AM COMPUTATIONAL TECH Software

Manual of the free version

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https://www.manufacture.technology

MANUAL

Software for process modeling of metals additive manufacturing

Thermomechanical simulation and simulation of microstructure

Chapters

- Introduction
- Menus and toolbars
- Example I: Simulation of DLD printed sample
- Example II: Simulation of SLM printed sample

INTRODUCTION

AM Computational Tech (ACT) is software for process modeling of metal 3D printing. This manual explains how to simulate metals 3D printing process with the free version of ACT software. The free version of ACT has some computational algorithms for thermomechanical simulation of metals 3D printing with direct laser deposition (DLD) and selective laser melting (SLM) methods. Although the free version of ACT has limitations, this is useful for teaching and research activities.

Computational features of ACT software for DLD method are:

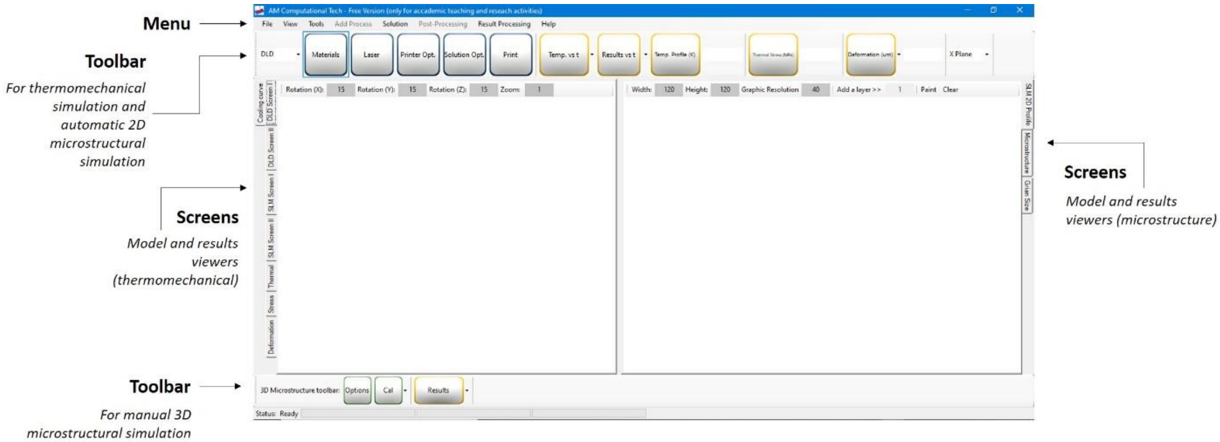
- Time-dependent thermomechanical simulation (thermal history, thermal deformation, and thermal stress)
- Extracting cooling/heating curves for any desired point of the printed sample
- 3D microstructural simulation (grain topology of solidified and heat-affected zones)
- Manual printing of simple 3D shapes
- Adjusting print parameters
- Simplifying laser heat input by a constant temperature
- Exporting results to excel
- Saving snapshots of the results

Computational features of ACT software for SLM method are:

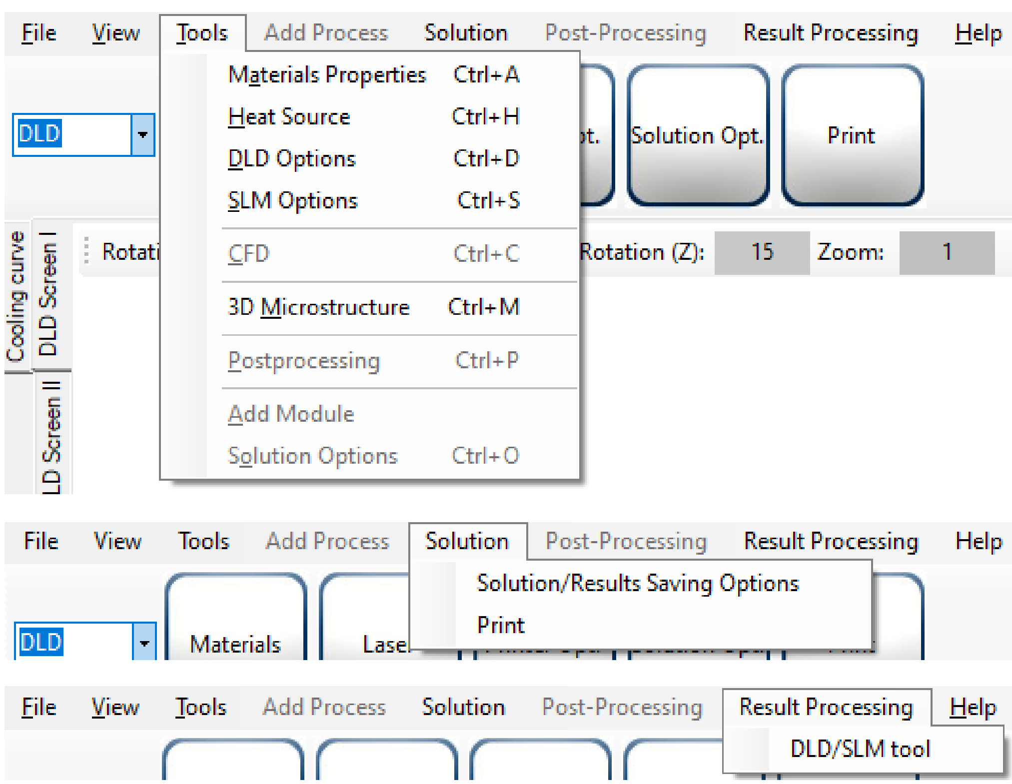
- Time-dependent thermal simulation
- Creating a 3D shape to print
- Adjusting print parameters
- Extracting cooling/heating curves for any desired point of the printed sample
- 3D microstructural simulation (grain topology of solidified and heat-affected zones)
- 2D solidified microstructure
- Predicting melt-pool shape
- Predicting the final printed sample
- Considering Gaussian function for laser heat input
- Exporting results to excel
- Saving snapshots of the results

MENUS and TOOLBARS

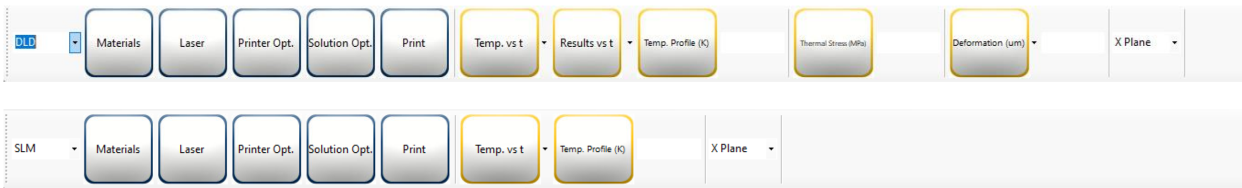
ACT software has a menu, a toolbar for thermomechanical simulation and results-postprocessing, a toolbar for manual 3D microstructure simulation, and several screens.



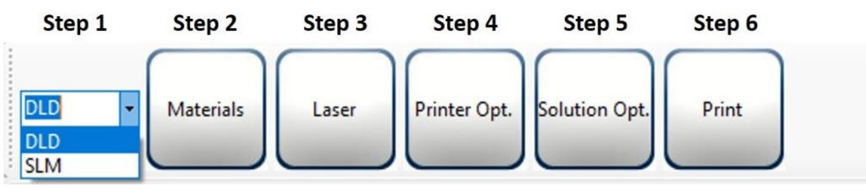
Although everything is available for simulation in the menu, toolbars are designed for easy using computational tools.



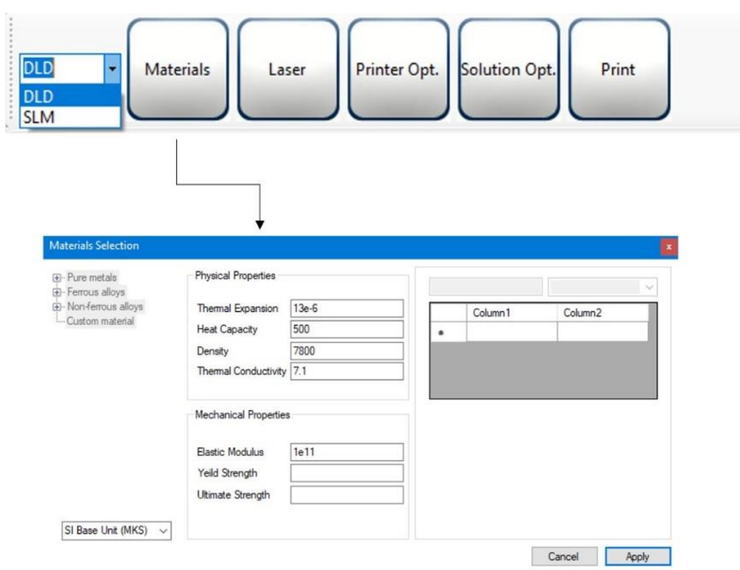
ACT has two toolbars. In the toolbar for thermomechanical simulation, you can choose the print method (DLD or SLM). For each method, different results-postprocessing tools are available.



