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Debinding Simulation Guidelines for 3D Printed Parts using Ultrafuse® 316L

As binders are removed during catalytically debinding, some part features lacking structural integrity can experience collapse or distortion under their own weight. Often improper design or printing orientation have proven to be significant factors in part collapse. Internal tensile and compression stresses, resulting from gravitational forces, must be considered when choosing the appropriate design and orientation of Ultrafuse 316L full metal parts.

The follow procedure will guide users through the setup and execution of the Debinding (or Brown Part Stability) analysis. The results of this tool can greatly increase the success rate of new metal fused filament fabrication users or those advanced users wishing to push their projects to the limits of lightweight structures, minimized print times, and final part performance.

Model Conditions and Assumptions:

1. The simulation assumes ideal print results free of delamination, warpage, porosity or other errors resulting from poor printing outcomes.
2. These instructions hold for solid parts of 100% infill.
3. Supports must be present in the solid model or set as a fixed constrain of the part in order to be evaluated.
4. Debinding and sintering orientation must match the printing orientation.
5. Once the maximum tensile of compressional stresses are reached breakage is assumed.

Simulation Software and Setup:

1. Any Computer Aided Design (CAD) software with a Finite-Element solver can be used to check brown parts stability (eg. Autodesk Inventor, SolidWorks, Siemens NX).
2. Debinding analysis employs a linear-static analysis method to approximate gravitational forces during debinding.

Instructions

Step 1: Meshing

1. Load the part file into the chosen CAD software.
   a. Ensure that the appropriate printing oversizing scale has been applied.
2. Rotate the part according to the print orientation (global z-direction is the print direction).
3. Mesh the part using 3D solid elements, as seen in Fig 1. (tetrahedrons, hexahedrons, etc.).
4. Ensure that a minimum of 3 mesh elements are present across the thinnest part features.
   a. The finer mesh the higher accuracy but at the cost of calculation time and stability.

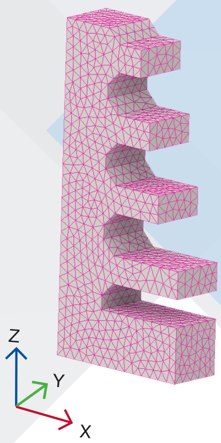

Fig 1: Meshed example part

Step 2: Boundary Conditions and Forces

1. Constrain the areas of the part which are in contact to the build plate.
   a. If supports are to be used ensure that they are cons trained both to the part and build plate.
2. Apply a distributed gravitational force (g=9.81 m/s²) opposite the print direction (-Z direction in Fig 2).

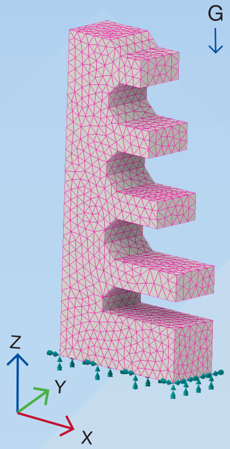

Fig 2: Meshed example part with boundary conditions and gravitational force

Step 3: Material properties

1. Apply a linear elastic material model to the part with the following parameters:
   a. Young's Modulus E = 210 GPa
   b. Poisson's ratio v = 0.4
   c. Density p = 4700 kg/m³
2. Define linear static analysis with deformation and stresses as output.
3. Run the simulation.

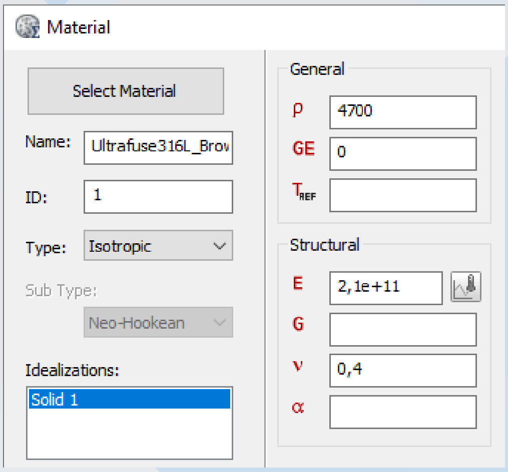

Fig 3: Material model

Step 4: Results and interpretation

1. Check for deformation if the loading direction and boundary conditions were correctly defined.
   a. Scaling up the deformation magnitude can assist in identifying small deformations.
2. Plot the stresses in global x, y and z direction.
3. Check if the stresses are within maximum thresholds:
   a. Xmax & Ymax = +6 kPa Tensile, -7kPa Compression
   b. Zmax = +0.5 kPa Tensile, -7 kPa Compression
4. If areas exceed one of the max thresholds, debinding will likely fail
   a. Tensile and compression stress greater than their max thresholds correspond to the red and blue areas seen in Fig 4. below.

