HEI MAKERS

LESSON #2
3D PRINTING PROCESS PARAMETERS

Technical creativity in 3D printing module

Co-funded by the Erasmus+ Programme of the European Union
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OUTLINE OF THE LESSON #2

- Topic 2.1. 3D Printing orientation
- Topic 2.2 Process parameters in 3D Printing
- Further learning
- Hands-on activities
- Tasks for reflection

2.1. 3D PRINTING PART ORIENTATION

- In this lesson you will learn how 3D printing (3DP) orientation impacts part accuracy, mechanical properties, time and cost, etc.
- Expected learning outcomes: being able to optimize 3DP prints orientation relative to given criteria.

Duration	1 academic hrs
Author / Lecturer	Diana Popescu, UPB CAMIS
Delivery methods	Individual / Teamwork / P2P
Evaluation methods	Test / Report / Feedback / Exam etc.

3D PRINTING PART ORIENTATION (1/10)

- Choosing the parts' optimal orientation is a fundamental problem for 3DP. It is significantly influencing:
  - Surface quality
  - Dimensional and form accuracy
  - Mechanical properties
  - Building time and cost
  - Positions and volumes of support structures

3D PRINTING PART ORIENTATION (2/10)

- 3D parts orientation on the building platform is set using 3D software. Further examples will refer to the open source Ultimaker Cura (https://ultimaker.com/en/products/ultimaker-cura-software)

Ultimaker Cura software

Ultimaker Cura prepares your model for 3D printing. Optimized, expert-tested profiles for 3D printers and materials mean you can start printing reliably in no time. And with industry-standard software integration, you can streamline your workflow for maximum efficiency.

Windows
Ultimaker Cura 3.6
(64 bit)

Download for free

Download Ultimaker Cura 4.0 (beta)