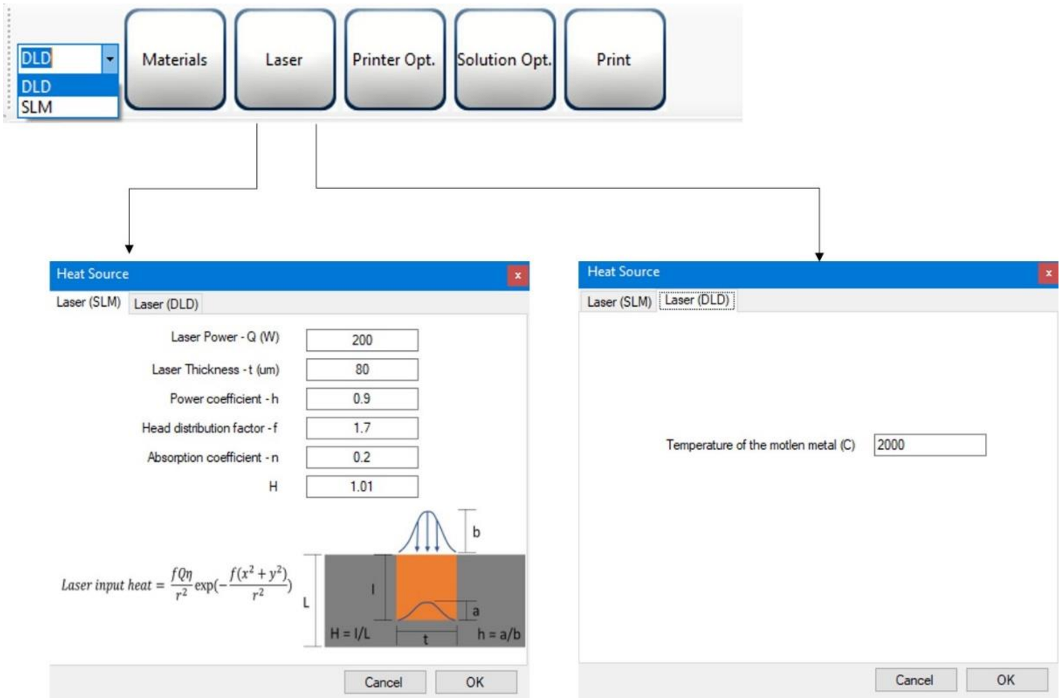
Simulation steps are straight forward with the toolbar.



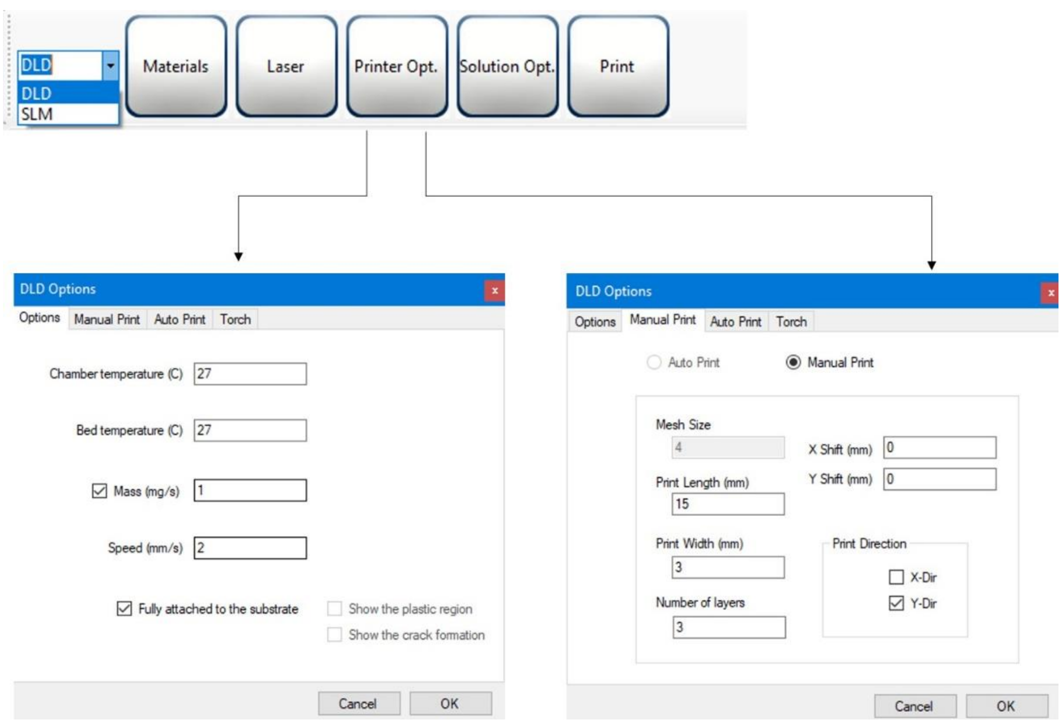
The next step is applying materials properties after selecting the print method. In the free version of ACT, only constant value for the material properties could be applied.



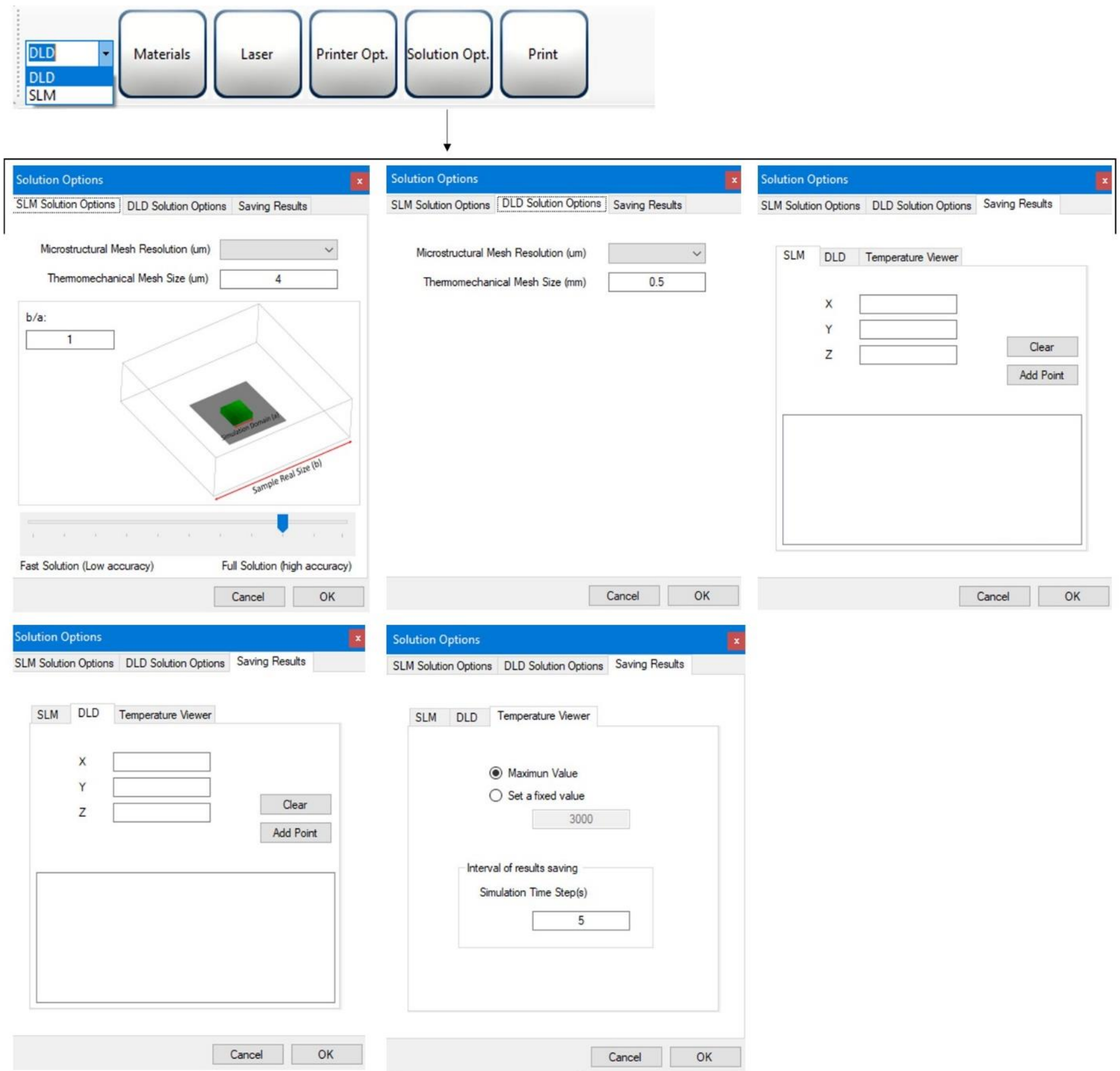
The third step is the definition of laser heat input.



The next step is the adjustment of some technical parameters for printing like chamber temperature, powder feeding rate in the DLD method, scan speed, hatch spacing, the print pattern in the SLM method, etc.

