3DXpert Guide

3DPrinting Exercise

Build Simulation - Calibration

Tutorial_V9 - Updated: 14,0301,1635,1169(SP3P1)

3D SYSTEMS

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Introduction

The need behind printing or build simulation

3D Printing in metal is a challenge, specifically when printing large volume parts.

Preparing a part involves several printing iterations to assure high quality results, and this is usually a very costly process. In addition to the actual print failure, such prints may even end in damage to the equipment.

The purpose of Build Simulation is to reduce the number of iterations, optimize your supports design and validate that you get the expected deformations according to the allowed tolerances.

About Build Simulation

3DXpert's Build Simulation is a macro scale estimation of the process.

It is based on the geometry of the model itself (its topology and welding conditions). As such, it is much faster than the actual printing time and therefore practical.

For accurate simulation results, this method also involves the calibration of the machine and material.

Hardware Specification

Build Simulation runs on a separate PC through an Offload Calculation Seat (also known as the Superbox or Build Simulation Server).

The Offload Calculation Seat acts as a server. It receives the data from 3DXpert, does the calculation and returns the results to 3DXpert.

Since Build Simulation calculation deals with lots of data, the Build Simulation Server should use a professional high-end graphics card.

The minimum and recommended specifications for this server are as follows:

Minimum Spec –

CPU: 4 Cores, RAM: 16 GB RAM, Graphics Card: nVidia QUADRO P2000

Recommended Spec –

CPU: 6 Cores i7 (i7-6850K), RAM: 32 GB RAM, Graphic Card: nVidia QUADRO P6000

Calibration

The calibration process is performed per each material, in order to optimize the Build Simulation results and thus achieve a more accurate simulation.

In general, the calibration is a preliminary process in which you print a predefined calibration test part with constant geometry, then remove it from the plate and make specific measurements on it.

The results of these measurements are then input into the system and from that point onwards, are used by the Build Simulation engine (when simulating with this specific material).

Validated materials are supplied with pre-defined calibration information, therefore, it is important to note that when using such materials, calibration is not a prerequisite for build simulation.

However, a dedicated calibration on site will take into account the local conditions and hence can improve the quality of simulation results (i.e., the results will be closer to the real result).

The Model of Ideal Plasticity

Build Simulation assumes an ideal plasticity model. To explain this, some theory is required.

Let’s begin with some definitions:

What is Stress?

Consider a bar of cross sectional area A, being subjected to equal and opposite forces F, pulling at the ends so that the bar is under tension. The material experiences a stress defined to be the ratio of the force to the cross sectional area of the bar:
Stress σ = F/A

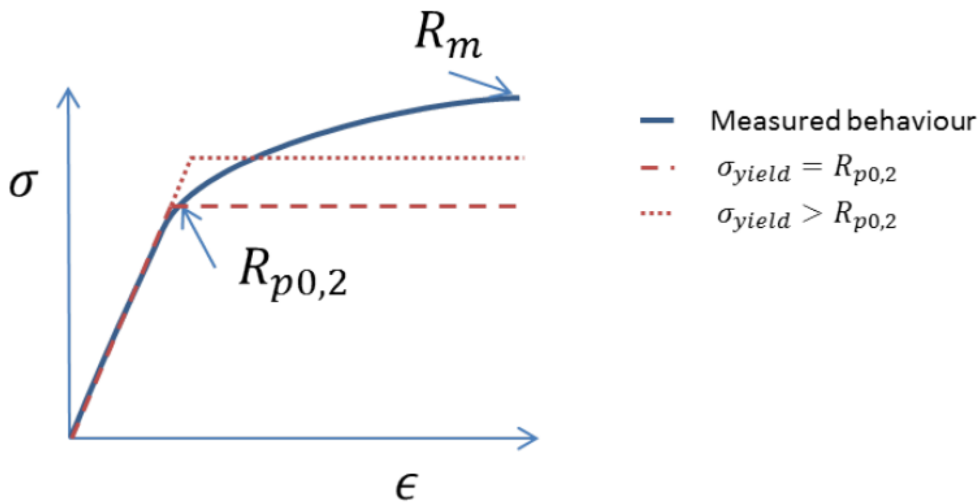
What is Strain?