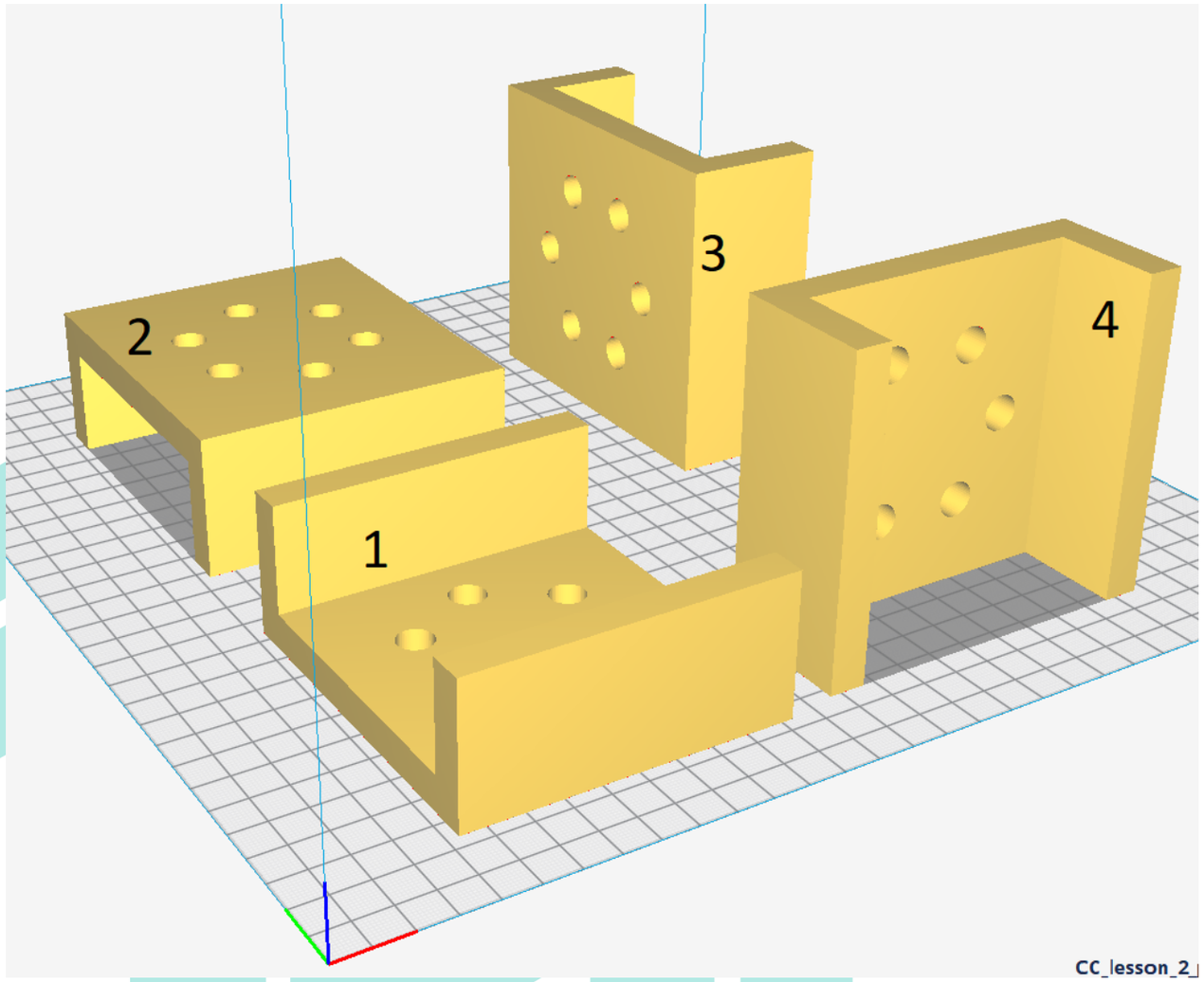
View the Ultimaker Cura manual

View all versions

Release notes

3D PRINTING PART ORIENTATION (3/10)

- For some parts, 3DP orientation is obvious – 1 (on blue you can see the support structure).



