Means of Support for Additive Manufacturing

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Sacrificial support structures used in metal additive manufacturing consume material and add build time, so they should be as light as possible while ensuring that they can support the part during the build process. Simulating the stresses and deformations experienced by the supports has been time-consuming because it is necessary to model the heating and cooling resulting from processing of the part during the build to determine the thermomechanical forces on the supports. Researchers at the University of Pittsburgh developed a much faster, simpler simulation approach that reduces solution time by more than 99% yet still maintains necessary accuracy. This makes it practical for the first time to use lattice-based topology optimization to make the supports lighter to reduce manufacturing costs and time.

Additive Manufacturing Simulation
ansys.com/additive-manufacturing

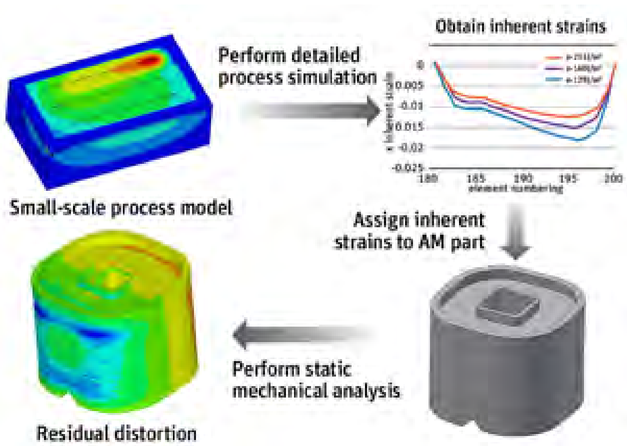
Support structures play an important role in metal additive manufacturing by bracing overhang geometry and serving as pathways to conduct heat from the part during the build. Topology optimization has tremendous potential for minimizing the mass of support structures while ensuring that internal stress does not exceed the yield stress. In the past, thermomechanical simulation of the complex metal additive manufacturing process has taken so long that it has not been practical to run the hundreds of simulation iterations required for this approach. University of Pittsburgh researchers have addressed this challenge by developing a streamlined method for simulating additive manufacturing that can be completed in under a minute, compared to hours or even days for traditional transient simulation. This new process, which enables significant cost reductions in metal additive manufacturing, will be included in an upcoming release of ANSYS Mechanical.

> **“This streamlined method for simulating additive manufacturing can be completed in under a minute, compared to hours or even days for traditional transient simulation.”**

METAL ADDITIVE MANUFACTURING PROCESS

The powder bed fusion metal additive manufacturing process produces parts by sequentially melting tiny areas of a powder bed with a moving laser. As each section of the part on the top layer cools, the solid underlying layers resist the thermal contractions, applying a tensile stress to the top layer. Likewise, the top layer applies compressive stresses to the solid area beneath it. These stresses have a significant impact on the loading of the supports.

Engineers can simulate the metal additive manufacturing process with tools such as ANSYS Additive Print and ANSYS Workbench Additive. These simulation tools predict residual stresses and deformation, and their effect on the finished part and supports. This requires a thermomechanical simulation that takes hours to compute. University of Pittsburgh researchers explored using topology optimization to start from the design space allocated for the supports and iterate to an optimized design while altering both the basic shape and dimensions of the supports to minimize their weight and cost.



Modified inherent strain method

But topology optimization typically requires running hundreds of simulation iterations in a batch, so performing the full thermomechanical simulation required to simulate metal additive manufacturing would take too long to be relevant in a real-world engineering environment.

MODIFIED INHERENT STRAIN METHOD

University of Pittsburgh researchers developed a new method that substantially reduces the time required to simulate metal additive manufacturing. The new approach, which they call the modified inherent strain method, begins with using ANSYS Mechanical to perform a detailed thermomechanical simulation of a small section of the build as it is briefly heated to a high temperature by the laser and then cools. This section, called the representative volume element (RVE), is typically several millimeters in length and width and one build layer thick. The simulation calculates the modified inherent strain, which is defined as the difference between the total strain for the initial state when the laser has just heated the RVE and the elastic strain at the final state when the RVE has cooled to room temperature. The modified inherent

