Design for Additive Manufacturing using *GENESIS*

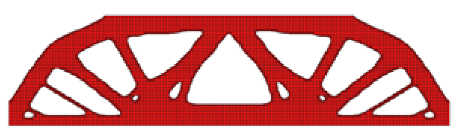
Overview

Additive Manufacturing (AM) is an emerging manufacturing technology in which a structure is typically fabricated by adding material in a layer-by-layer fashion, as opposed to the 'Subtractive' traditional machining, in which material is removed from a raw block. AM can be used to make parts with complex shapes that are hard to achieve with traditional manufacturing methods. The increased freedom in part shapes makes it possible to fully exploit topology optimization to significantly reduce weight of parts, to consolidate parts in an assembly, to perform rapid prototyping and to reduce the time from concept design to manufacturing. GENESIS, an integrated structural analysis and optimization software package from Vanderplaats Research & Development, includes several capabilities directly applicable to design for additive manufacturing. In this document, we demonstrate two important techniques which can effectively convert the design freedom into structures with minimal weight, maximal stiffness/performance, and with a lower cost for manufacturing. The techniques are:

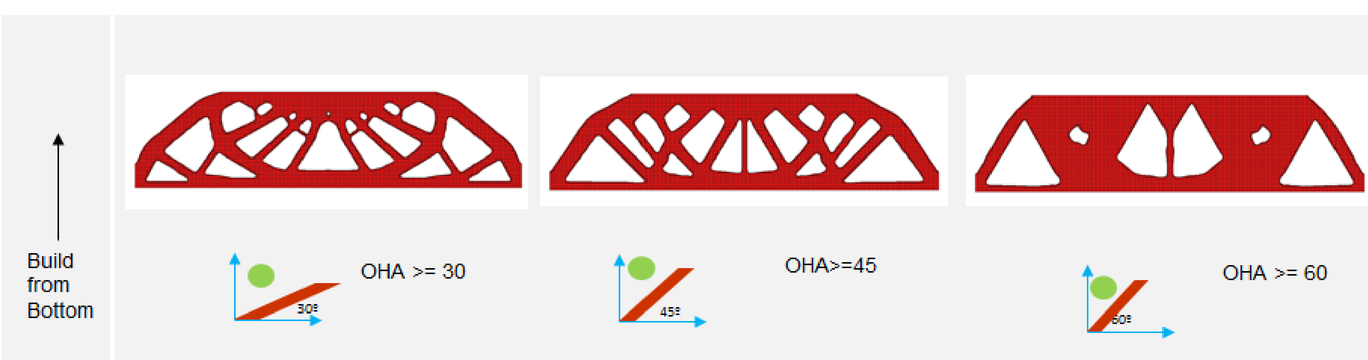
- Topology optimization with additive overhang angle constraints
- Homogenized lattice optimization

Topology Optimization with Additive Overhang Angle Constraints

Topology optimization is used to find the best material distribution in a design space for given loads and boundary conditions, while optimizing for performance. With the great design freedom given by AM, topology optimization is becoming an essential tool in designing parts for additive manufacturing. Although AM brings great freedom for the part shapes, results from topology optimization cannot always be successfully or easily printed. For example, structural members that are flat or shallow will need to have extra support during 3D printing. The extra non-structural support not only increases material cost and printing time, but also requires an additional post-processing step for cleaning up. Therefore, it is very important to take into account the limitations or requirements from AM during the topology design process. GENESIS enables additive overhang angle constraints, which can prevent the final design from containing overhang members that would either fail or require non-structural supports. This technique generates structural design proposals that are manufacturable using 3D printing with minimum changes and at a lower cost.