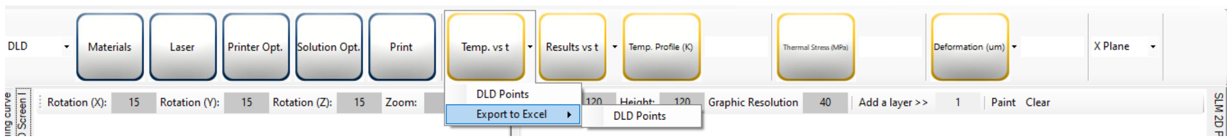


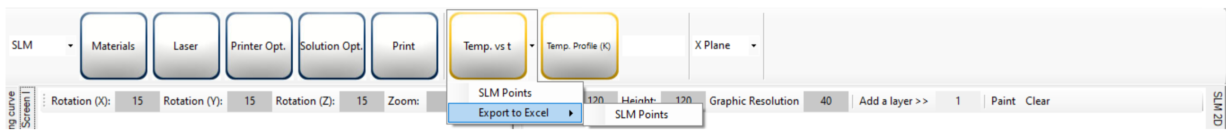
The fifth step is numerical solution options and some configurations for results-postprocessing.



The sixth/last step is a click on the print button. A simulation with ACT needs several minutes to hours, depending on the size of the model and the accuracy of the simulation.

Some results-postprocessing options are available for each of the DLD or SLM mothed to extract results versus time at any point and results from the profile at any cross-section.

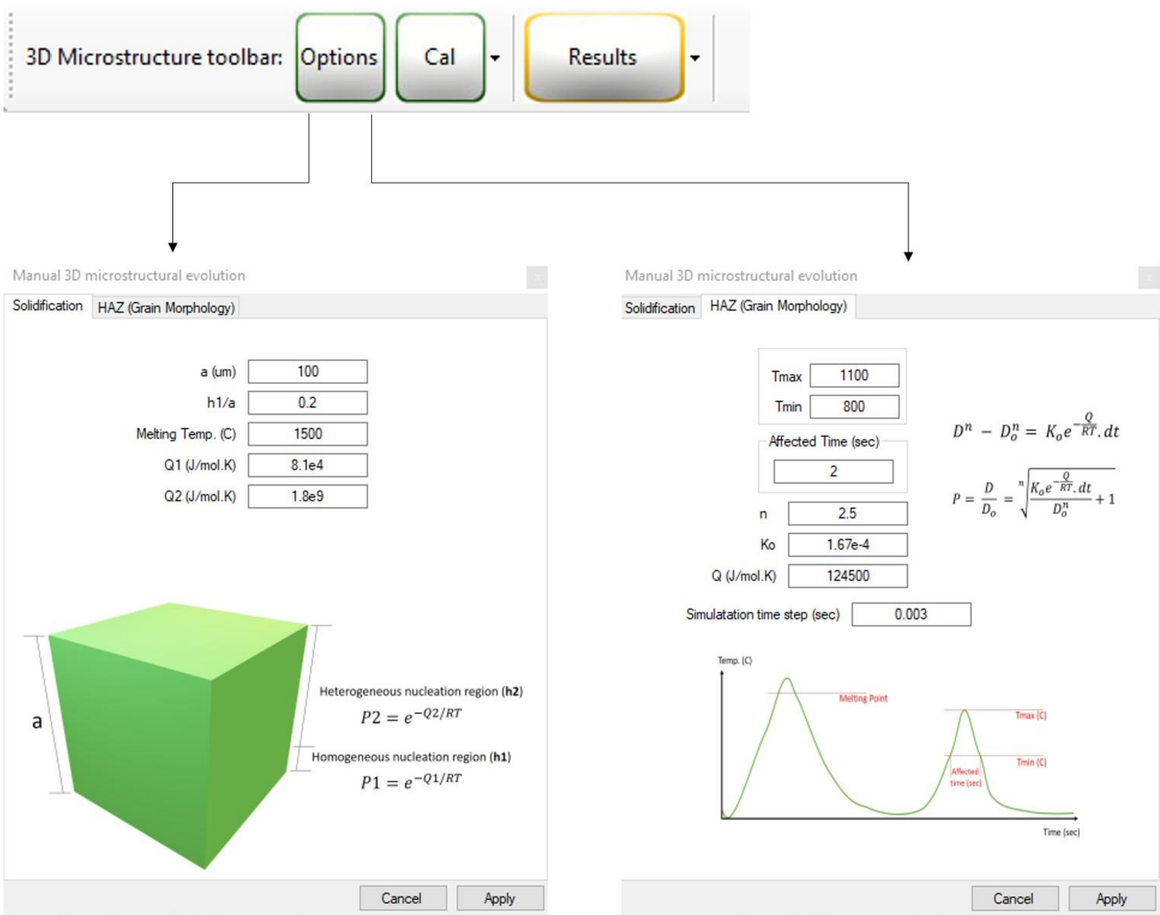


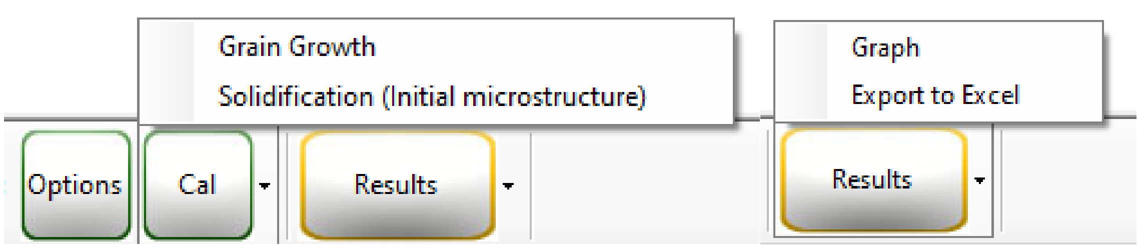


It is possible to extract results at any cross sections by selecting the ‘X Plane’ or ‘Z Plane’ and position of the cross-section from the origin.

Manual simulation of 3D grain structure is simple with its toolbar. First, the size of the simulation domain needs to be specified (a) in µm. Then, melting point and kinetics parameters must set for heterogeneous and homogeneous nucleation by considering Arrhenius forms. Then, the software is using the Cellular Automata method for microstructural simulation.

If the heating/cooling curve is available for the point selected for microstructural simulation, heat affected zone microstructure could be estimated, too.



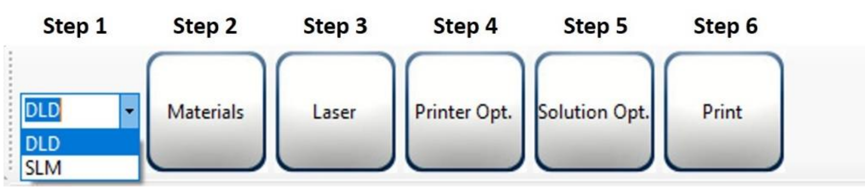


EXAMPLE I: Simulation of DLD printed sample

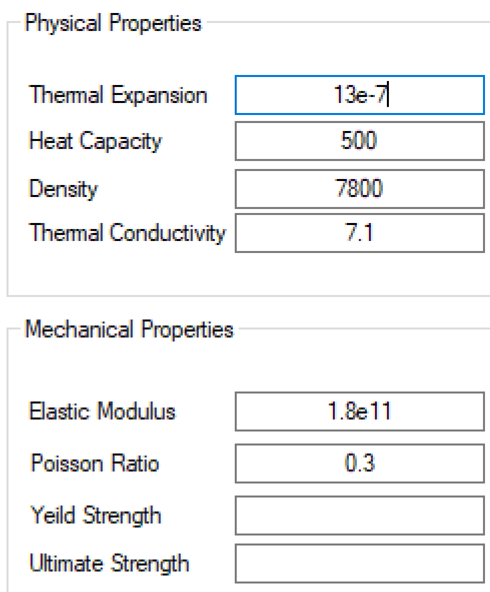
In this example, a wall will be printed with the DLD method. The thickness of the wall is 3 mm, and the length is 15 mm. The scan speed is 1 mm/s, the metal powders feeding rate is 1 mg/s, and the laser temperature is 2000 C. Print five layers on each other.

<u>Solution:</u>

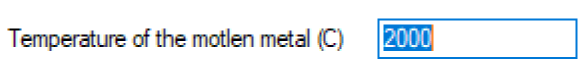
Step 1: Select DLD in the toolbar.



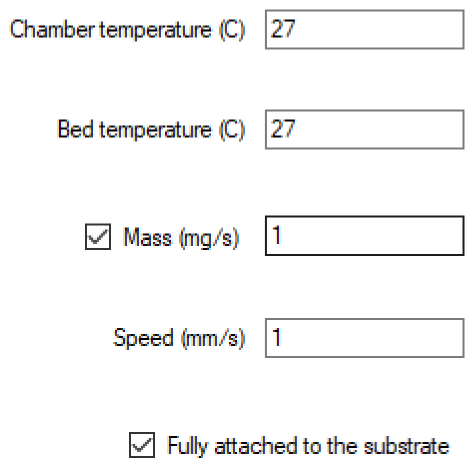
Step 2: Insert material properties.



