University of Pittsburgh

Support Structure Optimization via Fast Process Simulation for Additive Manufacturing

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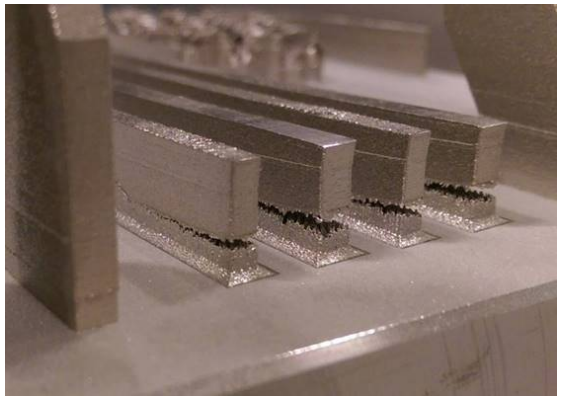
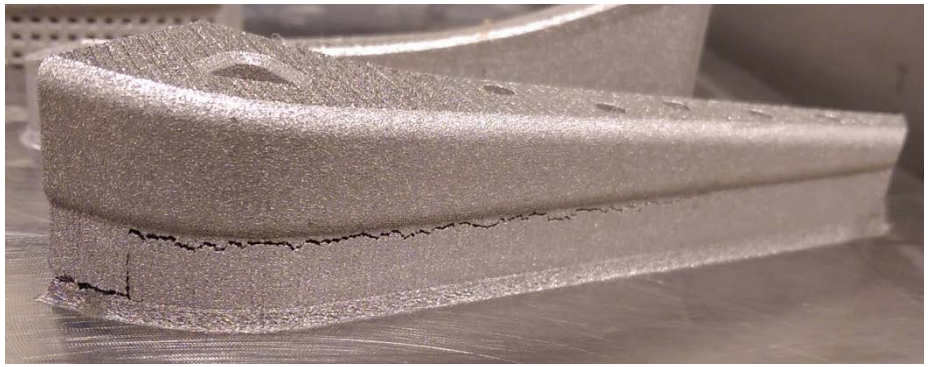
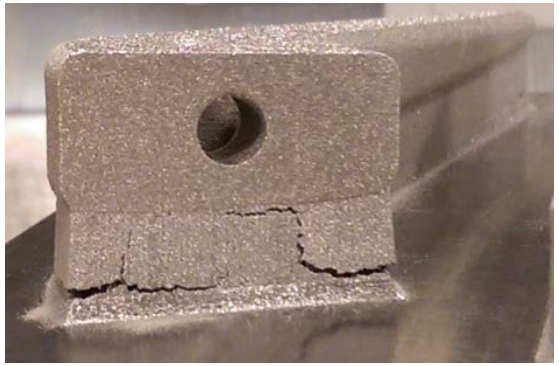
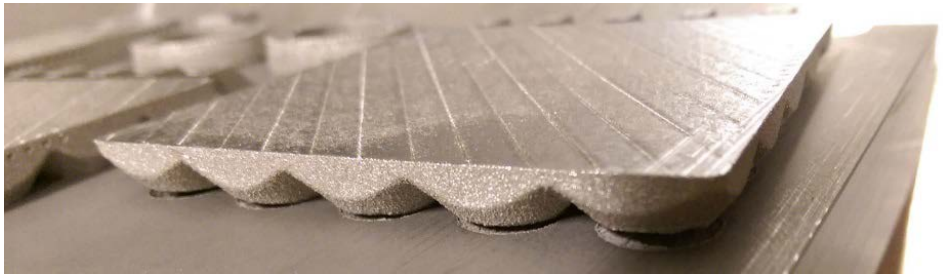
Build Failures

- One of the most critical issues in AM
- Very common in practice
- Result of residual stress or residual distortion