Optimum using standard topology



Topology optimization with different overhang angle constraints

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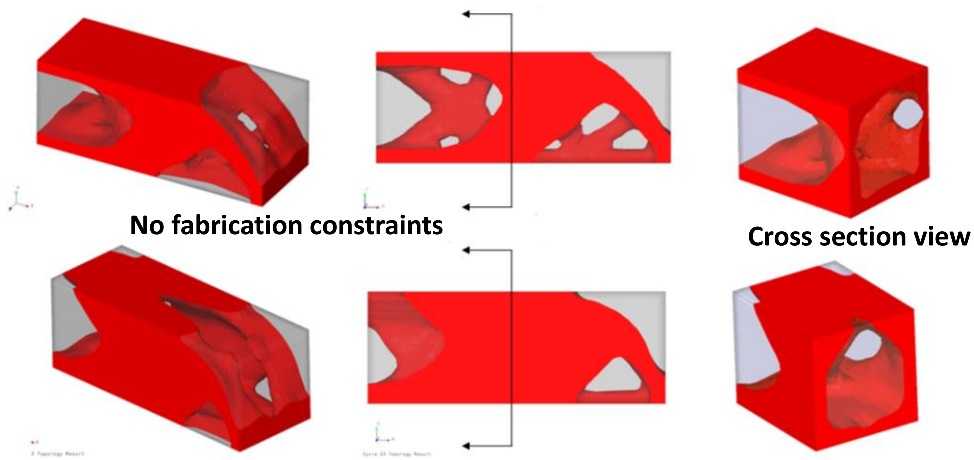
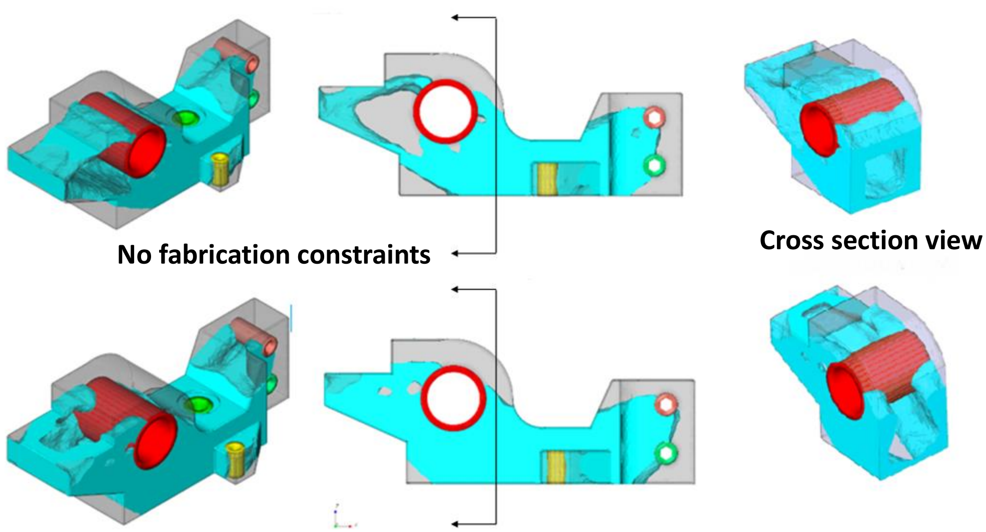
In the example above, a classical 2D truss is designed with and without the overhang angle constraints. It is clear that the standard free topology optimization creates members that are flat or with shallow angles which would need extra support. Topology optimization with overhang angle constraints forms the members with angles that are greater than the required value. Similarly, in the 3D cantilever beam example as shown below, topology optimization with overhang angle constraints produces self-support members.



No fabrication constraints | Cross section view

With overhang angle constraints (>= 45 degree) | Cross section view

For more complex part shapes with functional surfaces such as cylindrical holes, or surfaces which will be in contact with other parts, the optimization will try to preserve or partially preserve these features. More precisely, topology optimization with additive overhang angle constraints tries to create self-supporting members for all the interior material within the part boundaries. This is very important in designing components that will interact with other components in a larger assembly.



No fabrication constraints | Cross section view

With overhang angle constraints (>= 45 degree) | Cross section view

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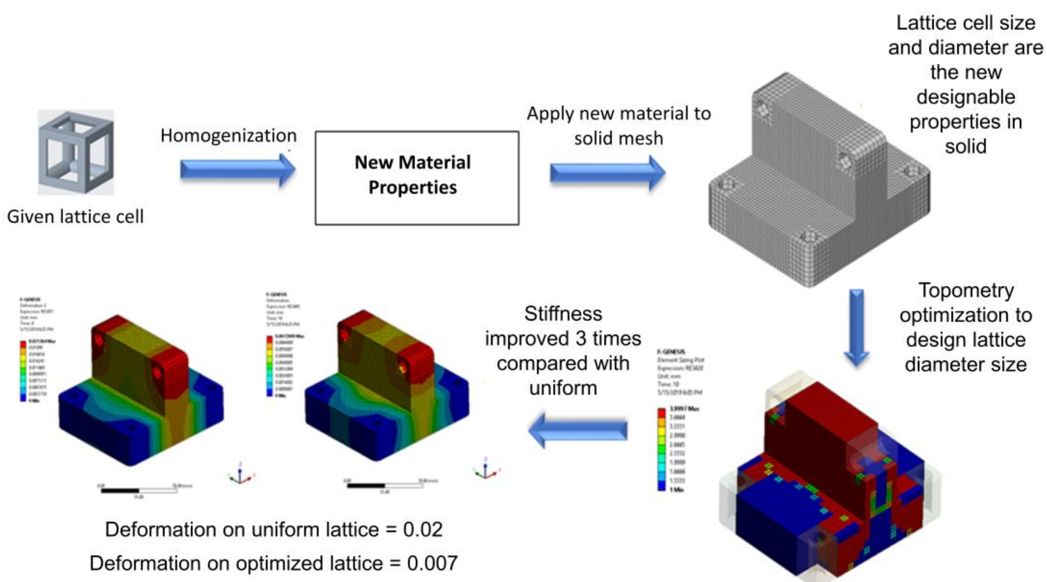
With today's AM technology, part size is still limited in many 3D printers. In this case, typically the model would need to be split into multiple pieces and built separately. With GENESIS you can specify different build regions, each with its own build direction, to ensure the structural members in each region are self-supported.