The ratio of total deformation (l) to the initial dimension of the material body (L) in which the forces are being applied.
Strain e = (L-l)/L

The curve shown in the image below is called the stress-strain curve. This curve is unique for each material and is created by measuring the amount of deformation (strain) at distinct intervals of tensile or compressive loading (stress). Such curves describe the properties of the material.

The blue curve in the image shows the stress-strain behavior based on measurements.

The red curves represent the ideal plasticity model.



The model of Ideal Plasticity assumes that in most cases, the stress value where a plastic deformation of 0.2% (Rp0.2) will occur, is identified as the yield (yield stress is the stress at which a material begins to have a plastic deformation). From then on, the stress is constant.

The blue curve represents the true behavior of the part under load; for simulation purposes, the red curves (ideal plasticity) are considered.

In other words, strains exceeding this boundary are treated as plastic strains (irreversible dislocations within the material). Speaking of additive manufacturing, the yield strength of a given material limits the residual stress and therefore the warpage of parts after release.

However, in some cases, such as when the yield stress is low, it should be better to set a higher yield stress value, lying between Rp0.2 and the maximal measured stress Rm.

This will lead to a better approximation of the physical behavior of the material.

Note: At the time of writing, strengthening effects are not considered, so the test specimens (see page 7) should not be subjected to any heat treatment.

A reliable simulation is based two ingredients, one is theoretical and the other is practical. The theoretical ingredient is composed of a set of material properties and the practical ingredient is composed of a set of values for bending, measured on a printed test model.

Material Properties

As stated above, a set of theoretical material properties is required. These properties are:

- Yield Stress
- Young's Modulus
- Poison's Ration

For some materials, the values of Yield Strength and Young's Modulus are supplied within the material datasheets, which are provided with the materials (they are obtained from tensile testing).

Note, however, that for some materials the Young's Modulus may not reported (as this is not always required by the ASTM standards). If the properties are not included with the material datasheets, contact your material vendor.

The Poison's Ratio is also theoretical, and the value for this can be found in engineering handbooks.

Build Simulation Calibration

The calibration process is composed of the following actions:

1. Prepare and print test specimens
2. Measure the printed specimens
3. Set material data & measured values

1. Prepare and Print Test Specimens

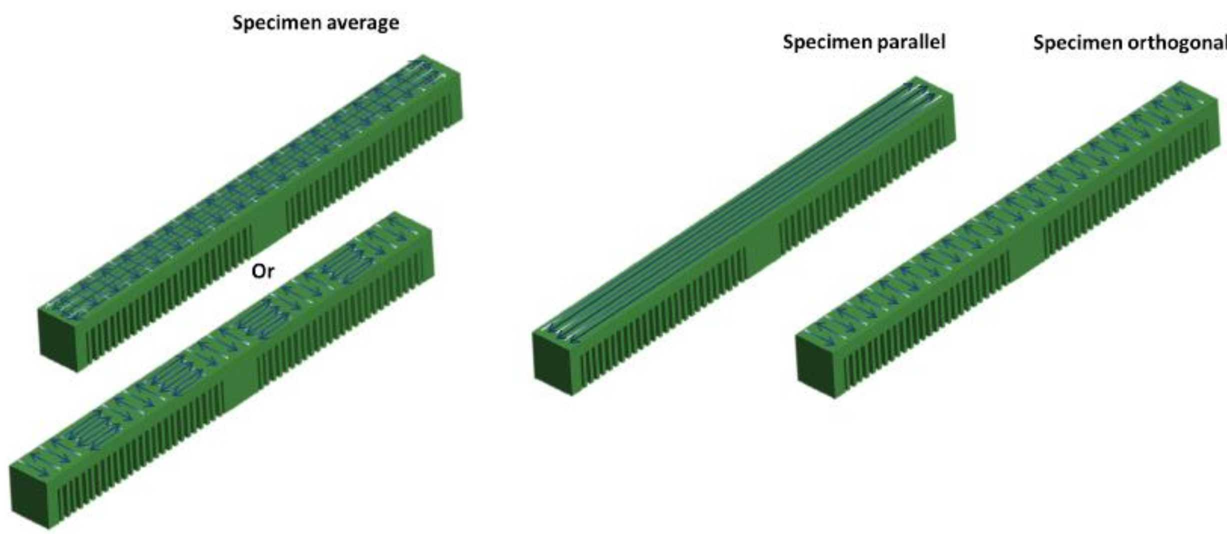
Build Simulation relies on experimental calibration data, with known material properties at room temperature. For these calibrations, use the cantilever model that we supply.