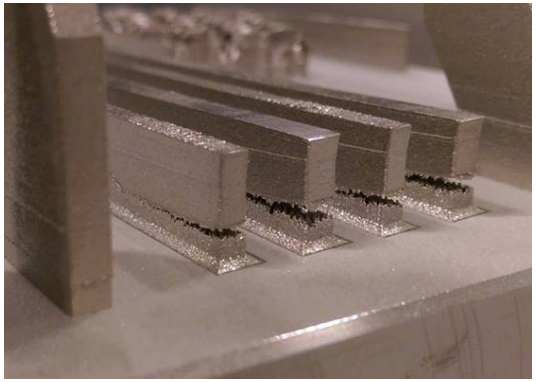


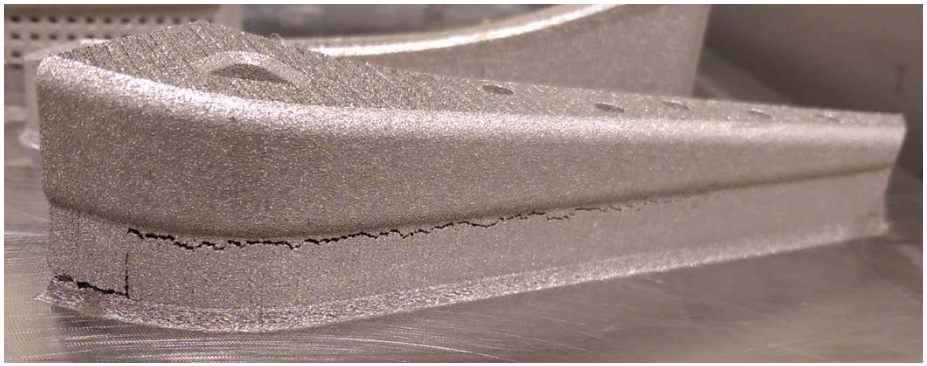




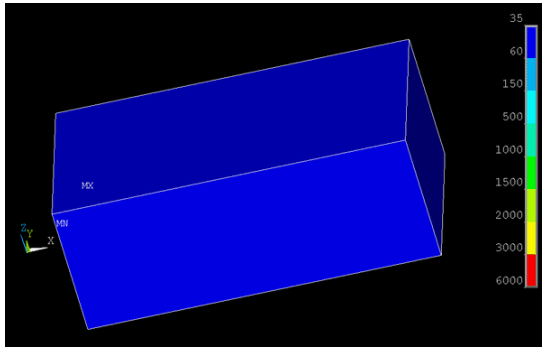
AM Support Structure Optimization

- AM support structure
  - Current design solely based on experience
  - Many build failures → huge problem!
- Use topology optimization for support design
  - Reduce # of trials, save material, save build time
- Technical barriers
  - Topology optimization requires 50-300 iterations
  - Current AM process simulation is too slow (hours to days)