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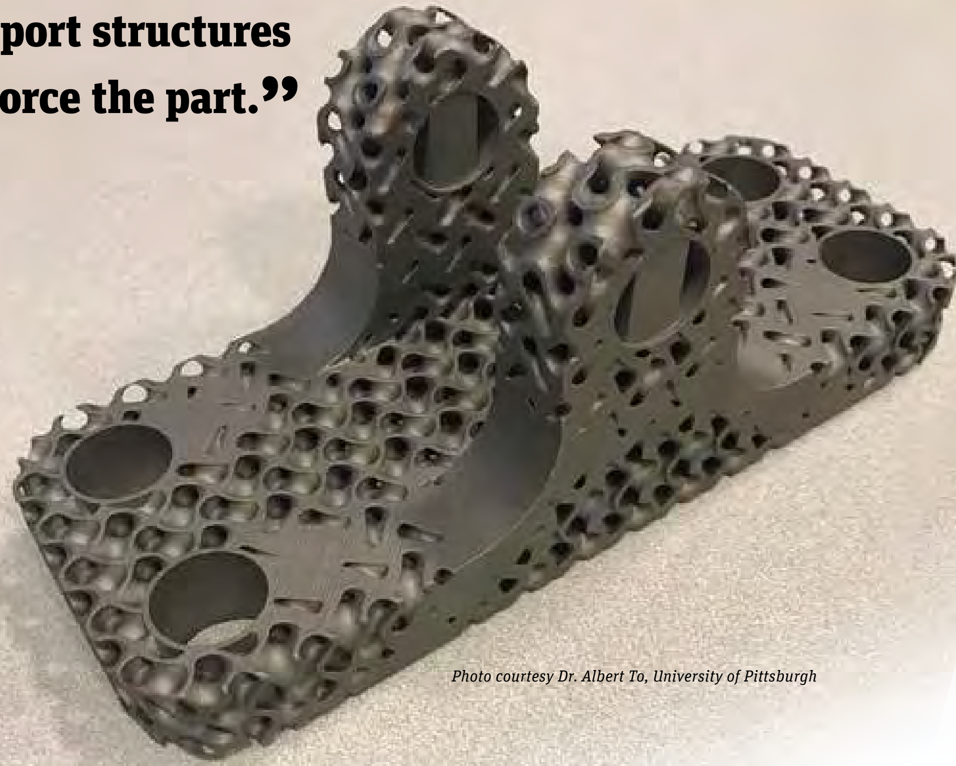


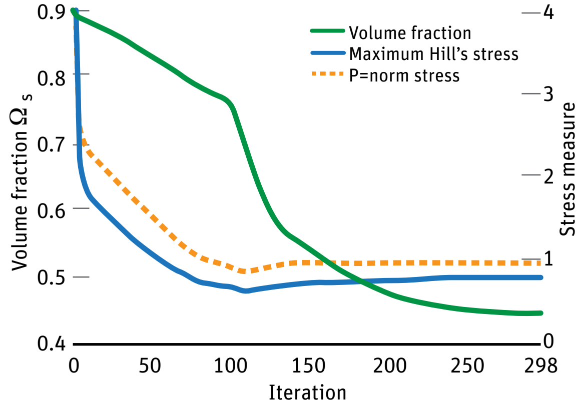
Photo courtesy Dr. Albert To, University of Pittsburgh

strain is assigned to the entire finite element model. Then, a single static mechanical equilibrium analysis, which takes a fraction of the time required for thermomechanical simulation, is performed. The results of the modified inherent strain method match the results of conventional thermomechanical simulation within a few percent.

The researchers have found that the most efficient way to optimize the support structures and, in some cases, the part itself, is to construct them with variable density lattice structures. These structures would be far too expensive to produce with traditional manufacturing but can be produced with additive manufacturing with no cost penalty. The lattice is designed by choosing the maximum bridge span that is self-supporting and determining the diameter of each section of lattice by topology optimization.

ITERATING TO A LOWER-COST SUPPORT STRUCTURE

The researchers developed a stand-alone code to set up a series of ANSYS Mechanical simulations, including the relative density for each element. The inherent strains obtained from the inherent strain method are applied to the finite element model as initial strains. The output from the finite element model is the stress and deformation of each element. Based on these results, the stand-alone code increases the relative density of elements with high stresses and deformations, and reduces the relative density of elements with low stresses and deformations.



Support mass was reduced by 53% during the optimization process.

The code then executes another ANSYS Mechanical simulation. This process iterates until the support design is optimized. A complete thermomechanical simulation of the additive manufacturing process is performed to validate the optimized design.