There are three types of test specimens; each type represents different slicing technology. To set the technologies, edit a **build style** and set the relevant parameters.

The Average specimen - Use your standard average process parameters, such as rotated layer or islands where hatches in neighboring areas are rotated against each other.

The Parallel specimen - Calibrating the simulation loads which are parallel to the hatch direction.

The Orthogonal specimen -- Calibrating the simulation loads which are orthogonal to the hatch direction.



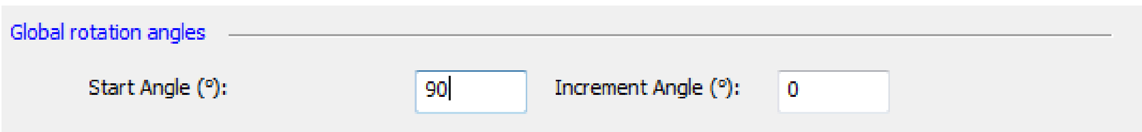
Recommendations for slicing

Use layer thicknesses which are available in the validated materials; so for example, for the ProX 320, use both 30 and 60 microns.

General Parameters:

Set the layer thickness.

Set the start angle according to the orientation of the part on the plate, and do not apply any rotation of scan vectors between the layers.

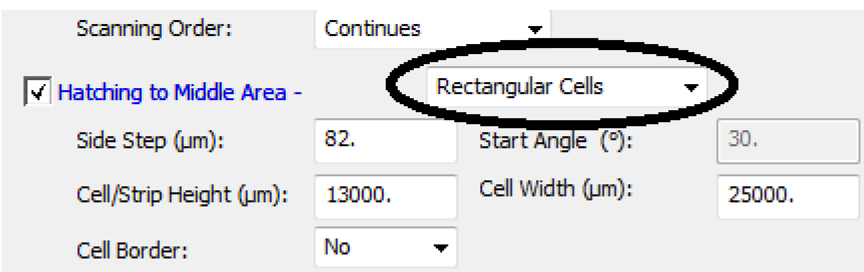


Note that the value of 90 degrees shown here for the Start Angle is just an example.

Hatching Parameters:

For the hatching, it is important to use Rectangular Cells instead of Stripes, so that the entire part will be scanned with vectors in the size of the part.

The size of the cell can be as high as possible, so in essence each layer is composed of a single cell.



Note: The cell Height and Width shown here are not indicative.

It is also important to exclude any effects that you might get from scanning too many vectors on top of each other. To do that, the vectors need to be shifted slightly on a layer-to-layer basis.

One way to overcome this is to slice the part with double the layer thickness of the final part.

This way you can superimpose two parts, but move one sideways by half a side step and upwards by one layer thickness.

Once the technologies are ready, print the specimens.

You should have a printed part for each specimen and layer thickness, with all specimens on the same base plate in the same job.

Ideally, a calibration can be done for each layer thickness individually.