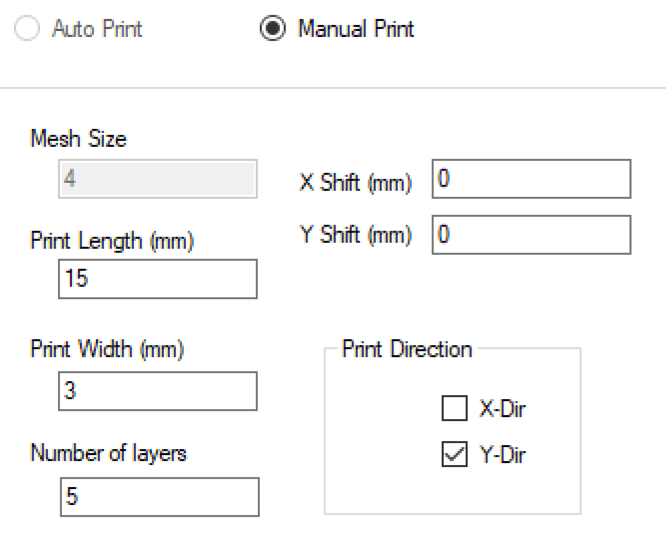
Step 3: Apply molten metal temperature received from the nozzle.



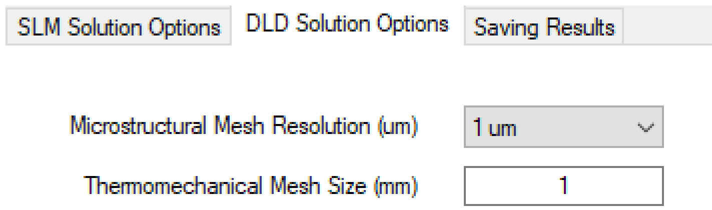
Step 4: Apply metal powders feeding rate and scan speed.



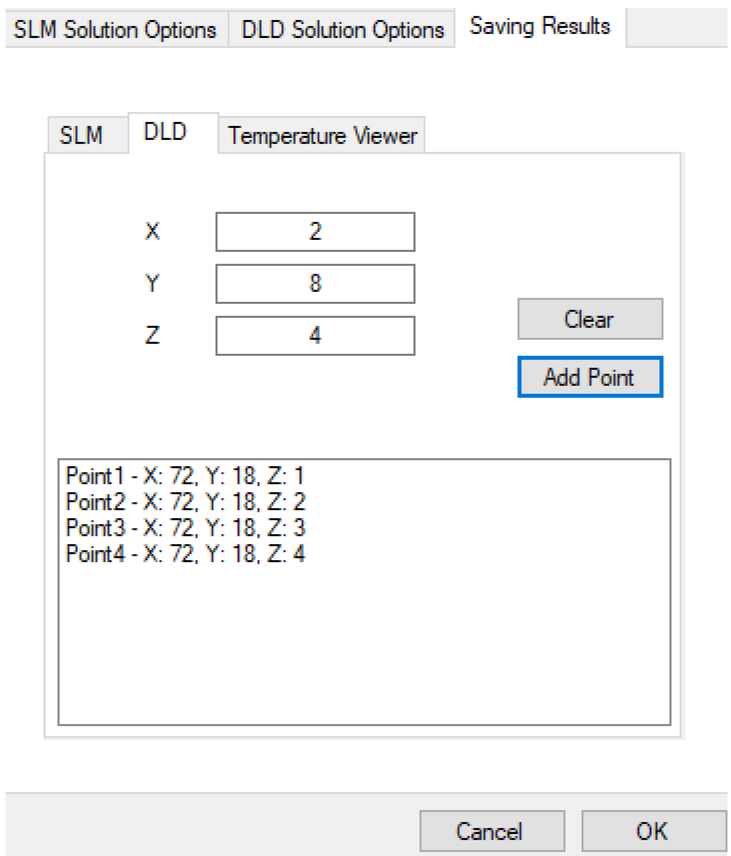
Continued Step 4: Define the number of the print layers, the print length, and width.



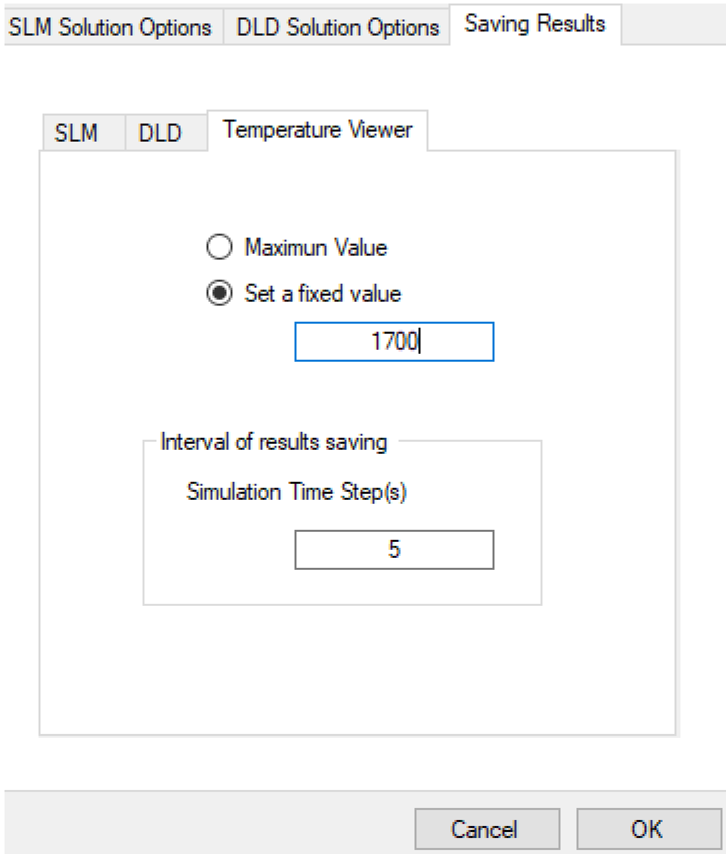
Step 5: Set the mesh size of the thermomechanical numerical simulation. Although you can select any value lower than the wall size, 1 mm is selected.



Continued Step 5: Select some points to extract results versus time.

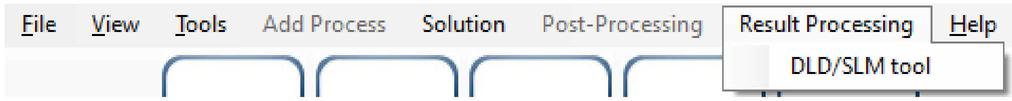


Continued Step 5: Adjust some parameters for results-postprocessing. Saving results in folder '...\Results\DLD\Thermo' for every five time-steps.

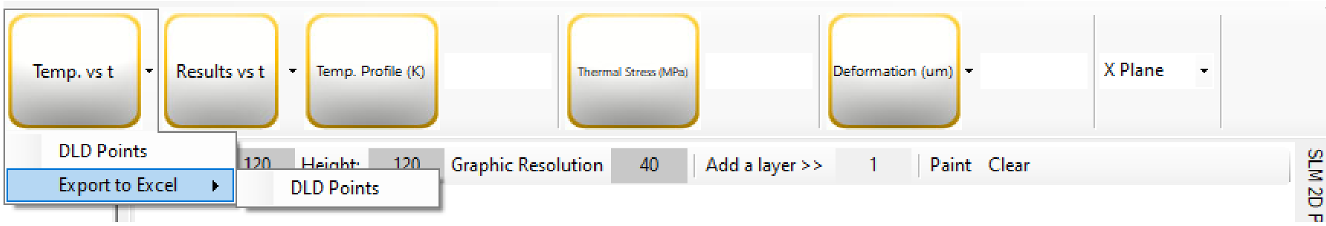


Step 6: Run simulation!