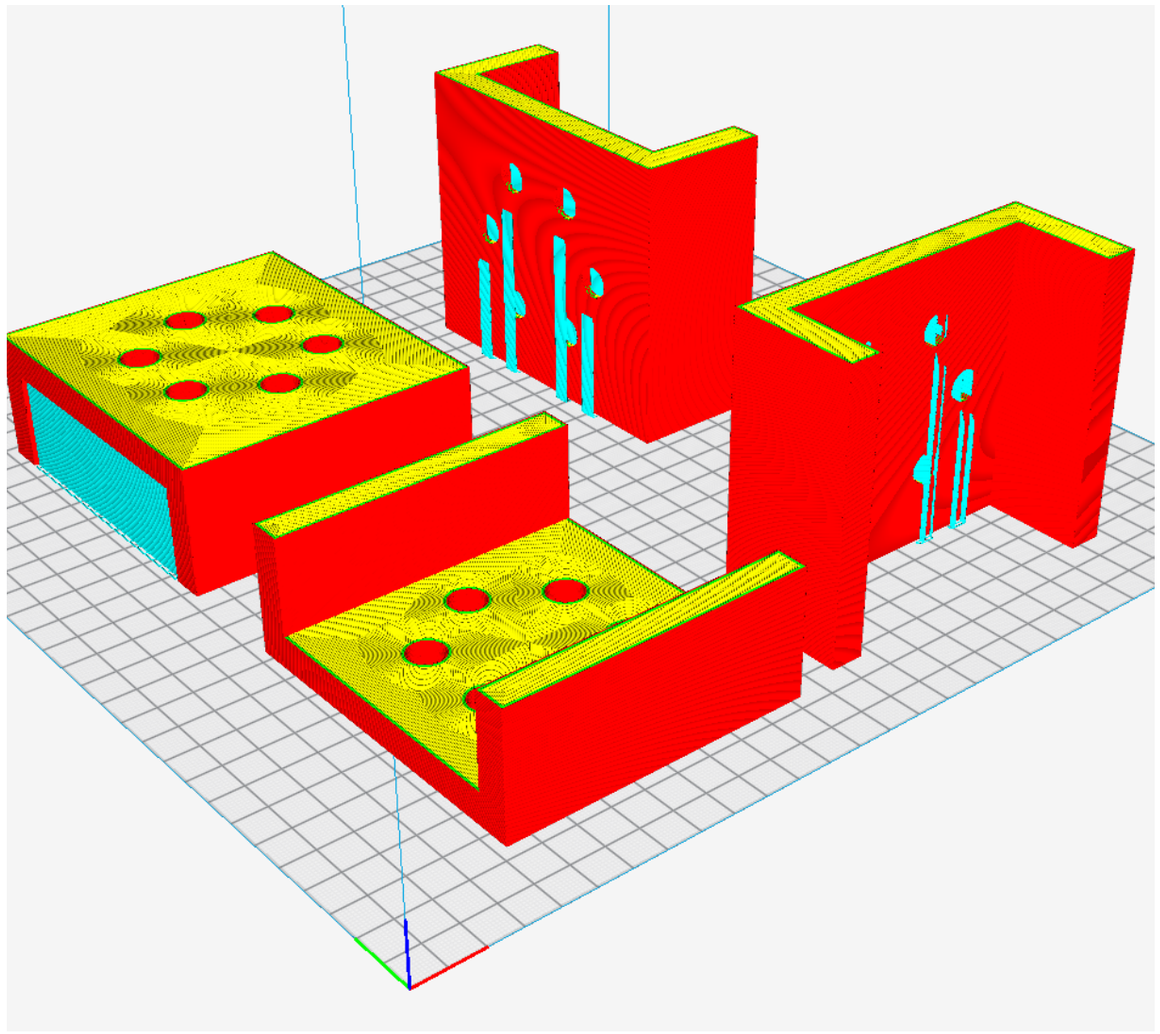


Figure 2.1.1. Possible 3DP part orientation

3D PRINTING PART ORIENTATION (4/10)

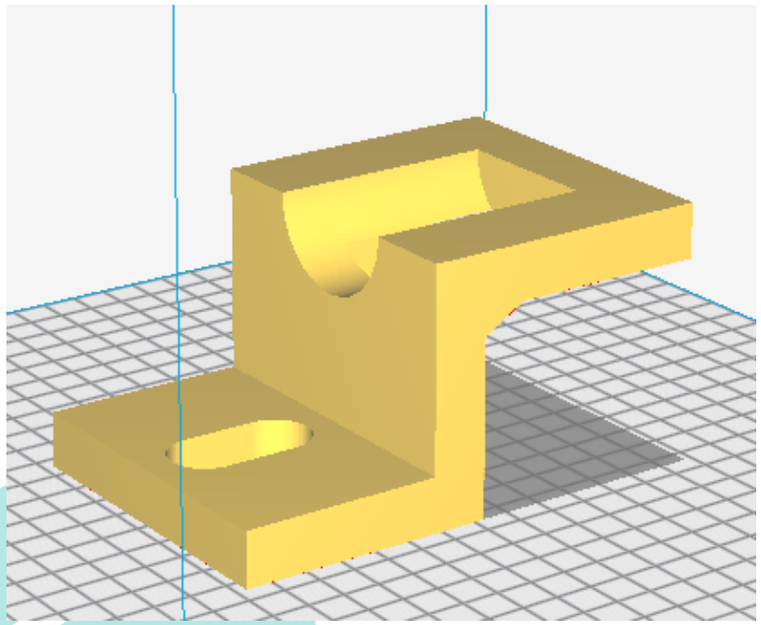
- However, for parts with complicate design, 3DP orientation is difficult to set. In these cases, some rules based on users' experience, scientific measurements and tests can be applied.

