DIGITAL INDUSTRIES SOFTWARE

Additive Manufacturing: Consumer Goods Industry applications

Using cohesive additive manufacturing lifecycle development workflow to increase sustainability in the Consumer Goods Industry

Executive summary

Technological advancements are becoming more sustainable as we enter the world of Industry 4.0. They key to designing for purpose is to use sustainable manufacturing processes. With available capabilities such as full additive manufacturing lifecycle workflows that can quickly turn ideas into reality, technology is paving the way for long-term innovation. This paper will highlight the full lifecycle workflow that engineers can use to design for purpose.

SIEMENS

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Design for Purpose is the saying created to describe how engineers and inventors exemplify the global shift in ecological conscientiousness. With environmental conservancy now being valued higher than ever, consumers are considering all aspects of a product and its company when making purchasing decisions. There is a worldwide revolution occurring in every industry, including consumer goods, sporting goods and footwear.

Innovation in the Consumer Goods industry with 3D printed lattice structures

Did you know that a single shoe can contain up to 65 parts and require approximately 360 steps in a manufacturing process? Reframing the industrial shoe design process will help cut material waste and allow for increased recyclability.

Through 3D printing technology, shoes can be customized based on an individual's footprint, including their running style, foot shape, performance needs and personal preferences. Advanced software allows for rapid designs, simulations, and prototyping to take place. Many other companies are already exploring additive to design for purpose, showing that the future of the industry must be centered around sustainable choices.

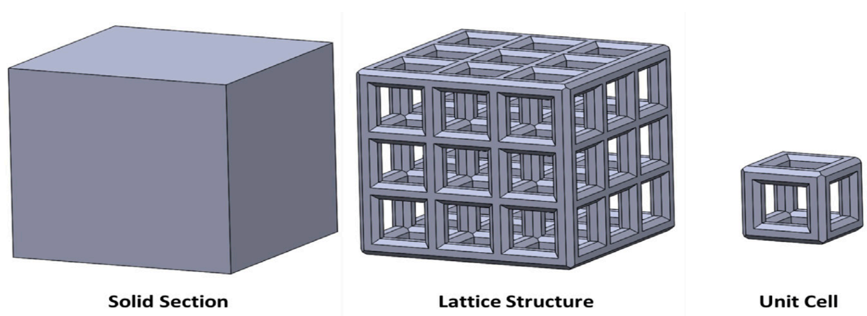
In this document we will see how additive manufacturing offers the ability to build lightweight components designed through topology optimization, incorporating lattice structures.

Figure 1. Innovation in the shoe industry showing 3D printed lattice sneakers.

Introduction lattice structures

Sustainable innovation movement
Lattice structure techniques are growing in functionality and popularity due to the increase in additive manufacturing technologies. The tunable nature of lattices enables engineers to refine designs to match their application. Integrating lattices in designs enables significant mass reduction, which reduces cost associated with resources, tooling procedures and shipping and energy consumption. Although additive manufacturing decreases material waste by eliminating the need for additional tooling byproduct, lattice structures in design enable further material conservation due to the porosity of the lattices.

Designs are engineered for performance due to lattices' low stiffness and their ability to withstand and recover large strains. They protect products by absorbing impact, energy and vibrations. The strength-to-weight ratio can be significantly enhanced and the structural integrity/ fatigue life can be improved with virtual simulation and material testing of the lattice designs.



The breakdown of a simple model illustrating the differences between solid body, lattice structure and individual unit cell models.

Designing lightweight components for Additive Manufacturing

Lattice structures to optimize processes in manufacturing

Here's an example of how lattice structures can be used in manufacturing to optimize part-creation processes. Modernizing the design for additive manufacturing reduces part weight and improves structural properties, extending a product's lifespan. By increasing collaboration and decreasing file transfer errors, this workflow enables engineers to bring products to market more quickly.

Capabilities such as synchronous and implicit modeling make designing and redesigning parts easier. Implicit modeling allows for more robust part designs to be created in less time than traditional modeling tools. Using implicit modeling capabilities, this part was shelled in minutes rather than hours.

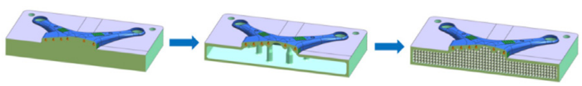


Figure 3. Implementation of implicit modeling and lattice structures in an injection die mold.

Body lattice structures enable users to create their own 3D repeating pattern in a part. This option enables design flexibility and easy customization with endless possibilities and combinations. An example of body lattice structures can be seen below in figure 2.