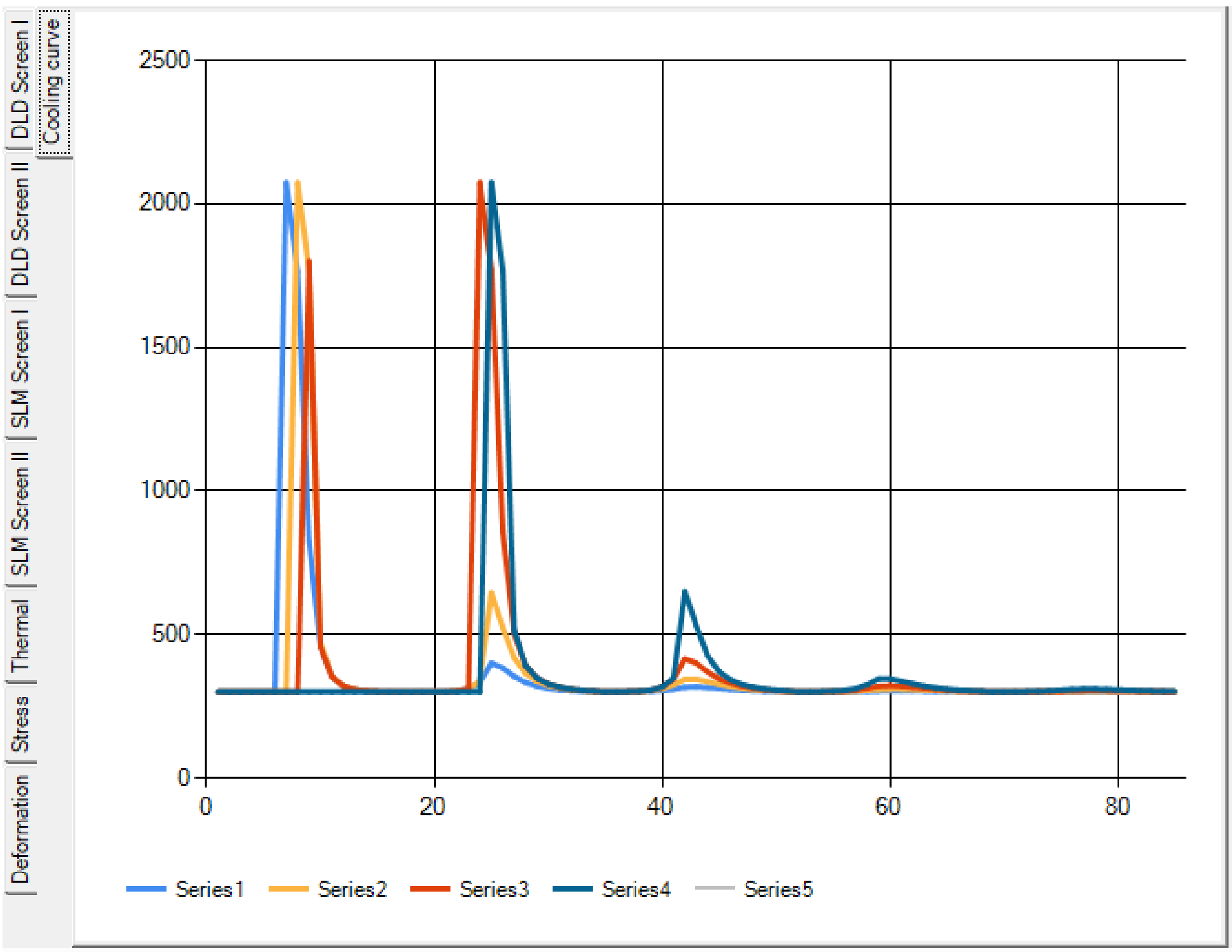
Activate results-postprocessing after solution.



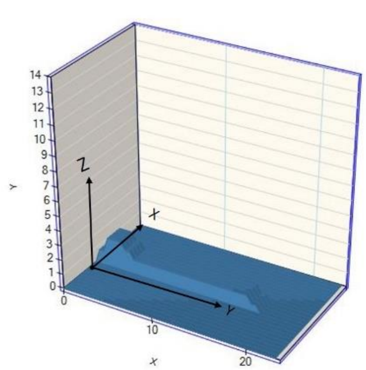
Export the results of the selected points by click on DLD Points.

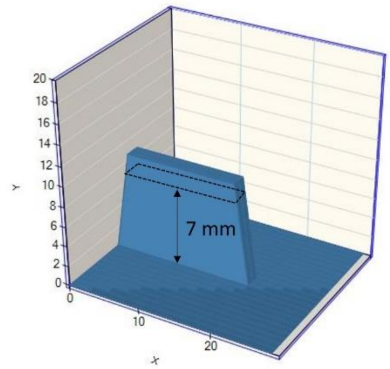


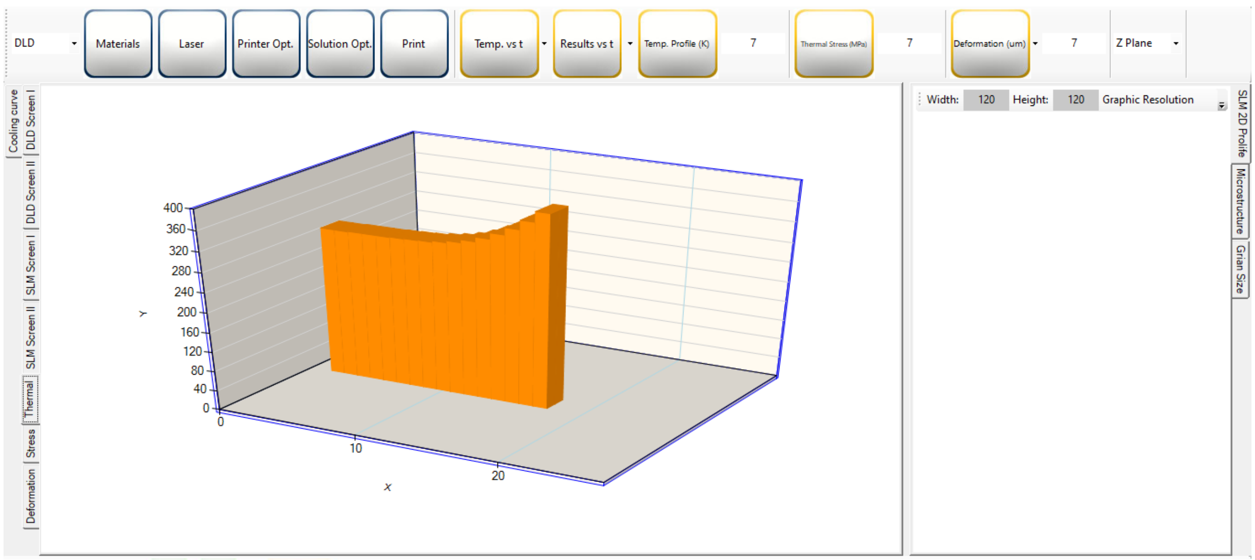
Then, results could be found in the cooling curve screen.

