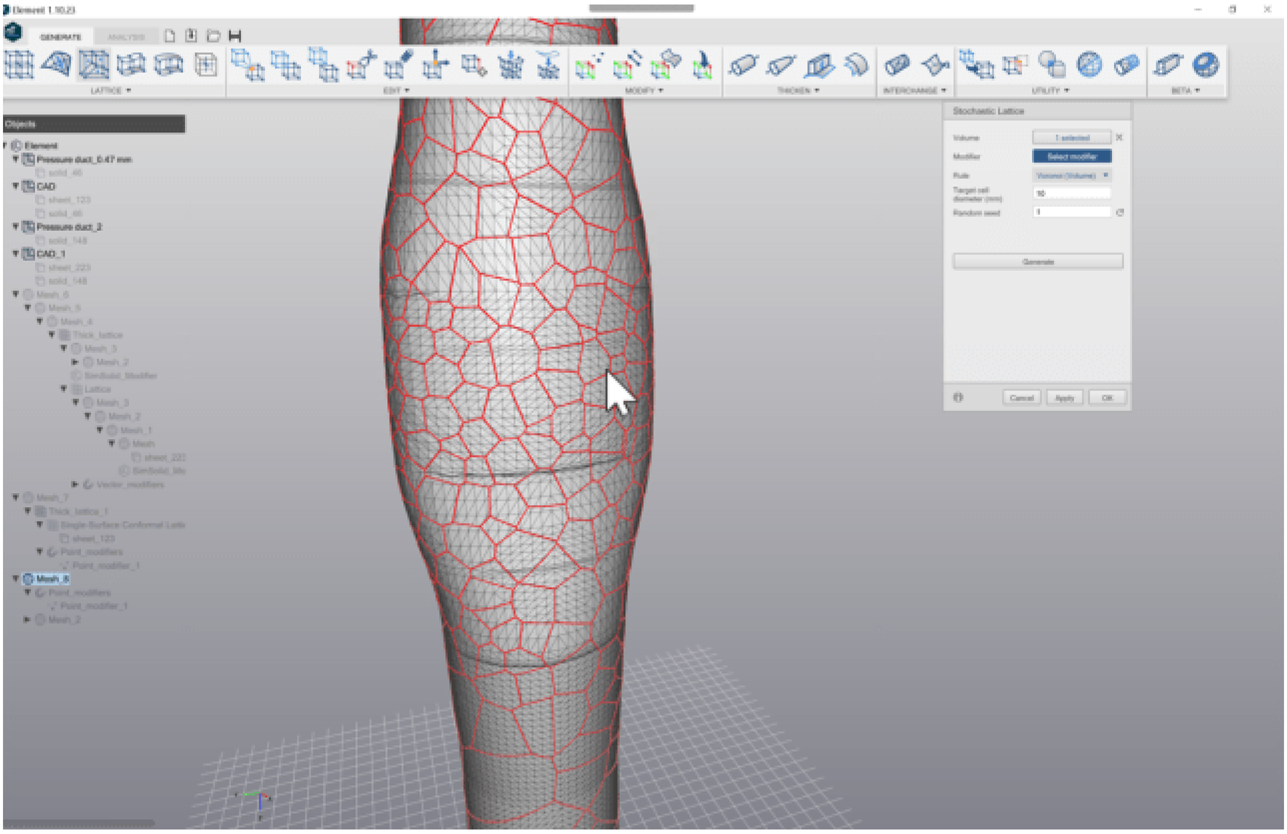
To further reduce the weight of this part, unique topology, such as a lattice or cellular structure, can be applied. According to nTopology Mechanical Engineer Skand Mishra, it was possible to create the same pressure vessel with a lattice structure to reduce the weight by 50 percent and slightly reduce the stress values.

This structure can be optimized in a number of ways, including changing the shape of the vectors that make up a lattice to be a hexagon, rather than a square; the orientation of the vectors; or the overall pattern itself. For instance, rather than using a lattice, it's possible to randomly generate shapes, providing a similar stochasticity as seen in nature. "You can also create structures to increase heat dissipation or that have high surface areas to increase the frequency intake," Mishra said.

The Future of Element

Of course, for many of the shapes that one might want to create in Element, 3D printing may be the best technology for bringing the design into the physical world. The software, however, isn't limited to 3D-printable shapes.

"Our design process is a constraint and physics-driven design process. We don't have constraints for CNC milling or injection molding, but I think we could build in functions so that, instead of building ribs that are normal to a surface, we can make sure the ribs have a certain draft angle that would be necessary for CNC machining. That would allow you to model with those new constraints, necessary for CNC machining," explained Rothenberg.



A stochastic lattice generated in Element.

Key to the future of Element's development is the ability to generate designs optimized through computer assistance. As it stands now, it's possible to manually determine the thickness of a generated topology or what shape the individual vectors are, but nTopology is working on introducing tools that automatically determine the optimal structures based on simulation data.

"Right now, our program is built so that an engineer could explicitly define a complex structure and generate that structure very easily. We're in the process of building more automated tools so that a computer can help you define the structure," Rothenberg said.

Of the way that generative design will impact design and manufacturing overall, Rothenberg explained, "Traditional CAD software has not kept pace with advancement in manufacturing. You can manufacture complex shapes, but you can't design complex shapes. That's a waste of technology. Only Element can take the full advantage of these advancements."

Currently, Element Pro has a price of $10,000 per seat per year. Element Free allows users to generate a number of predetermined patterns and define the parameters for those patterns, but Element Pro adds a number of the features discussed in this article, such as the Rule Builder, stochastic structures and offset thickening.

Both a trial license of Element Pro and a free license of Element Free are available through the nTopology website.