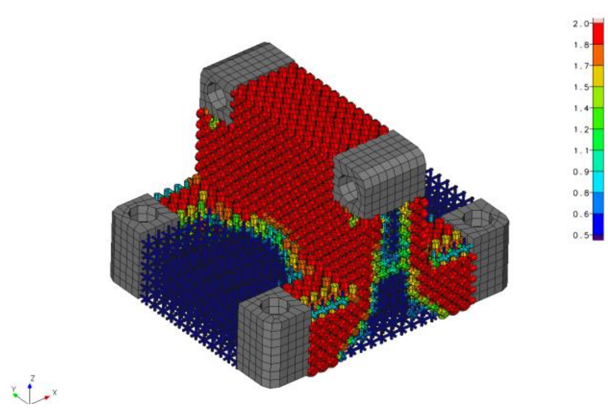
Homogenized Lattice Optimization

With AM, it is also possible to print lattice structures more easily than with conventional manufacturing. There are many benefits for lattice structures, for example, good strength to weight ratio, excellent shock absorption and impact protection behavior, high surface area which can help to dissipate the heat, and more. However, the details in lattice shape could lead difficulties in CAD modelling and FE meshing, thereby posing challenges to analyze and optimize the lattice structure. In the latest GENESIS release, solid elements can be used to simulate lattice structures. GENESIS uses homogenized materials that represent either a built-in lattice pattern or a user-supplied lattice pattern. Sizing and/or topometry can be applied to the homogenized lattice properties on solid elements to optimize for the diameter/thickness of the lattice structures directly.

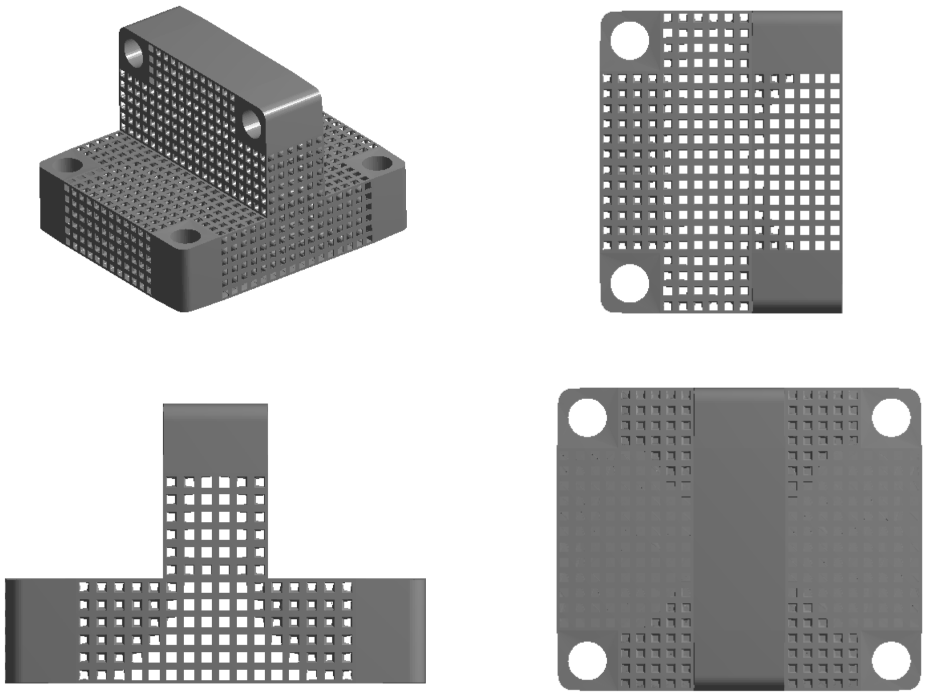


Lattice Optimization workflow

After lattice optimization, the lattice optimization result can be exported as an FE mesh using Design studio, or mapped to an STL lattice model.



Lattice model in FE mesh by Design Studio for GENESIS



Map optimized lattice diameter size to geometry in STL format

With homogenization, the lattice type is not limited to the bar type lattice. Other types of lattices can also be homogenized and optimized using the lattice optimization capability in GENESIS. The lattice material properties are assumed to be orthotropic in GENESIS, which means non-symmetric type or off-center types of lattices can also be designed with GENESIS.

Summary

With additive overhang constraints, you can incorporate the requirements for AM in the early design stage, and therefore reduce the cost in material, printing time and part post-processing. The new lattice optimization capability provides one more option for designing the structures to be structurally efficient. Additive manufacturing makes it possible to fabricate complex designs. With GENESIS topology and lattice optimization tools, you can maximize the potential for additive manufacturing.