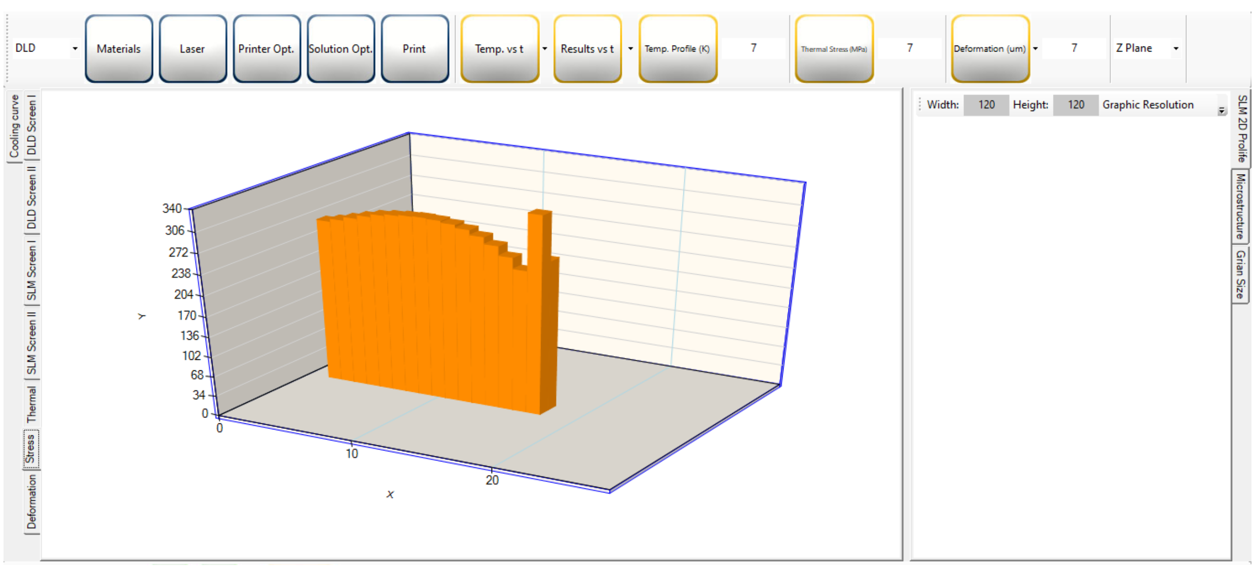


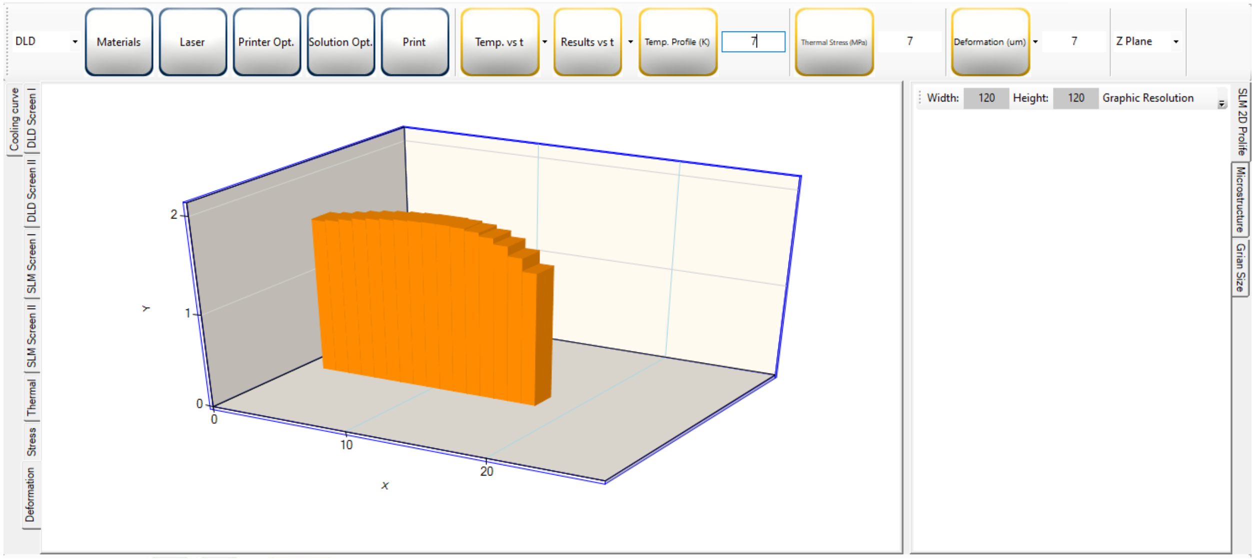
Select ‘Z Plane’ and 7 mm as an off-set to extract profiles of the last time step results (temperature, von Mises stress, and deformations). You can find the results in thermal, stress, and deformation screens.


Z
X
Y
x
y

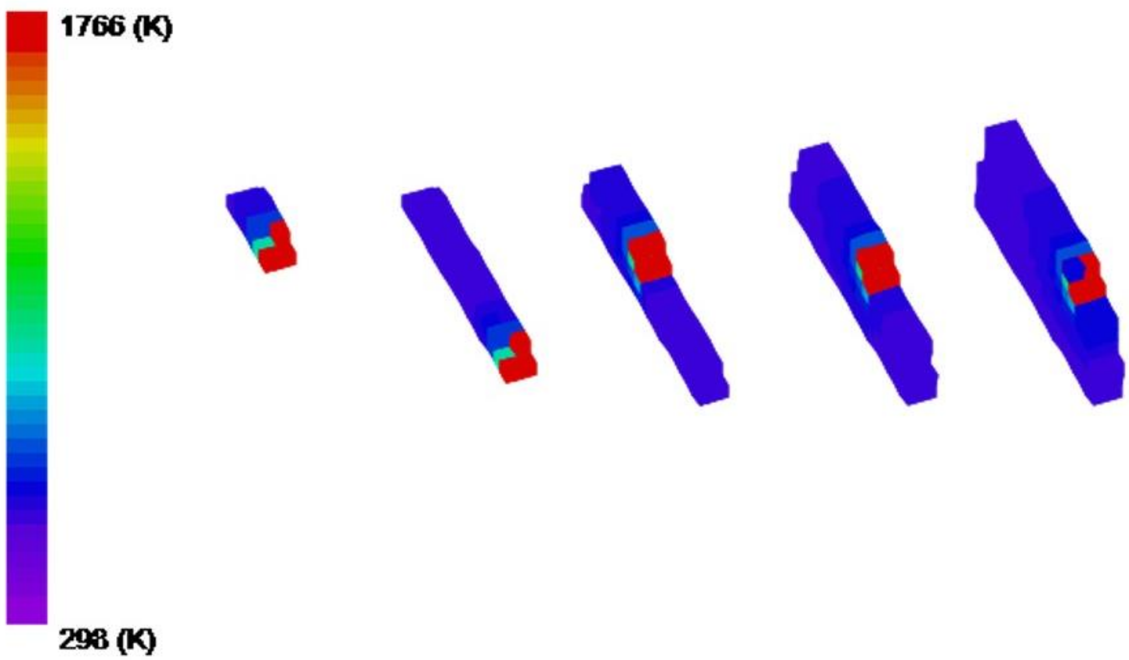

7 mm
x
y

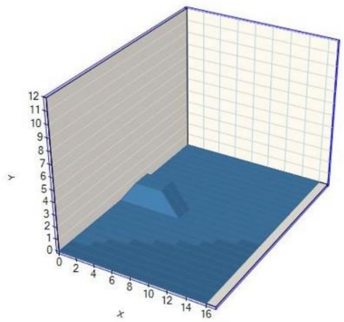

DLD
Materials
Laser
Printer Opt.
Solution Opt.
Print
Temp. vs t
Results vs t
Temp. Profile (K)
7
Deformation (um)
Z Plane
Width: 120
Height: 120
Graphic Resolution
Cooling curve
DLD Screen I
DLD Screen II
SLM Screen I
SLM Screen II
Thermal
Stress
Deformation
SLM 2D Profile
Microstructure
Grian Size

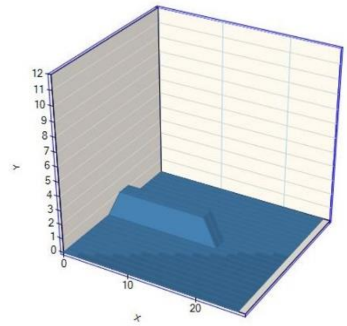

DLD
Materials
Laser
Printer Opt.
Solution Opt.
Print
Temp. vs t
Results vs t
Temp. Profile (K)
7
Deformation (um)
Z Plane
Width: 120
Height: 120
Graphic Resolution
Cooling curve
DLD Screen I
DLD Screen II
SLM Screen I
SLM Screen II
Thermal
Stress
Deformation
SLM 2D Profile
Microstructure
Grian Size

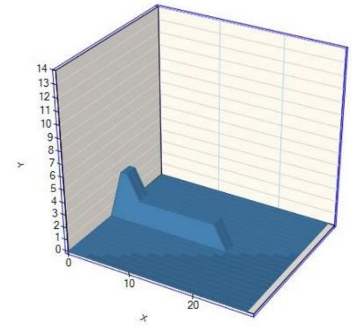


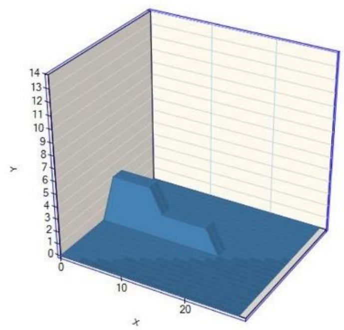
Some snapshots could also be found in '...\Results\DLD\Thermo'.