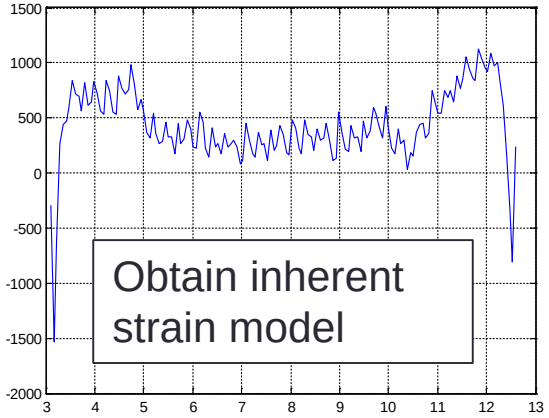


Fast Process Modeling

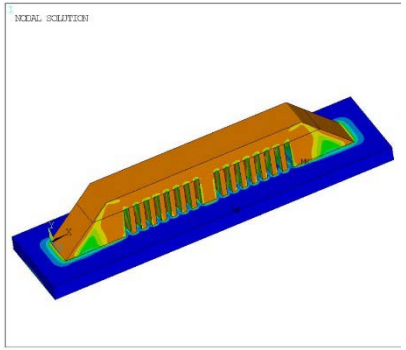


RVE process model

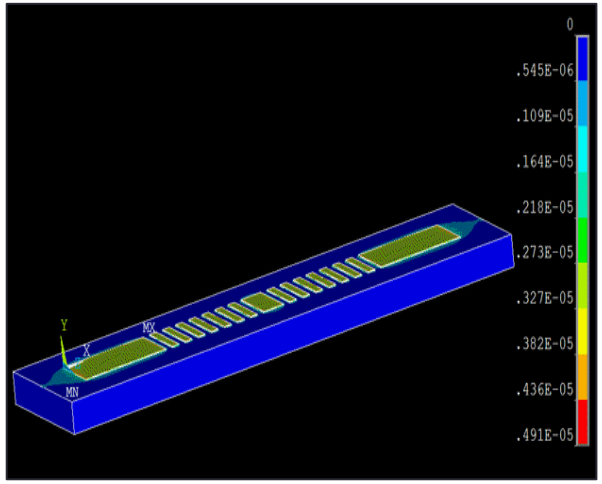
Perform detailed process simulation



Assign inherent strains to AM part

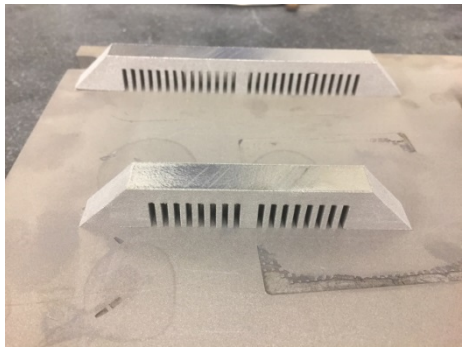


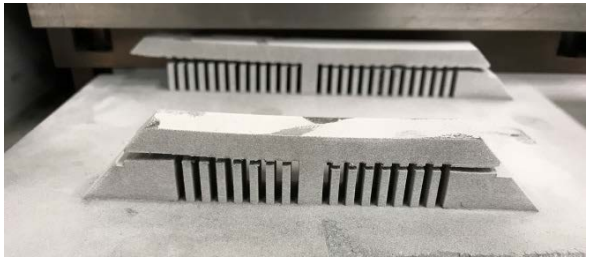
Perform static mechanical analysis

