e-Xstream engineering | CASE STUDY

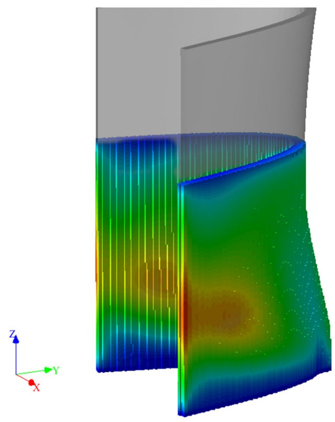
Simulating effects of warpage in an additively manufactured composite layup tool

Development and validation of Additive Manufacturing process simulation

Overview

For more than 25 years, Stratasys has been a defining force and dominant player in additive manufacturing – notably inventing the Fused Deposition Modeling (FDM) Technology. The company's solutions provide customers with unmatched design freedom and manufacturing flexibility – reducing time-to-market and lowering development and manufacturing costs.

FDM® (fused deposition modeling) is becoming the technology of choice for rapid production of high-temperature (> 177 ° C), low-volume, composite lay-up and repair tools, as well as for moderate-temperature (<163 °C) production sacrificial tooling. Relative to traditional tooling materials and methods, FDM offers significant advantages in terms of lead time, tool cost and simplification of tool design, fabrication and use, while enabling increased functionality and geometric complexity.



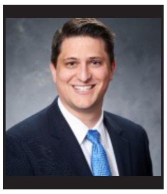
Virtual printing of the composite tooling in Digimat-AM

Challenge

To unlock the full value additive manufacturing has to offer, simulation tools are needed to predict and mitigate part warpage as well as realize the impact of design decisions on the manufacturing process before the part is printed. Several challenges face the development of this process simulation:

- The complex thermomechanical loadings that occur during the layer-by-layer deposition of the material and the successive cooling of the part
- Additive manufacturing is a true multi-scale challenge: the position of bead deposition creates specific microstructures based on the printing toolpath pattern, which drives the macroscopic mechanical behavior – typically inducing anisotropy.
- The thermal history of the material deposition generates differential shrinkage between adjacent beads or layers that affects the end tolerances of the part.

Overall, modeling the printing process requires taking into account the material state evolution, to model the stress build-up as well as the stress relaxation over time. Numerical predictions of warpage need to account for the process parameters, the material characteristics and the printing strategy (part orientation, toolpath, supports etc…).



"For engineers to unlock the design freedom that additive manufacturing offers, they need tools for accurate and effective analysis. Working with e-Xstream, we're enabling 3D printing to become a high performance production technology."

– Scott Sevcik, VP of Manufactruing at Stratasys

Solution

Stratasys is working with e-Xstream to create FDM process simulation via a multiscale approach as a function of process setup and material choice:

- Solve a fully coupled thermomechanical problem of the deposition process to identify the warpage behavior of the printed material accounting for thermal exchanges inside the printer build (conduction, convection and radiation)
- Load the toolpath issued from the manufacturing processing software and extract information about the deposition sequence
- Model via micromechanics the heterogeneous material microstructure as a function of the toolpath (e.g., porosity volume fraction and orientation)
- Predict the resulting warpage induced by the printing process
- Iterate the design and optimize the manufacturing process parameters to minimize the warpage.

Results/Benefits

Print it right the first time!
Iterate designs and parameters through simulation rather than wasting time and materials with iterating through printing

Save time & material!
Anticipate printing issue with simulation (e.g., evaluate the impact of the printing direction and location on results)

Minimize warpage in only two steps!
Thanks to a predeformed geometry

Optimize the manufacturing process!
Quickly explore at virtually zero marginal cost the sensitivity of process parameters on the process quality and part fidelity

Access to an easy, efficient and user-friendly GUI!
Designed to follow the printing workflow and accessible for non FEA experts

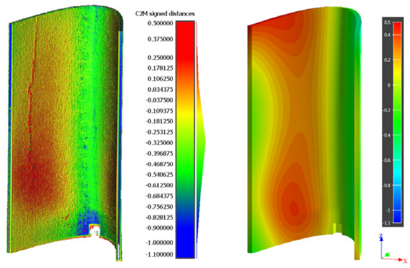
Key Highlights:

Digimat:
Digimat-AM

Industry:
Additive Manufacturing

Application:
Warpage prediction of a part

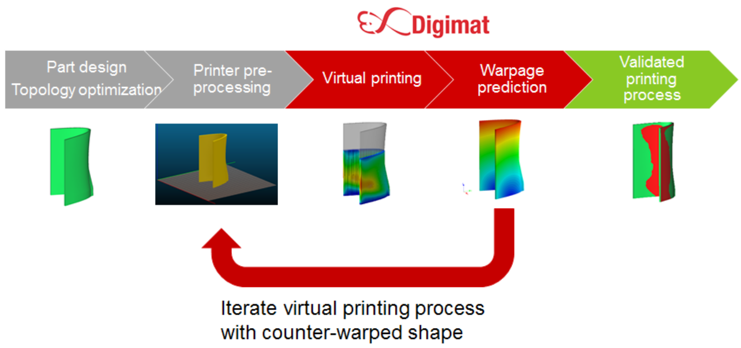
Performances:
FDM process simulation



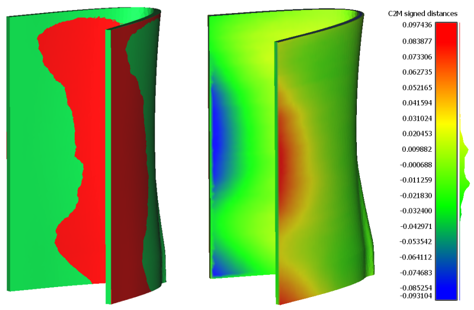
Comparison between measured warpage on a physically printed part (RMS signed distance, left) and Digimat-AM warpage prediction (X displacements, right)

Results/Correlation to test data

The warpage prediction has been compared to 3d-scan measurement of a physically printed composite tool. Given the different modeling assumptions, the comparison shows a good general correlation with similar deformation pattern and amplitude. The warpage compensation procedure decreases significantly the maximum deviation between the reference geometry and the as-printed part (0.5 mm to less than 0.1 mm).



Digimat-AM simulation approach for optimal printing



Warpage prediction after geometry compensation in Digimat-AM. Left: superposition of the as-printed (red) and as-design (green) parts. Right: RMS signed distance. Maximum deviation is below 0.1 mm.

For more information on Digimat and for additional Case Studies,
please visit www.e-Xstream.com

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