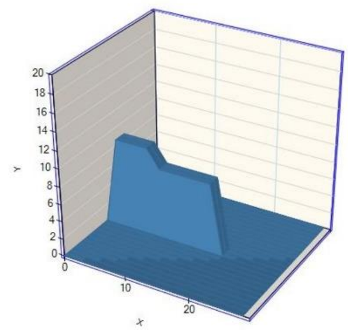


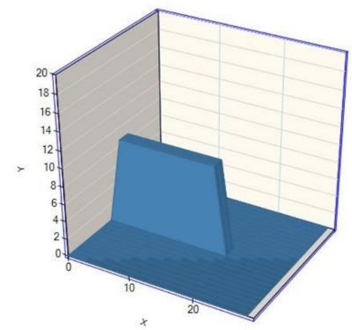

Y
0 1 2 3 4 5 6 7 8 9 10 11 12
x
0 2 4 6 8 10 12 14 16


Y
0 1 2 3 4 5 6 7 8 9 10 11 12
x
0 10 20


Y
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
x
0 10 20


Y
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
x
0 10 20


Y
0 2 4 6 8 10 12 14 16 18 20
x
0 10 20

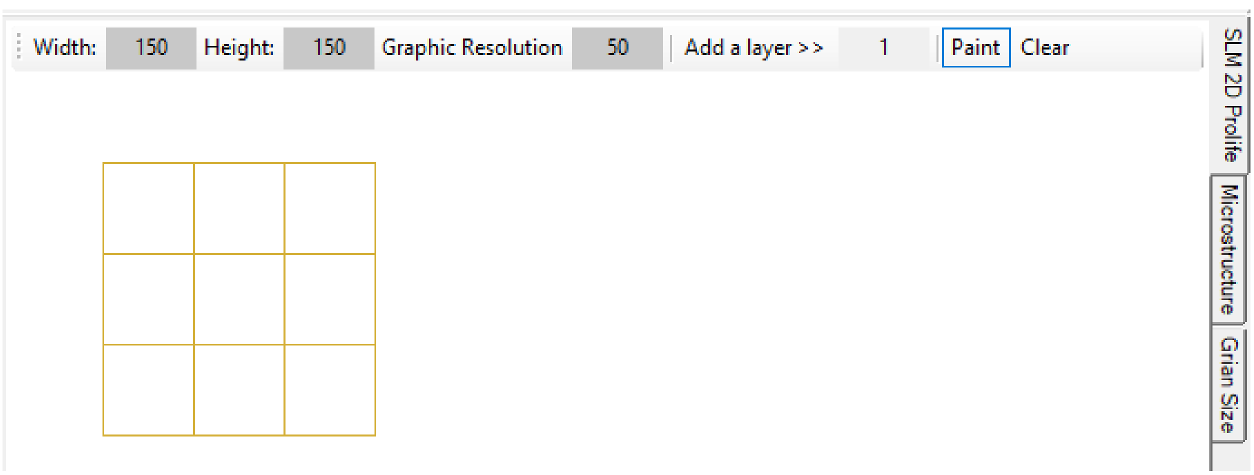

Y
0 2 4 6 8 10 12 14 16 18 20
x
0 10 20

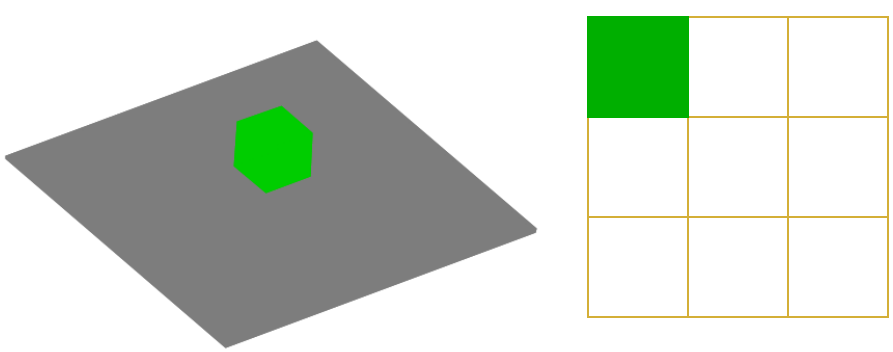
EXAMPLE II: Simulation of SLM printed sample

In this example, a cube will be printed with the SLM method. The size of the cube is 150 µm by 100 µm by 100 µm. The scan speed is 1250 mm/s. The laser thickness is 80 µm, and the powder layer is 30 µm. The hatch spacing is 50 µm, and the laser power is 200 W.

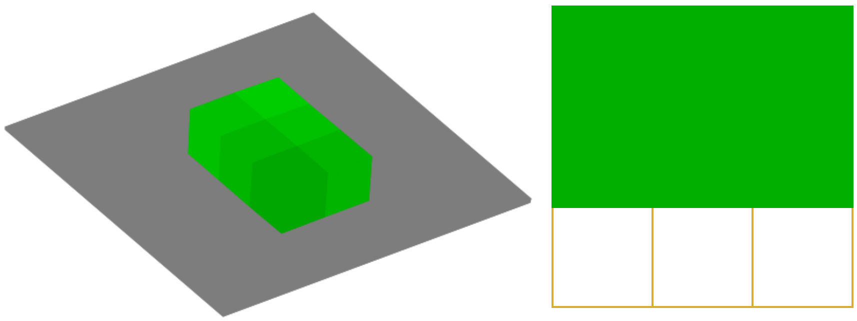
<u>Solution:</u>

First, create a model by drawing a grid with 150 µm width and 150 µm height. Different values could be selected for the resolution, but 50 µm is selected. The size of the graphic resolution will not affect the computational results. Click on 'Paint' when you input all the values of width, height, and graphic resolution to see the grid. If you click in each of the small squares of the grid, you will select it and create a cube 50 µm by 50 µm by 50 µm in the 3D view (SLM Screen I).



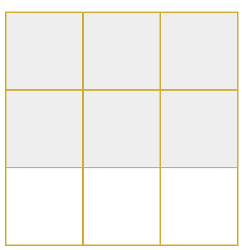


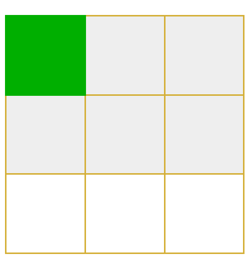
Continue selecting squares to create the first layer (150 µm by 100 µm by 50 µm).



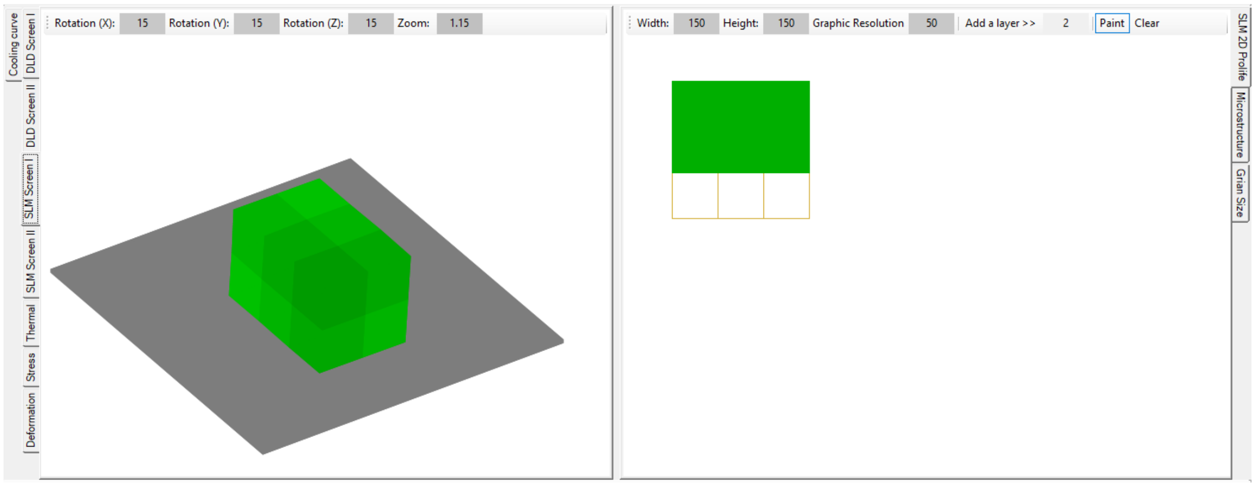
Click on ‘Add a layer’ to add a new layer on the previous one.

In the 2D graphic, the green color would be changed to light gray. Click on the gray ones to create the second layer.

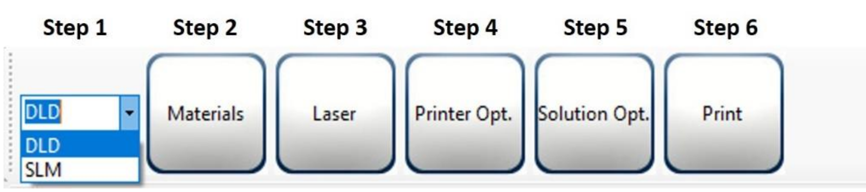




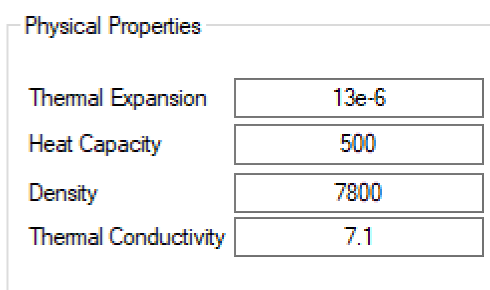
Finally, there is a cube with 150 µm by 100 µm by 100 µm size for simulation.



Step 1, select DLD in the toolbar.



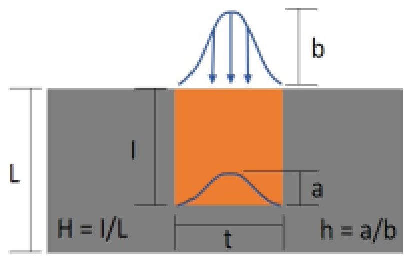
Step 2: Insert material properties.



Step 3: Apply the laser parameters.

Laser Power - Q (W)	200
Laser Thickness - t (um)	80
Power coefficient - h	0.9
Head distribution factor - f	1.7
Absorption coefficient - n	0.2
H	1.01

$$Laser\ input\ heat = \frac{fQ\eta}{r^2}\exp(-\frac{f(x^2+y^2)}{r^2})$$

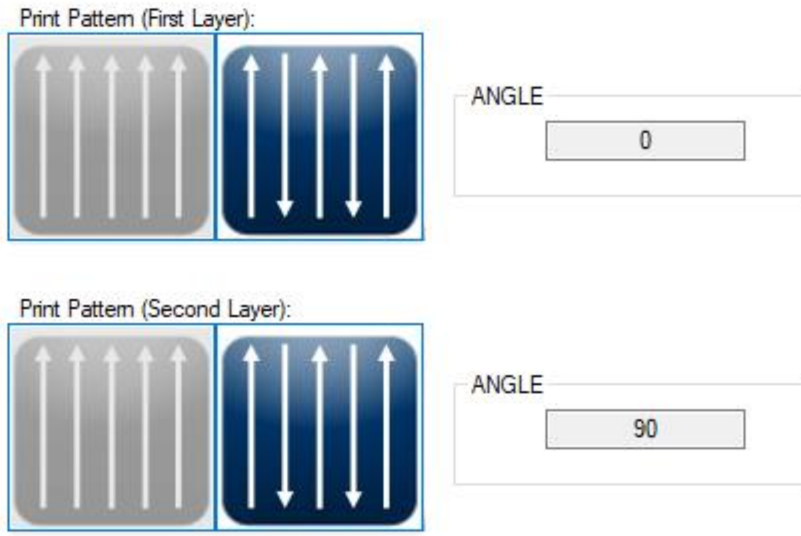


Step 4: Input the powder layer thickness, scan speed, and hatch spacing.