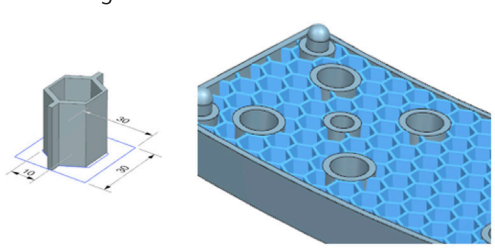


Figure 4. Body lattice applications that NX equips users with to design for purpose.

Graph-based structures are the most popular type of lattice, consisting of tessellating ball and strut configurations. There are many cell arrangements and each hold exclusive structural and thermal properties to innovate design. A few examples of graph-based structures can be seen in figure 3.

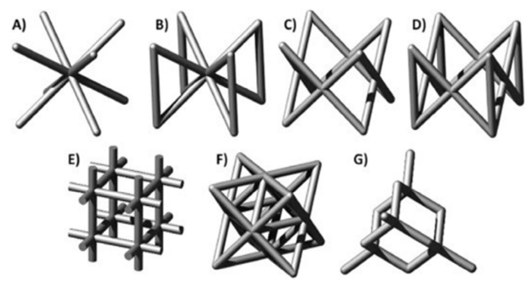


Figure 5. Graph-based lattice structures: (A) BCC, (B) BCCZ, (C) FCC, (D) FCC

Lattice structures with unit cells based on triply periodic minimal surface (TPMS) are free of self-intersections and have topologies generated by mathematical equations. Examples of these structures include the Schoen gyroid, Schwarz diamond and Neovius. TPMS structures are often self-supporting and provide great energy absorption. A few examples of TPMS structures can be seen in figure 1.

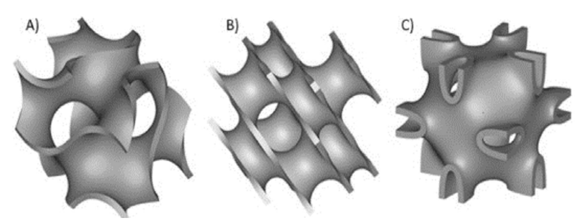


Figure 6. Triply minimal surface unit cells: Schoen gyroid (A), Schwarz diamond (B) and Neovius (C).

Predicting how, when, and why failure will occur in innovative materials

Integrating multimech for additive manufacturing

The second stage of the cohesive additive manufacturing product lifecycle development work flow is to incorporate materials engineering into part design and predict how, when, and why advanced materials fail at the microstructural level:

- Automatic microstructure generation and optimization: understanding how the material will perform under different conditions using only basic design variables.
- Examine manufacturing variability and flaws: zoom in on the material microstructure to determine the root cause of failure and which damage mechanisms affect structural performance.
- Perform multiscale material modeling and microstructure optimization for the most cost-effective performance.

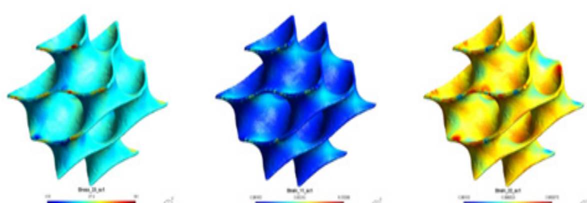


Figure 7. The stress and strains of on a triply periodic minimal surface diamond structure generated with Multimech.

Revolutionizing FEA (Finite Element Analysis)

Physical testing is still needed because new material models necessitate the use of analytical formulations to predict structural and safety properties. This model, however, is becoming obsolete with the introduction of smart materials and advanced engineered structures that cannot be changed on a microscale. When we observe how these materials fail and then fit them into predefined models, we begin to lose predictive power with analytical formulations.

Making predictions based on prior models is no longer a good practice; instead, reverse the process and build a material from the ground up. By directly modeling the physics that occur on the material level, engineers can be more predictive by building it up from the physics of the microstructure.

Using advanced material testing instead of physical observation improves validity. There is always some validation on physical testing and verification, but it is not required for every load case.

Virtual Validation and Sustainable Simulation

Virtual validation
The third step in this long-term process is to validate the product design using integrated simulation. Understanding how a component or product assembly responds to stress or vibration is critical, and as products and materials become more complex, engineers will require tools that go beyond linear statics analysis.

•Structural Simulation: simulate both linear and non linear analysis.

- Linear analysis is used to solve static problems, such as determining if a structure will fail under a prescribed load and can be used to solve transient problems where loads change over time.
- Nonlinear implicit and explicit analysis solvers enable engineers to address problems as simple as a plastic catch or as complex as a car body roof crush analysis. Integrated explicit dynamic capabilities enable engineers to perform metal forming analysis or evaluate electronic hardware performance during a high-impact drop test simulation.