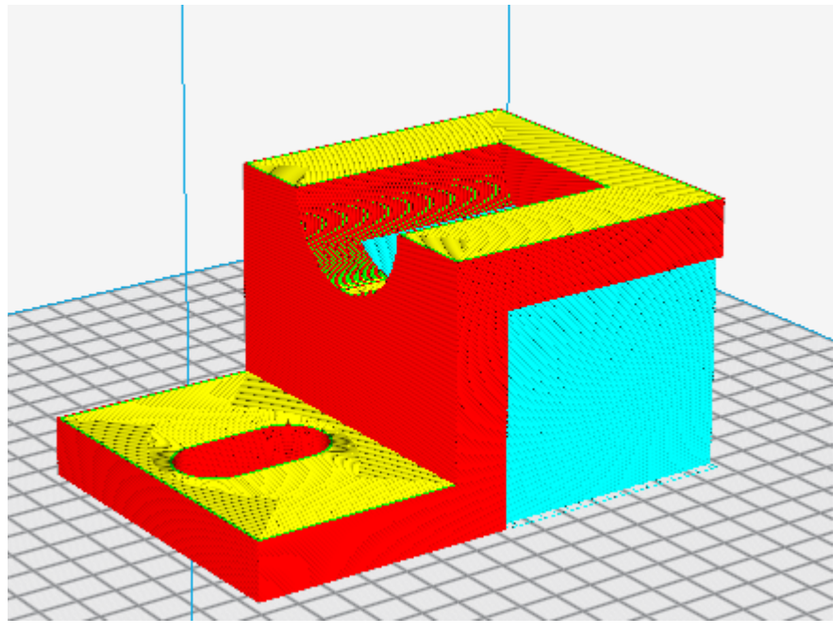
- Software, such as Autodesk Meshmixer, can also support the user in establishing building orientation based on selected criteria.

- Text, small features or geometric details might not be 3D printed correctly or 3D printed at all in some orientations, but to they might appear by reorienting the part.

3D PRINTING PART ORIENTATION (5/10)

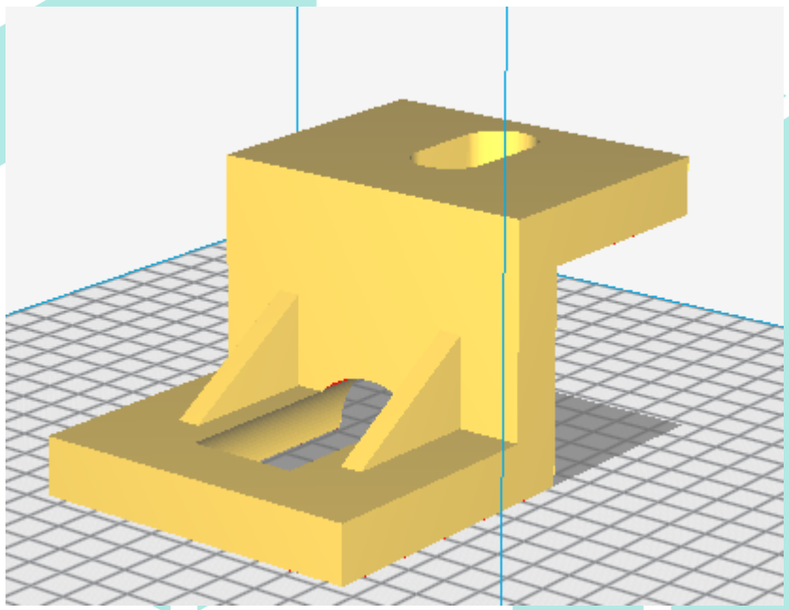
- Examples of build orientation estimations in print time and material consumption.