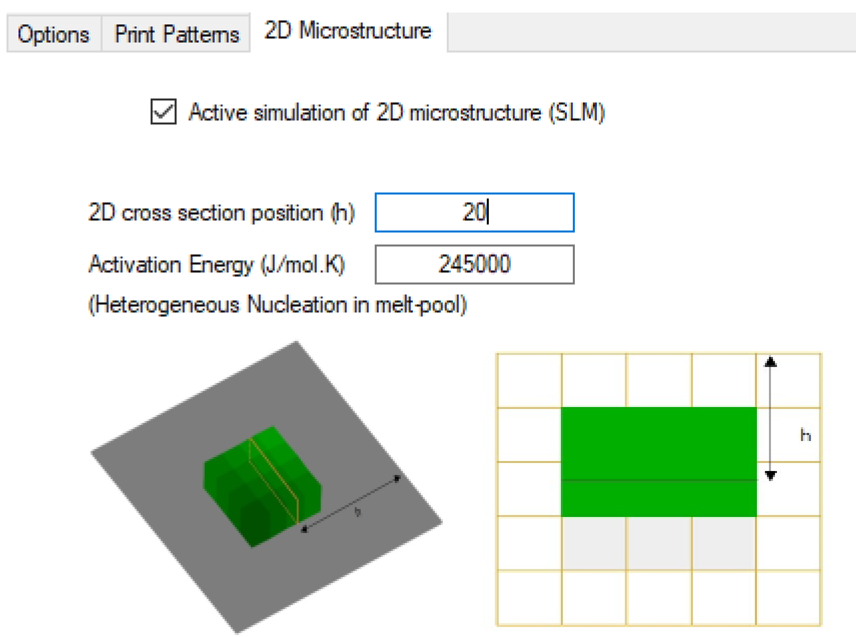
Chamber temperature (C)	27
Bed temperature (C)	27
Powder Layer Thickness (um)	30
Speed (mm/s)	1250
Hatch spacing (um)	50

☑ Fully attached to the substrate

Continued Step 4: Select a print pattern (Only a print pattern is available in the free version of ACT).

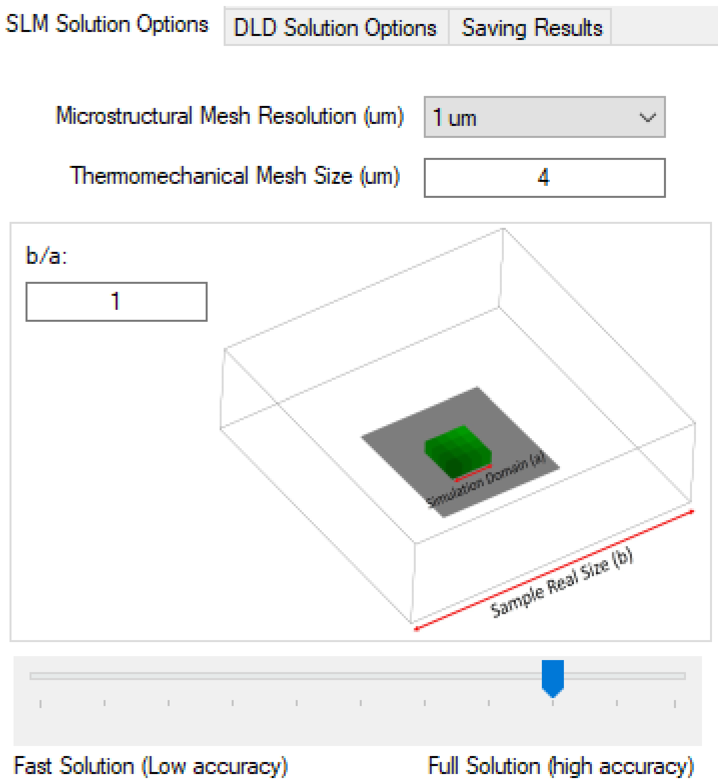


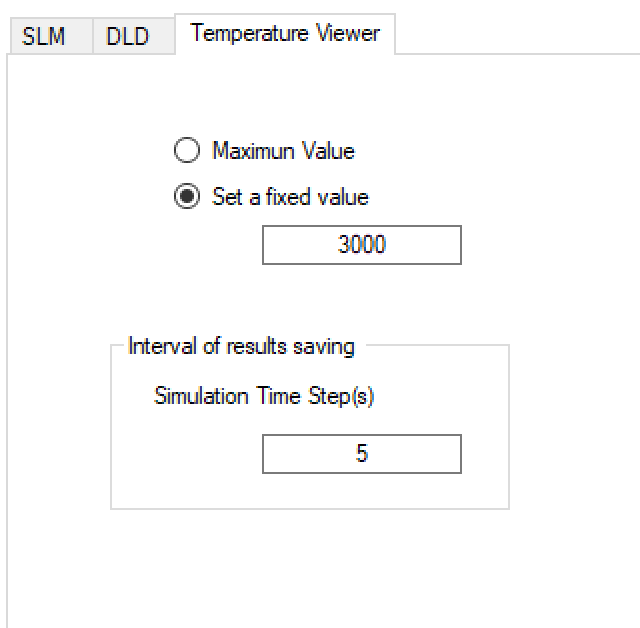
Continued Step 4: Select a cross-section to see the estimated melt pool shape and depth.



Step 5: Set the mesh size of the thermomechanical numerical simulation. Although you can select any value, 4 µm is selected.

Suppose the cube is the whole sample, input 1 for b/a parameter. If the sample is part of the real sample, you need to input another value for b/a.

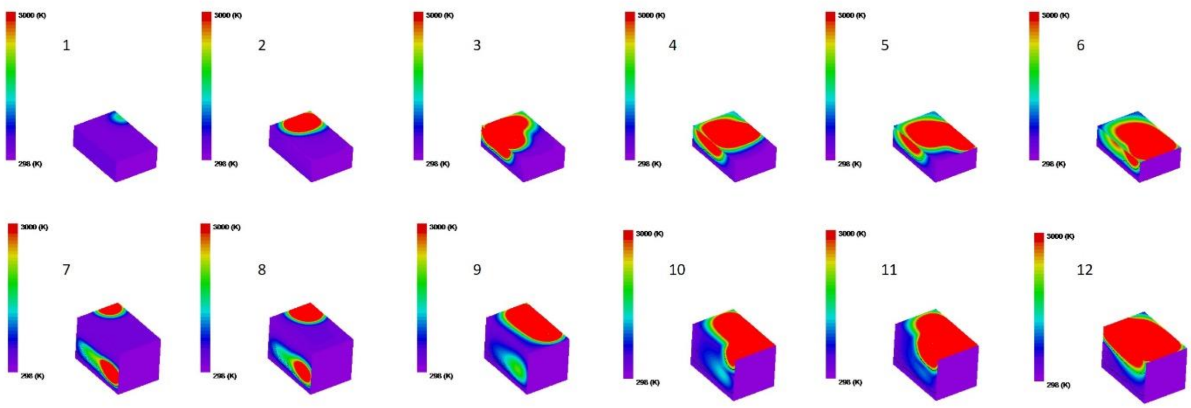




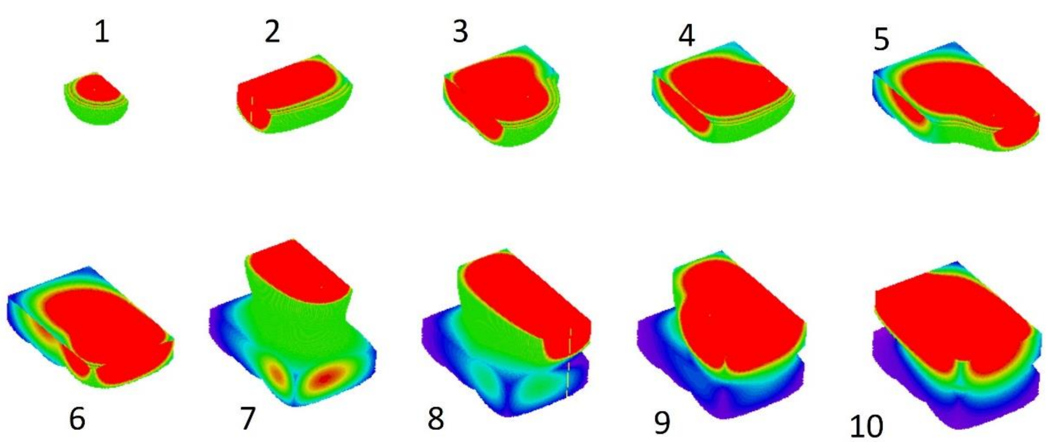
Step 6: Run simulation!

Activate results-postprocessing after solution.

Check the folder '...\Results\SLM\Thermo' for thermal results snapshots.



Check the folder '...\Results\SLM\ Micro' for 3D melt-pool shape and solidified shape.



Check the folder '...\Results\SLM\ Micro' for 2D melt-pool shape at the cross-section.