Lattice optimization with GENESIS and GSAM

New capability accelerates analysis time and enables determination of optimal lattice dimensions

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Additive manufacturing makes it possible to fabricate complex designs. Lattice optimization enables the design of structures that are structurally efficient. With GENESIS or GSAM optimization tools, you can maximize additive manufacturing's potential.

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. With AM, it is possible to print lattice structures that would be difficult or impossible to fabricate with conventional manufacturing. The increased freedom in part shapes makes it possible to fully exploit optimization to design parts with minimal weight and maximal stiffness/performance.
Lattice structures have many benefits such as good strength-to-weight ratio, excellent shock absorption and impact protection behavior, a high surface area which can help to dissipate the heat, and more. However, the details in lattice shapes can create difficulties in CAD modelling and FE meshing, thereby making it more challenging to analyze and optimize the lattice structure. The latest release of the structural optimization software, GENESIS, allows solid elements to 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 directly optimize the diameter/thickness of the lattice structures. The GENESIS lattice optimization workflow is shown in Fig.1.

Homogenization

For a given type of lattice cell and volume fraction, homogenization is used to obtain the equivalent material properties for solid elements. For triple symmetric cells, CAE material testing is performed for two load cases, axial and shear, as shown in Fig.2. For non-symmetric cells, additional load cases are used but are not shown here. The equivalent material properties are computed for a series of volume fractions, and a curve is fitted based on the test data (Fig.3). The fitted curve for material properties can be used in subsequent analysis and optimization. With homogenization, it is possible to analyze and optimize lattice structures without creating the actual lattice geometry and mesh for a macroscale model. The homogenized structure is much faster to analyze and optimize due to the reduction of the problem size.

In the current version of GENESIS, there are three built-in lattice types: cubic edges, edges with space diagonals and double pyramids. A user can also specify their own homogenized lattice properties with the user-supplied option (LATMAT). Note that the lattice type is not limited to a bar-type lattice. Other types of lattices can also be homogenized and optimized using GENESIS's lattice optimization capability. The software assumes lattice material properties to be orthotropic.

Lattice optimization using sizing/topometry

Through homogenization, we obtain the equivalent material properties of a given type of lattice and apply it to solid elements. In the latest release of GENESIS, a user can directly optimize lattice diameter/thickness using sizing or topometry optimization. Here the lattice cell size is pre-defined, and the designable quantity is the lattice diameter or thickness. The goals of lattice optimization and topology optimization are quite different. In topology optimization, we try to either keep material or remove material completely from the design region, so any areas with intermediate stiffness are unwanted. In lattice optimization instead, any diameter/thickness (within an allowable range) is acceptable, which actually enables the design to fully exploit the advantage of the lattice structure.
In the example below, a cylindrical column has a pressure load on the top (Fig.4(a)). The load path is typically not well defined for such structures, which makes this a good candidate for using lattice design. We start with a uniform lattice diameter, with the goal of maximizing the stiffness without increasing the mass. Topometry optimization redistributes the mass to the most critical location. Fig.4(b) shows the distribution of the optimized lattice diameter/thickness. The stiffness of the structure is improved by 21.9%.