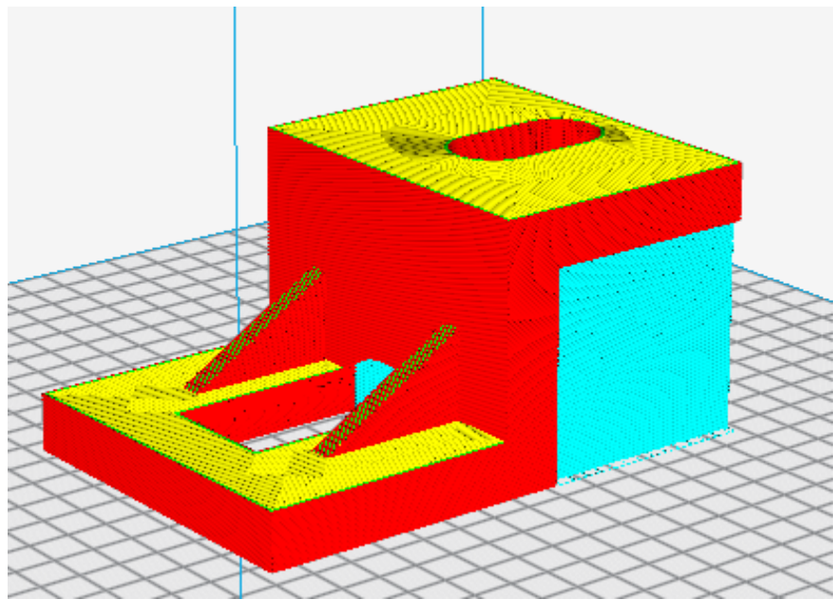




Orientation 1

- Print time=5h51min
- 27.83m of filament





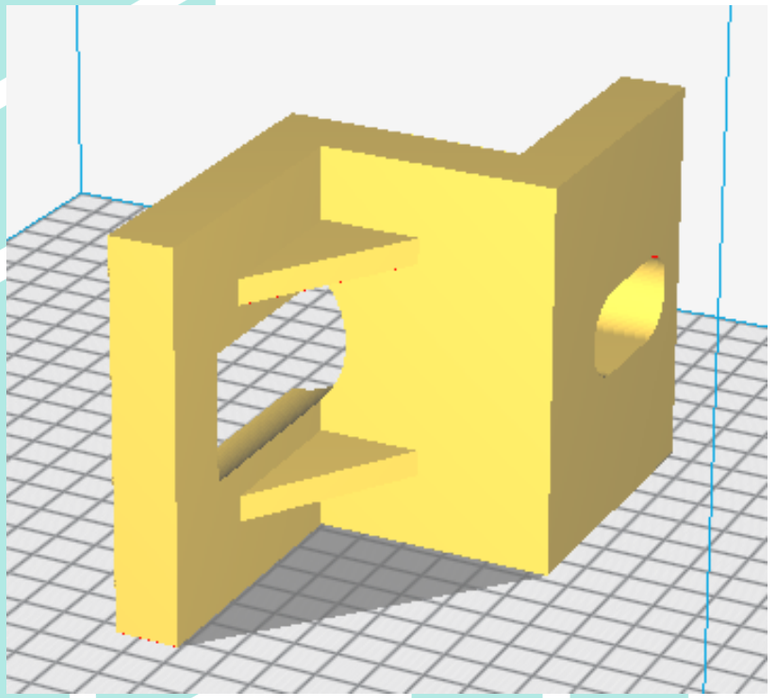
Orientation 2

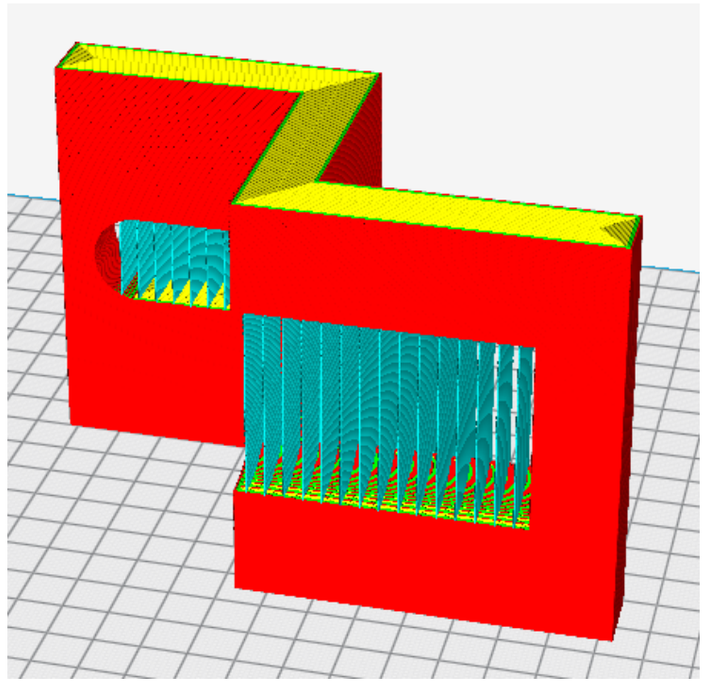
- Print time=5h59min
- 28.42m of filament

3D PRINTING PART ORIENTATION (6/10)

- There is no significant difference between orientations O1 and O2 in terms of the mentioned criteria (time and filament consumption).

- Considering orientation 3, it better satisfies these criteria. However, it has negative influence over the part' holes accuracy.