•Thermal simulation: Thermal management is a major consideration. For a wide range of products, including industrial machinery, automobiles and consumer electronics. Engineers have to understand the thermal characteristics of a product and tailor their thermal management solution for optimal performance.

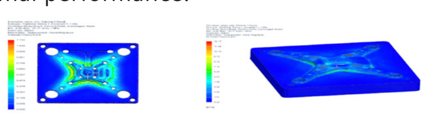


Figure 8. Stress gradient of a vertical simulation on the drone die mold.

Sustainable simulations
Computer aided engineering (CAE) provides virtual simulations and enables faster and more cost-efficient product development, manufacturing efficiency evaluations and simulation-as-a-concept demonstrations. This enables users to optimize resources and consume less energy. Virtual simulations provide sustainable designs of the manufacturing system and the product/service. Virtual engineering and simulations empower users to support sustainable manufacturing by providing a solution to resource scarcity, carbon emissions and customer attraction to environmentally friendly products.

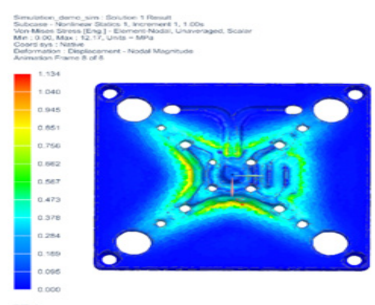


Figure 9. Stress distribution of the lattice structures located inside of the drone mold die

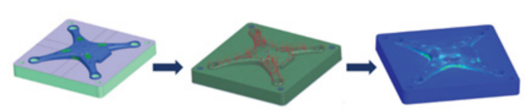


Figure 10. Process of conducting a virtual simulation on a drone mold die

Siemens proposal

Siemens NX Lattice Structures

Knowing the benefits of lattice techniques, Siemens NX provides users with three sets of lattice structures command sets: graph-based structures, body lattice structures, and triply periodic minimal surface structures. Each serves a distinct purpose and provides distinct benefits. Lattice structures with unit cells based on triply periodic minimal surfaces (TPMS) have topologies generated by mathematical equations and are free of self-intersections. The Schoen gyroid, Schwarz diamond, and Neovius are examples of such structures. TPMS structures are frequently self-supporting and have a high energy absorption capacity.

Multimech integration with Siemens NX

Multimech can be used to add the advanced material properties of the lattice structure to the drone mold die. This is a simple process! To begin, use Implicit Modeling to create a triply periodic minimal surface (TPMS) diamond structure, then import it into a FEM file to mesh the part for use in Multimech. Then, go to the Materials Engineering tab and export the diamond structure to Multimech to generate the material file format required for analysis. Finally, a simple analysis test is performed in which a small amount of stress is applied to the structure and the stress and strain results are analyzed. Save the material file after completing the test in Multimech for use in the next step of the lifecycle development workflow. You'll be able to reduce physical testing costs and reduce development time from months to days.

The process then moves on to combining lattice structures and Multimech into virtual simulation to truly confirm that additive manufactured designs perform as well as or better than traditionally manufactured parts.

Simcenter

Understanding how a component or product assembly reacts under stress or vibration is critical in any industry, but as products and materials become increasingly complex, engineers need tools that go beyond linear statics analyses. Simcenter includes the structural solutions you need for a wide range of structural analysis problems within a single user environment. You no longer need one tool for linear statics, another to study fatigue, and yet another for nonlinear analysis. As a result, engineering departments can consolidate analysis tools, and you only need to know a single user interface.

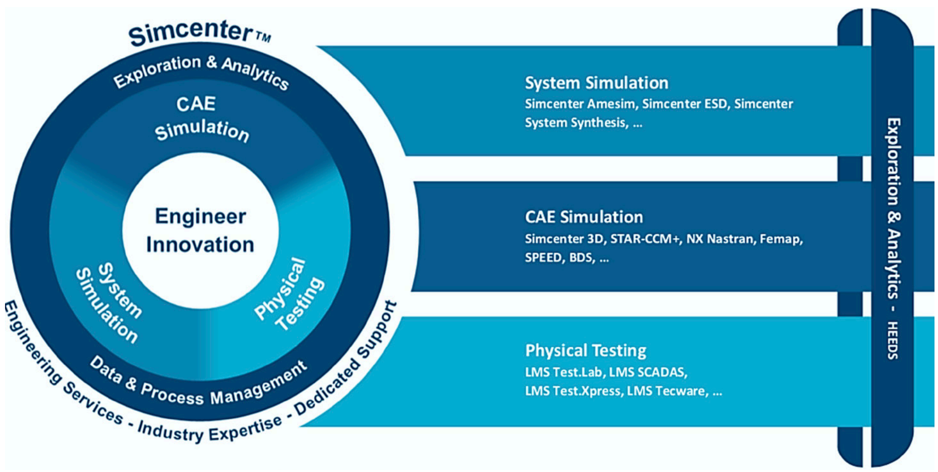
More Information

Want to know more about how to redesign products? How can you improve Additive Manufacturing? How do you transform research and development into the right business model? Learn more from our experts about an integrated design, data and process chain to accelerate the industrialization of Additive Manufacturing.