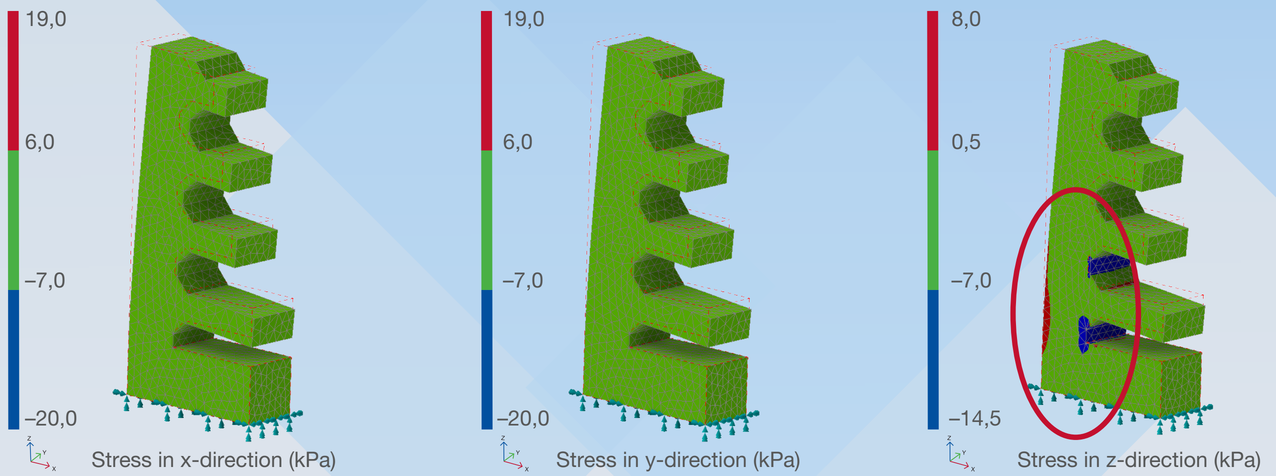

Fig 4: Brown Part Stability in each coordination direction
* Deformation is upscaled by a factor of 10 for illustrative purposes.

Step 5: Redesign the part

If failure is predicted, try the following and rerun the analysis:

1. Try different part orientations for both printing and debinding and sintering, as seen Fig 5.
2. Redesign red and blue areas by thickening thin features or smoothing sharp edges to avoid stress concentrations.
3. In general, smaller and lighter part designs reduce gravitational forces and increased rates of success.
    a. Part sizes of 60 X 60 X 60 mm have proven to provide an optimal balance between stability.
    b. Parts greater than 100 X 100 X 100 often will not be accepted by the debinding and sintering providers.
4. Increase the amount of supports and / add them directly to the part’s solid model.
5. Iteratively use this tool to ensure that all stresses have been identified and resolved any red or blue areas that might be encountered in the redesign.
6. Please feel free to contact if you have questions or more simulation needs.

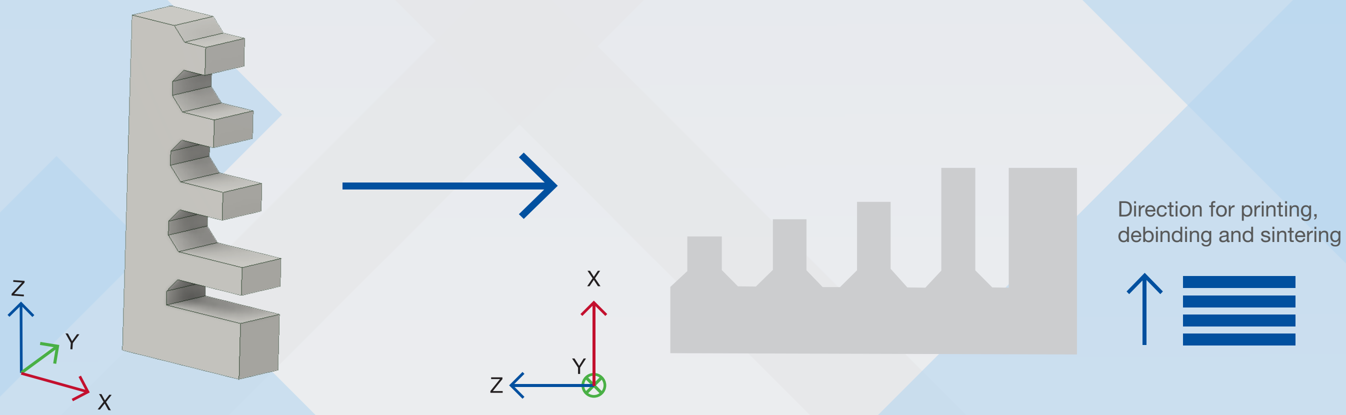

Fig 5: New part orientation for printing, debinding and sintering

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