Orientation 3

- Print time=5h09min
- 22.61m of filament

3D PRINTING PART ORIENTATION (7/10)

Some orientation rules

- Holes and cylindrical features should be oriented in vertical position for obtaining better shape and dimensional accuracy and better surface finishing.

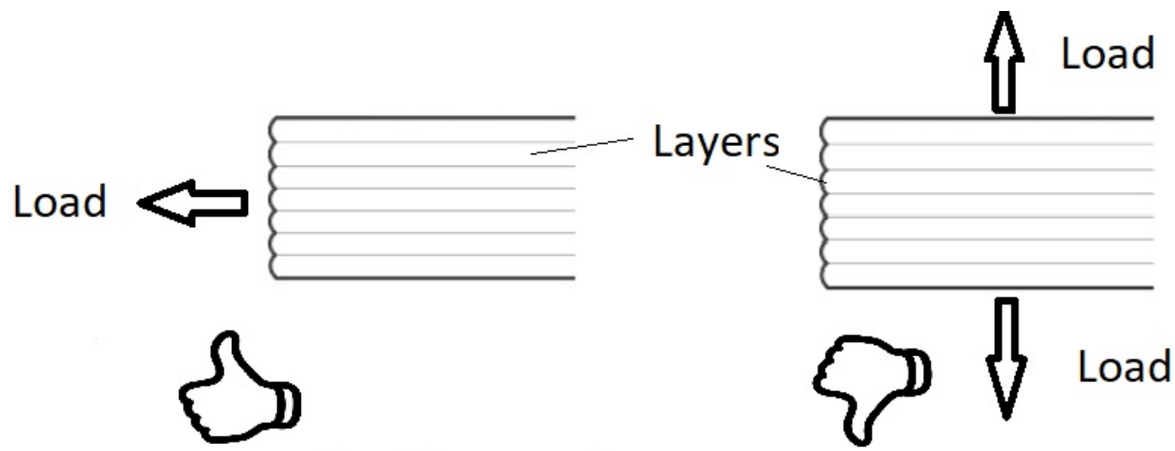
- Orient parts so that large surfaces to be on xy plane for saving money and time, but be aware of the warping effect.

Warping

3D PRINTING PART ORIENTATION (8/10)

Some orientation Rules

- As 3D prints are anisotropic, orientation affects their mechanical properties.
- Inter-roads adhesion is stronger than inter-layer adhesion.



Tensile strengh
Load along layers vs. load normal to layers

3D PRINTING PART ORIENTATION (9/10)

Some orientation Rules

- Avoid overhangs – be aware of the 45 degrees rule.

- Dimensional accuracy is better in x-y plane than in z plane, therefore parts important surfaces must be oriented accordingly.

3D PRINTING PART ORIENTATION (10/10)