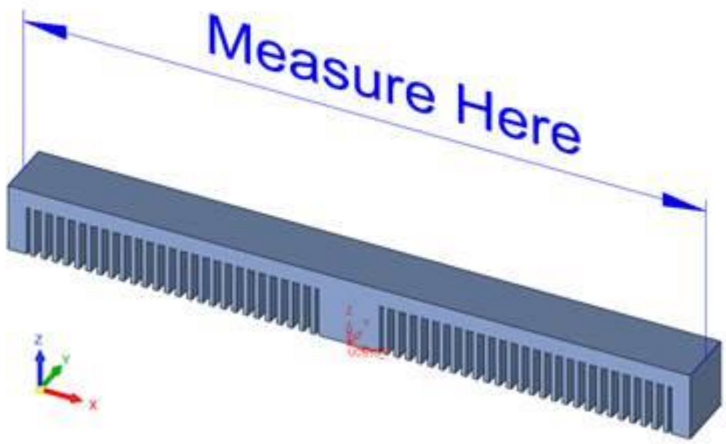
Once printed, gently remove each cantilever from the base plate. The calibration assumes that the part is carefully removed from the base plate by a gentle method, such as wire-cut EDM.

Do not remove the part from the base plate by any method that may cause breakage or warpage to the part.

2. Measure the Printed Specimens

Now that the test specimens are printed and separated from the base plate, we can measure the Bending values for each specimen.

The measuring should be carried out by a 3D scanning device, such as a GOM laser.



Avoid measuring near the corners of the part, as corners are further deflected.

So in order to avoid taking corners into account, draw a line from the middle of the narrow dimension of the cantilever. Measure the distance between the plane and the line in the center.

This is the value that you need, one such dimension per each test specimen.

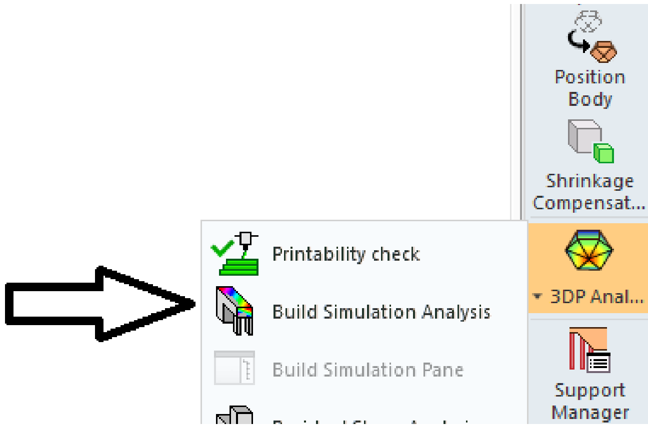
Since you have printed the part using different layer thicknesses, measure the bending value in each specimen, once for each layer thickness, and then calculate the average bending value for the same test specimen.

Once done, you will obtain three bending values and you are ready for calibration.

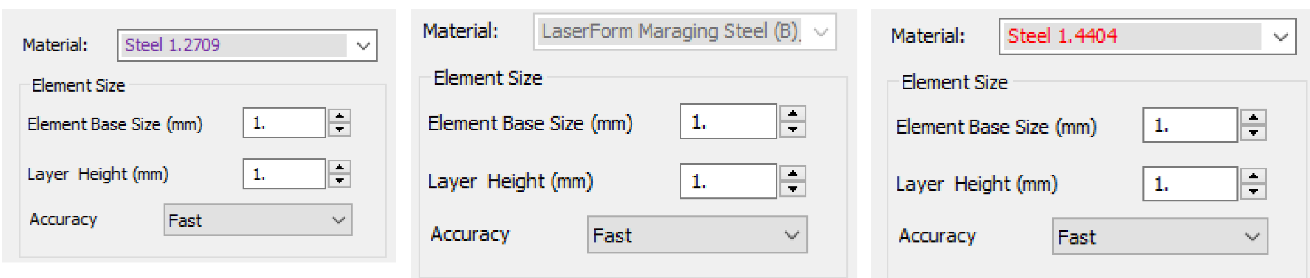
3. Set Material Data & Measured Values

Open up a 3DXpert project, define a printer and set the material.

Through the 3DXpert Guide Bar, select **3DP Analysis > Build Simulation Analysis**.



Notice the color of the material name, as this color has a meaning:



A **Purple** color means that the system did not find any calibration data for this material, and therefore it uses the next best calibration data from the list of calibrated materials. For example, if the material is recognized as any type of titanium, then it will use the generic titanium calibration.