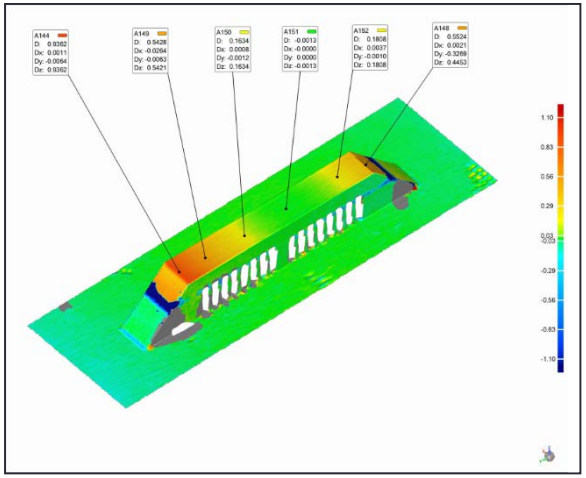


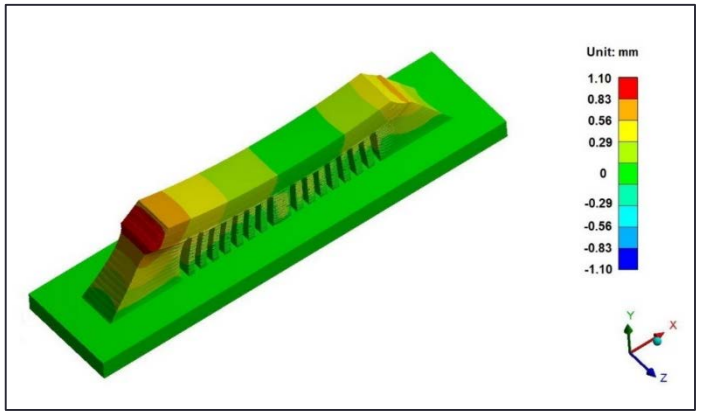
Residual distortion

Experimental Validation







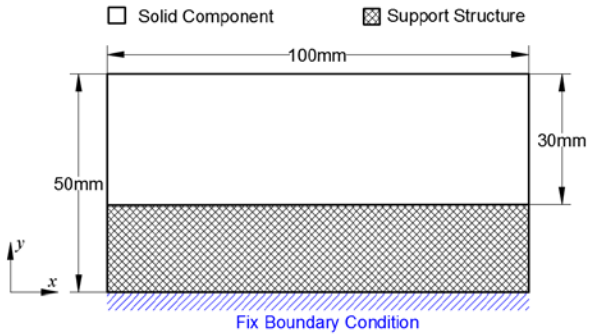


End Displacements of Double Cantilever Beam

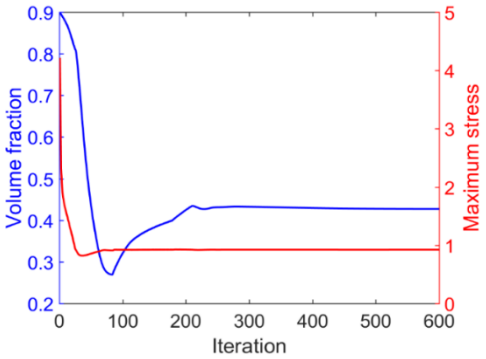
	Left end	Right end
Experiment	0.95 mm	0.56 mm
Simulation	1.07 mm	0.61 mm

- Simulation took less than 5 minutes!