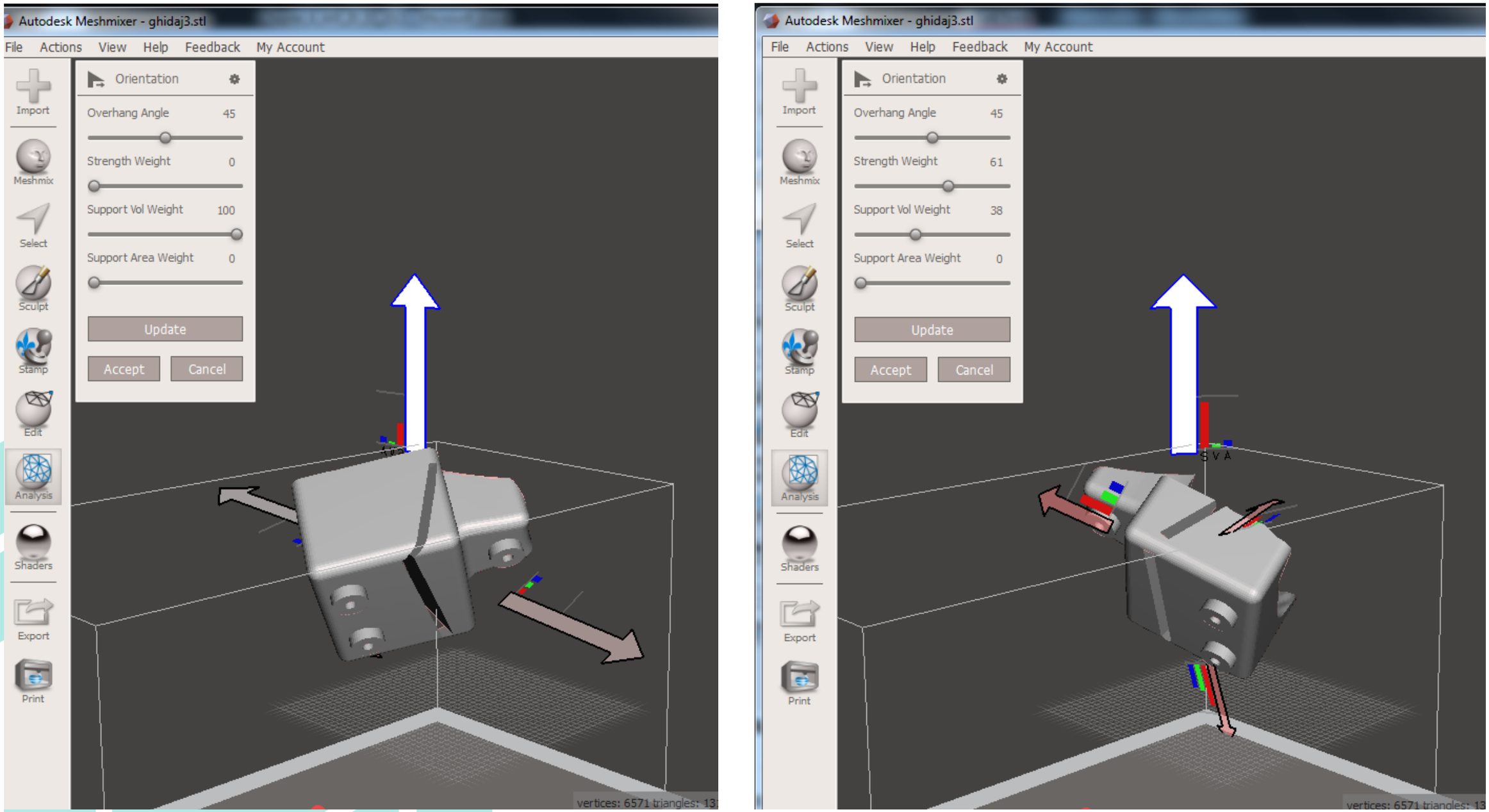


Figure 2.1.2. Optimizing part's orientation in Meshmixer

FURTHER LEARNING

Optimizing part orientation
http://www.cimetrixsolutions.com/blog/2016/02/optimizing-part-orientation-for-surface-finish-strength-and-build-time

3D printing best practice
https://help.grabcad.com/article/205-3d-printing-best-practices?locale=en

Starters guide to 3D printing
https://www.3dprintingsolutions.com.au/News/Australia/starters-guide-to-3d-printing-orientation

3D printing tips and tricks
https://3dprinting.eng.unimelb.edu.au/pdf/3D-printing-tips-and-tricks.pdf

3D PRINTING PART ORIENTATION HANDS-ON

- Hands-on session:
  - 3D model a part using a 3D CAD software and save it as STL file or download directly a STL file from an online repository such as Thingiverse (www.thingiverse.com)
  - Open the STL file in Cura and oriented so that to respond in turn to the following criteria:
    - Minimize the printing time
    - Minimize the support structure
    - Ensure good surface quality to cylindrical features (if any)

    Note: use the default 3D printing parameter settings in Cura

2.2. 3D PRINTING PROCESS PARAMETERS

- In this lesson you will learn about 3D Printing (3DP) process parameters.
- Expected learning outcomes: being able to identify and set process parameters in 3DP printing software.

Duration	2 academic hrs
Author / Lecturer	Diana Popescu, UPB CAMIS
Delivery methods	Individual / Teamwork / P2P
Evaluation methods	Test / Report / Feedback / Exam etc.

3D PRINTING PROCESS PARAMETERS (1/18)

- 3D Printing process parameters can be broadly categorized as such:
  - Slicing parameters (e.g. layer thickness);
  - Temperatures – environment (or envelope) temperature, extrusion temperature, bed or platform temperature.
  - Speeds (wall speed, infill speed, travel speed etc.)