Have Questions?

Contact us

HEEDS design exploration and optimization



Accelerate product development

Today, consumers are willing to pay higher prices for ecologically friendly products. Advancing design methods can drastically reduce energy usage and abate material byproducts. Although this is the goal for many engineers, using HEEDS can make it happen.

HEEDS is a design exploration and optimization software that enables engineers to determine the most efficient and sustainable design. It enables users to drive product innovation and accelerate the product development process by automating analysis workflows. HEEDS maximizes available computational hardware and software resources. This software package explores the design space for innovative solutions while assessing new concepts to make sure performance requirements are met. HEEDS integration enables engineers to save time and resources to get products to market faster.

Simcenter integration enables users to enhance design by providing the most adaptive work environment. Users can seamlessly analyze designs in multiple software options using Simcenter and NX.

Instead of requiring expert technical skills and simplifying models, engineers and designers can use HEEDS to unlock innovation. HEEDS includes a proprietary design space exploration functionality to efficiently find design concepts that meet or exceed performance requirements. It automatically adapts its search strategy as it learns more about the design space to find the top solution in the chosen timeframe. Using HEEDS helps engineers effortlessly compare performance over a wide spectrum of designs that display desirable features and robustness. Instead of an entire team of engineers spending weeks to create optimized designs, HEEDS enables engineers to do it in hours.

HEEDS is used to visualize design performance trade-offs between opposing objectives and constraints. Results are analyzed and plots, tables, graphs and images are automatically created. The numerous capabilities that HEEDS offers enables users to create production-ready designs, by creating a comprehensive digital twin. The HEEDS automated workflow facilitates easy product development cycles and enables users to quickly integrate technologies without custom scripting. The data is automatically shared between different modeling and simulation products to evaluate performance trade-offs and design robustness. Quick optimization allows for efficient designs that are lightweight, structurally improved and easily manufacturable. This process reduces material waste and energy consumption throughout the lifetime of the part.

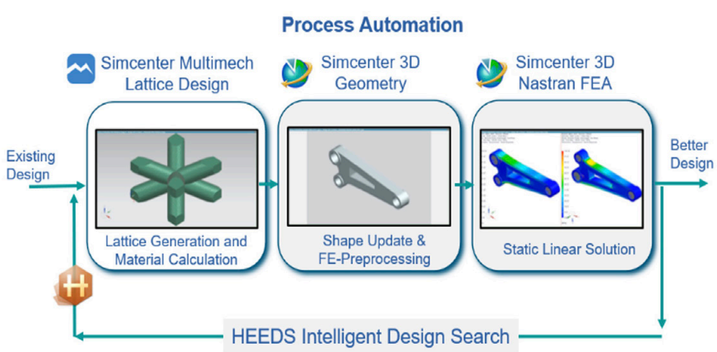


Figure 9. HEEDS process automation visual example.

Drive product innovation

Looking at the drone die mold part that has been redesigned with lattice structures for additive manufacturing, a HEEDS study can be run to explore 10 different design options. The changing parameter is the thickness of the lattice structures, ranging from 0.2 mm to 0.5 mm. To determine the optimal design, compare the von Mises stress outputs. The design that generates the least amount of stress will be chosen.

The workflow has three steps. First, generate the lattice structures with varying width. Second, analyze the lattice file generated in step one in Multimech and export to simulation when complete. Third, run the simulation on the drone die mold with the automatically imported material properties. To create a new HEEDS study, add portals (Simcenter, NX NASTRAN software and analysis portals) to generate the lattice and run the simulation. For each portal, add execution commands, input and output files, dependencies and environment variables. Study variables are identified and responses are created. Files containing the documented parameters are tagged so HEEDS can locate and record their values. The final step is to create the design set and response objective. For this example, ten designs of variable lattice structure thicknesses are evaluated to minimize stress.

This software delivers user-friendly process automation for straightforward and effortless configuration. With HEEDS, users discover better designs, increase productivity and lower material waste and energy usage.

Designing for purpose can be applied to nearly all designs and projects. The next section explains how to apply the integrated additive manufacturing lifecycle development process as a catalyst for sustainable innovation.

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