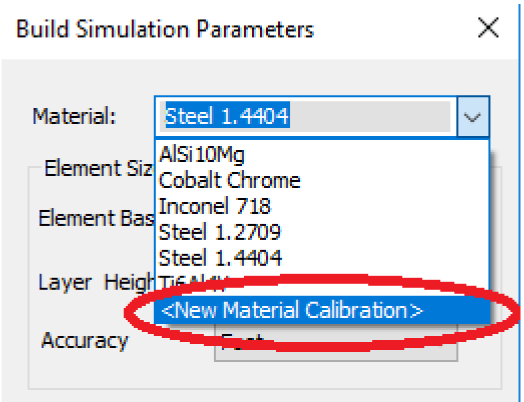
A **Black** color means that the material in use has been calibrated (i.e., calibration data exists within the material database).

A **Red** color means that the system could not find a suitable material in the list of calibrated materials. In other words, this material is not calibrated.

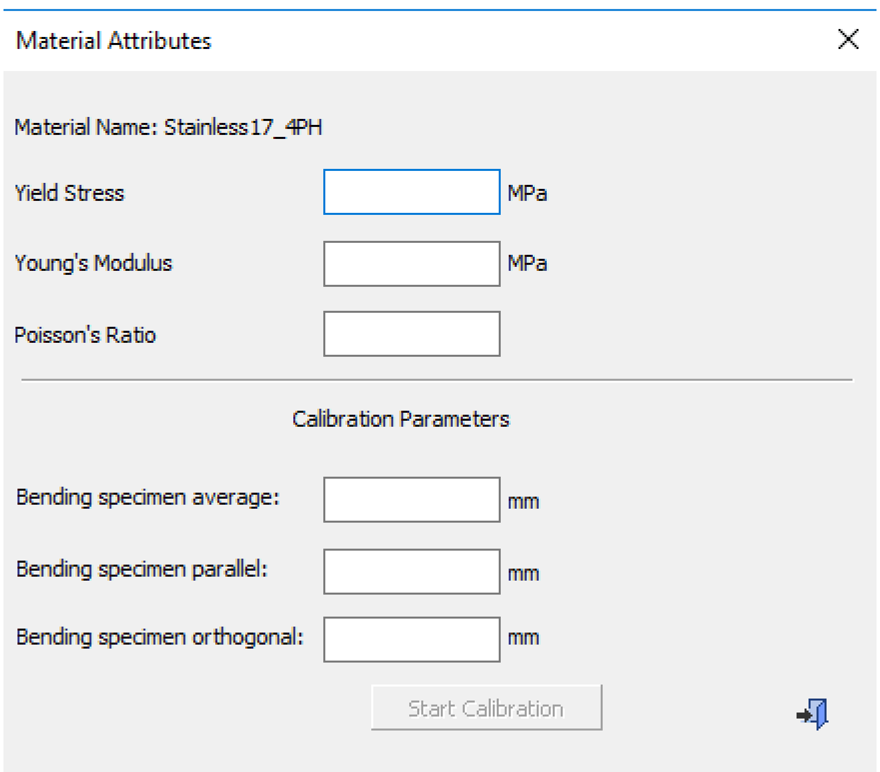
Remember:

As stated above, 3D Systems Validated LaserForm materials come with calibration data. Calibration may be required when you are using a non-validated material, or in case you wish to recalibrate the material based on local conditions.

If the material is not calibrated yet, its name will be displayed in red. From the list of materials, select the <New Material Calibration>:



The Material Attributes dialog is composed of two parts, the Material data and Calibration data.



Enter the material's theoretical values for Yield Stress, Young's Modulus and Poisson Ration. Enter the bending values, as measured on the test specimens. Most important is the Average specimen (see later in this document).