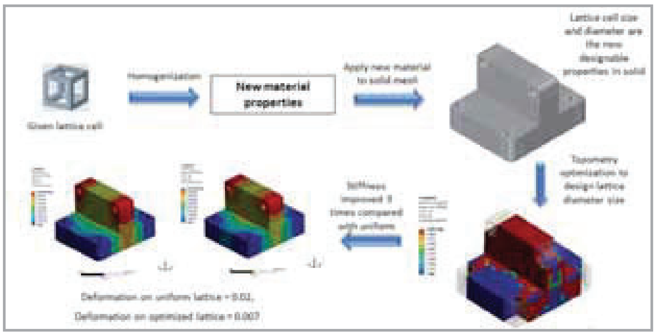

Fig. 1 - Lattice optimization workflow

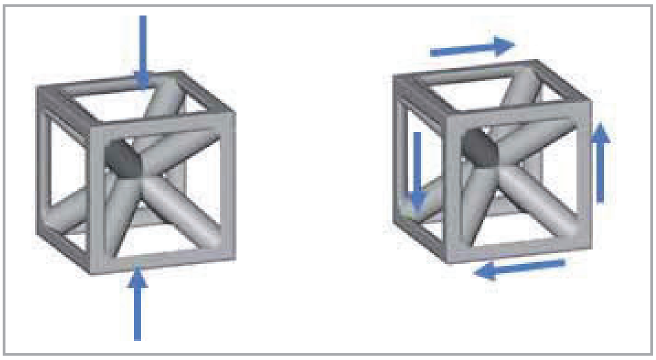

Fig. 2 - Uniaxial test and pure shear test

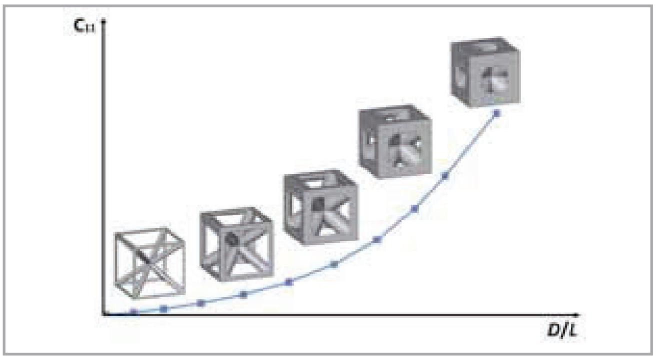

Fig. 3 - Material matrix coefficient vs diameter fraction

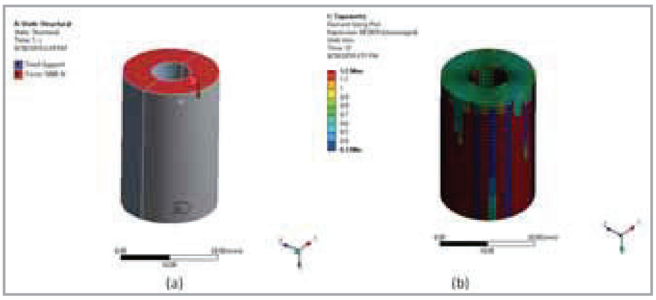

Fig. 4 - Topometry optimization of a solid part with homogenized lattice properties

The above example was created and solved using GSAM. GSAM is an ACT extension for ANSYS that uses GENESIS for optimization and ANSYS Mechanical for model creation and to display the topometry results. Design Studio was used for further processing.

Post-processing

After optimization, the result can be exported as an explicit lattice model using Design Studio for GENESIS (Fig.5). There are three export options:

1) Beam finite element mesh, which can be used for further analysis.
2) Graph (nodal locations) and Report (dimensions) files for Materialise 3-matic software, which can be used for printing.
3) STL model, which can be used for printing.

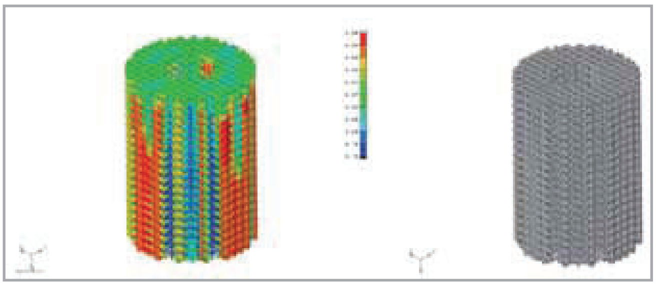

Fig. 5 - Lattice representation of optimization result

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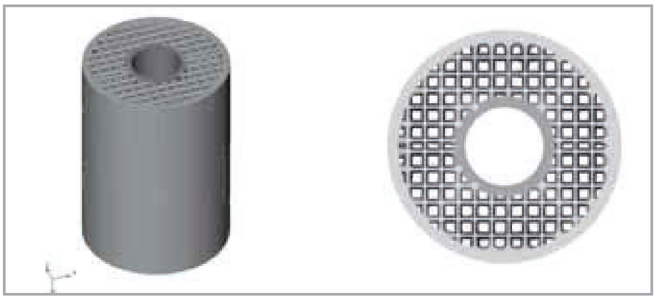

Fig. 6 - Lattice model with external skin kept

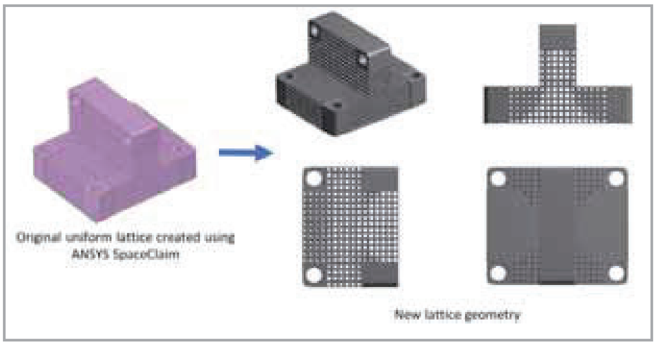

Fig. 7 - Map optimized diameter size to new lattice geometry

In creating a new lattice model, it is advisable to maintain the external skin of the original structure. This generates a more conservative structural design (Fig.6). Another post-processing option is to use a CAD tool, such as ANSYS SpaceClaim, to create a uniform lattice model (STL), and to use GSAM toolkit to map the lattice optimization result to a new variable thickness lattice model, as illustrated in Fig.7.

For more information
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