AM Support Structure Optimization – Test Case 1

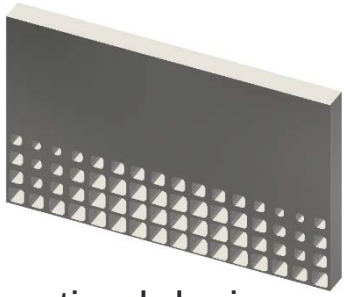


Constrained stress topology optimization coupled with fast process simulation

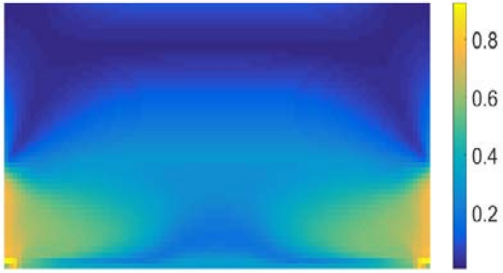


Convergence history

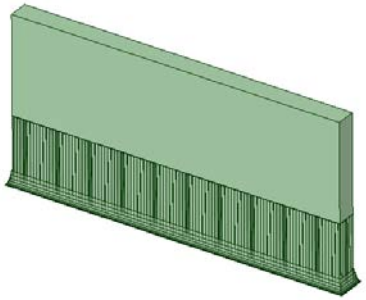
Density profile



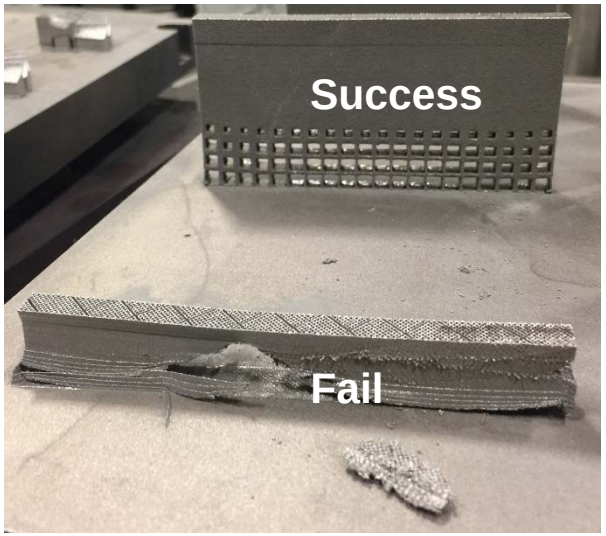
optimal design



Stress profile



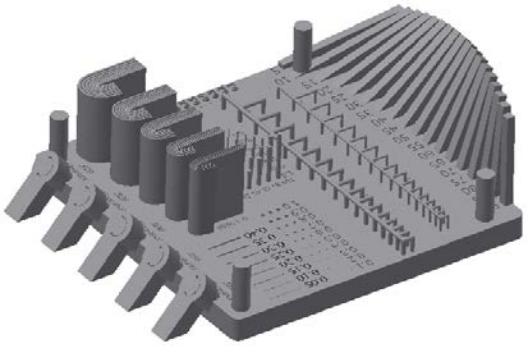
generic design



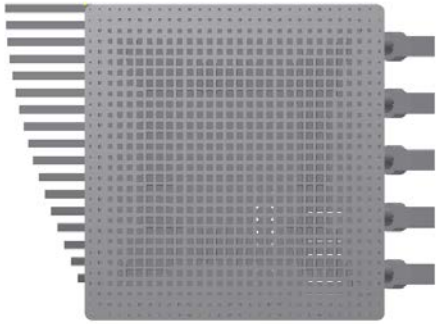
Printing in Ti6Al4V on EOS M290 DMLS

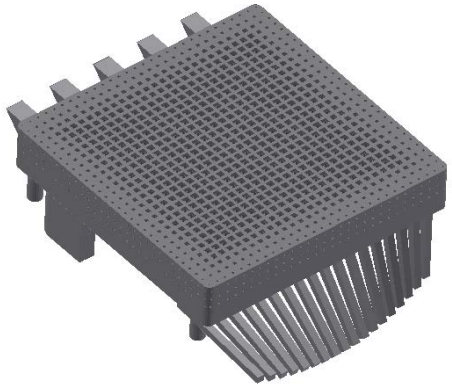
- 60% mass reduction

AM Support Structure Optimization – Test Case 2

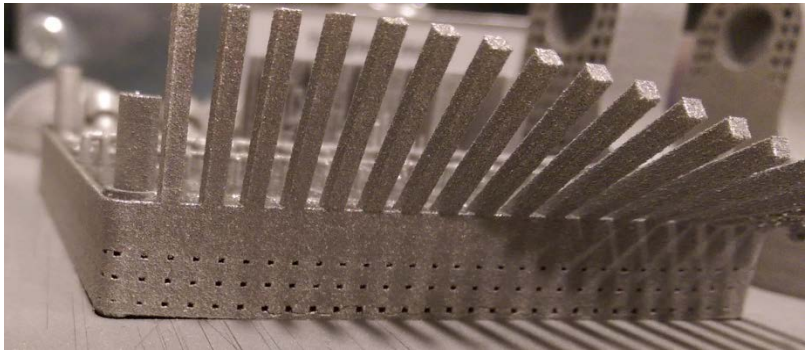


Complex part
for printing





Optimized support structure design



Successfully printed using
optimized design

Failed using generic support design

Conclusions

- Design of support structure is critical for mitigating build failure resulting from residual stress and distortion
- A fast process model based on eigenstrain theory has been developed to predict residual stress/distortion
- Preliminary results show good accuracy with 5-10% error
- Topology optimization, coupled with fast process model, seems to be feasible for support structure design
- More research needed to refine the fast process model and explore different optimization strategies