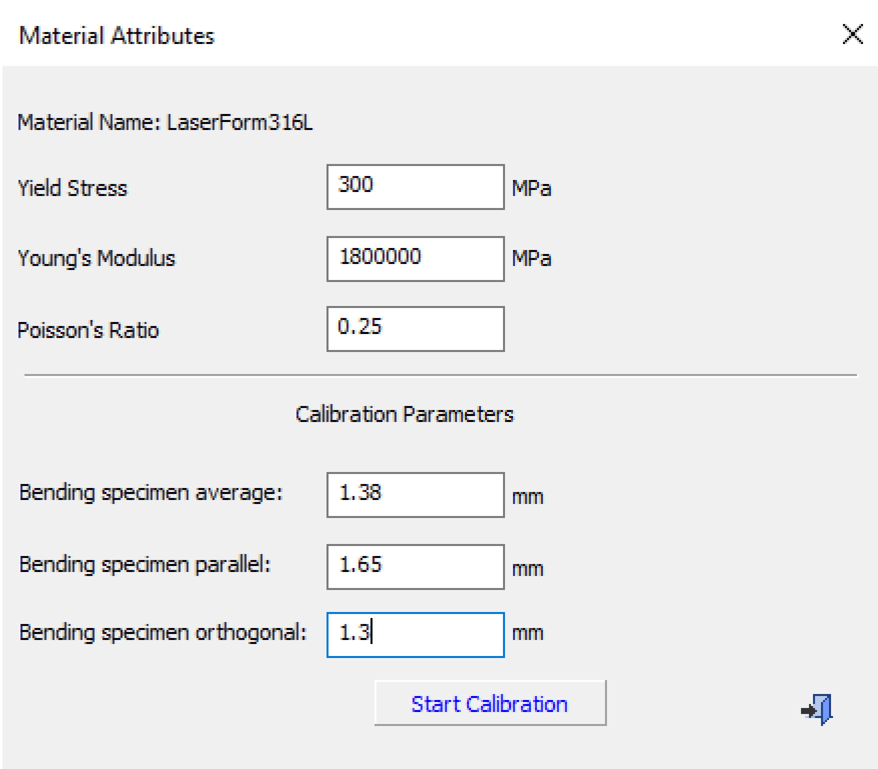
Important:

The Yield stress value is extremely important.

It should be measured on the same material that will be used in the actual build process (through a tensile test).

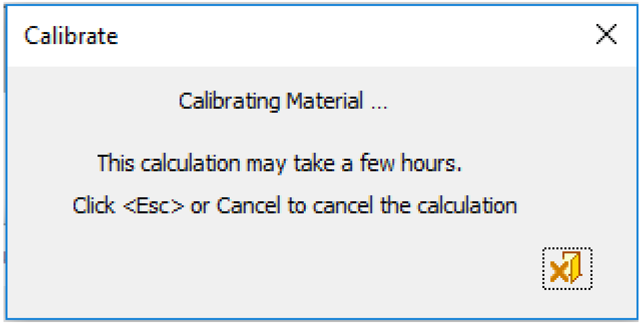
Make sure to get the correct values for the specific material, which you are using.

The following example refers to the material Stainless Steel 316L.

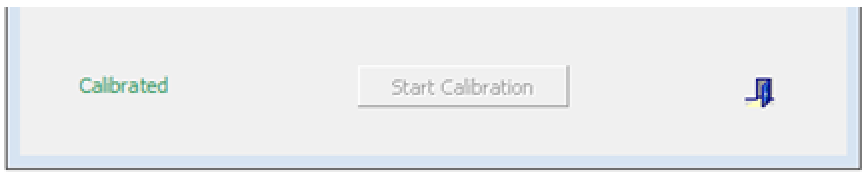


When done, press the **Start Calibration** button.

As long as the following message shows up, calibration takes place.



Wait for this to finish. At the end, the text **Calibrated** will be displayed at the bottom of the dialog.



The Calibration is complete.

A calibrated material data file (**CalibratedMaterial.dat**) has been saved to the specific material folder.

From this point onwards, the Build Simulation calculation will consider the calibration data.

Note: on Calibration Parameters

The measured bending values for the parallel and orthogonal specimen are not mandatory.

In some cases, for example when working with Aluminum, the bending values measured in the parallel and orthogonal specimens may be too high. This may even lead to calibration failure.

In such cases, enter a bending value of ‘0’ and only use the bending results from the Average test specimen.