Metal additive manufacturing is experiencing rapid growth, but cost reductions are needed to spur increased adoption. A promising approach is to optimize support structures to minimize material consumption and build time subject to stress yield constraints. Performing a complete thermomechanical simulation of the additive manufacturing process provides a very accurate simulation, but the time required for a solution limits the number of design iterations that can be evaluated. The new modified inherent strain method

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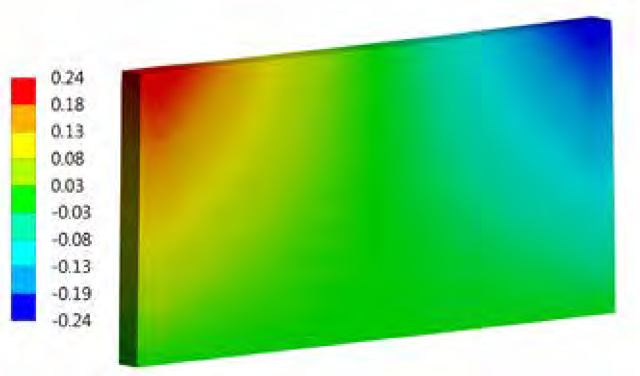
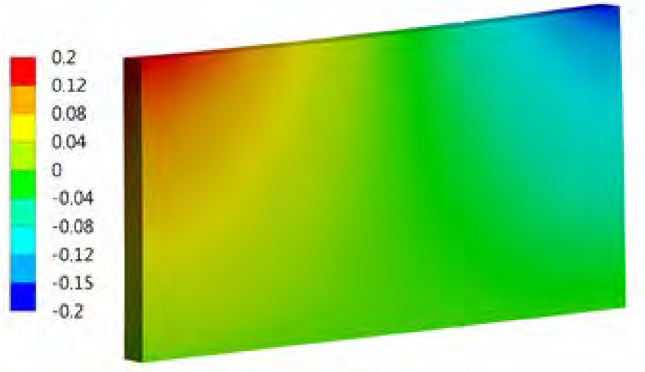
developed at the University of Pittsburgh provides accuracy close to transient simulation in much less time. This approach makes it possible to use lattice-based topology optimization to iterate to a design that reduces manufacturing costs while ensuring that the support structures can reinforce the part.

Reference

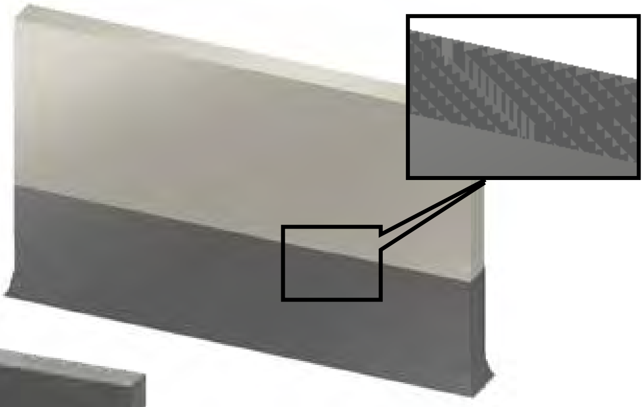
Liang, X.; Chen, Q; Cheng, L.; Yang, Q; To, A.C. “A Modified Inherent Strain Method for Fast Prediction of Residual Deformation in Additive Manufacturing of Metal Parts.” Proceedings of 2017 Annual International Solid Freeform Fabrication Symposium, 2017.



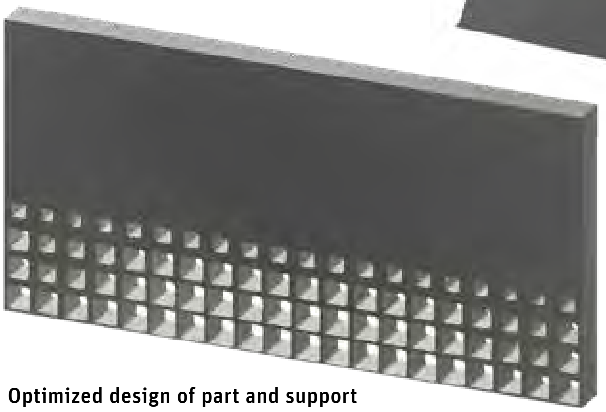
Deformation calculated with complete thermomechanical simulation in four hours



Deformation calculated with modified inherent strain method in less than one minute



Initial design of part (white) and support (gray)



Optimized design of part and support