3D PRINTING PROCESS PARAMETERS (2/18)

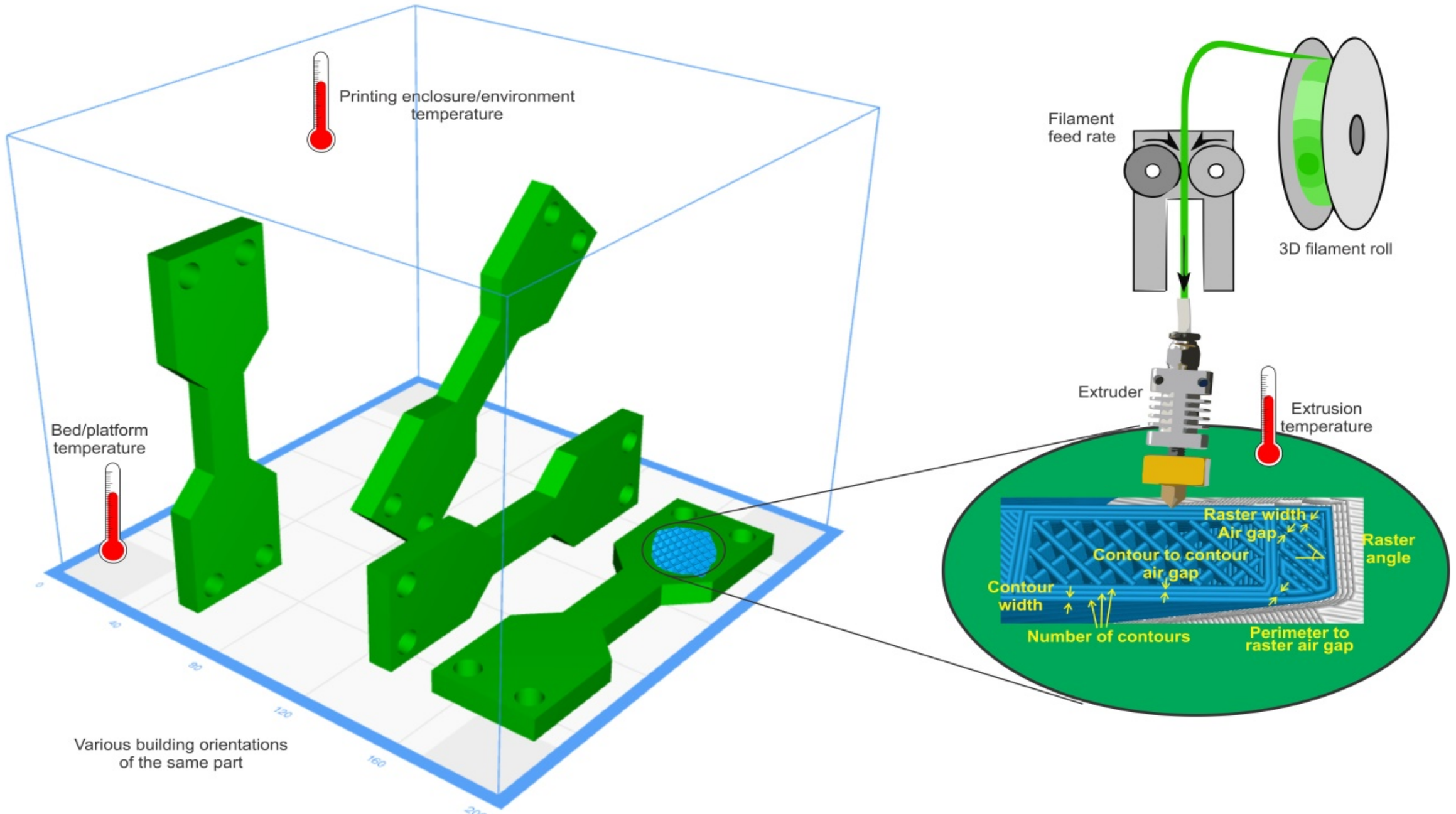


Figure 2.2.1. 3D Printing parameters

3D PRINTING PROCESS PARAMETERS (3/18)

Main slicing parameters:

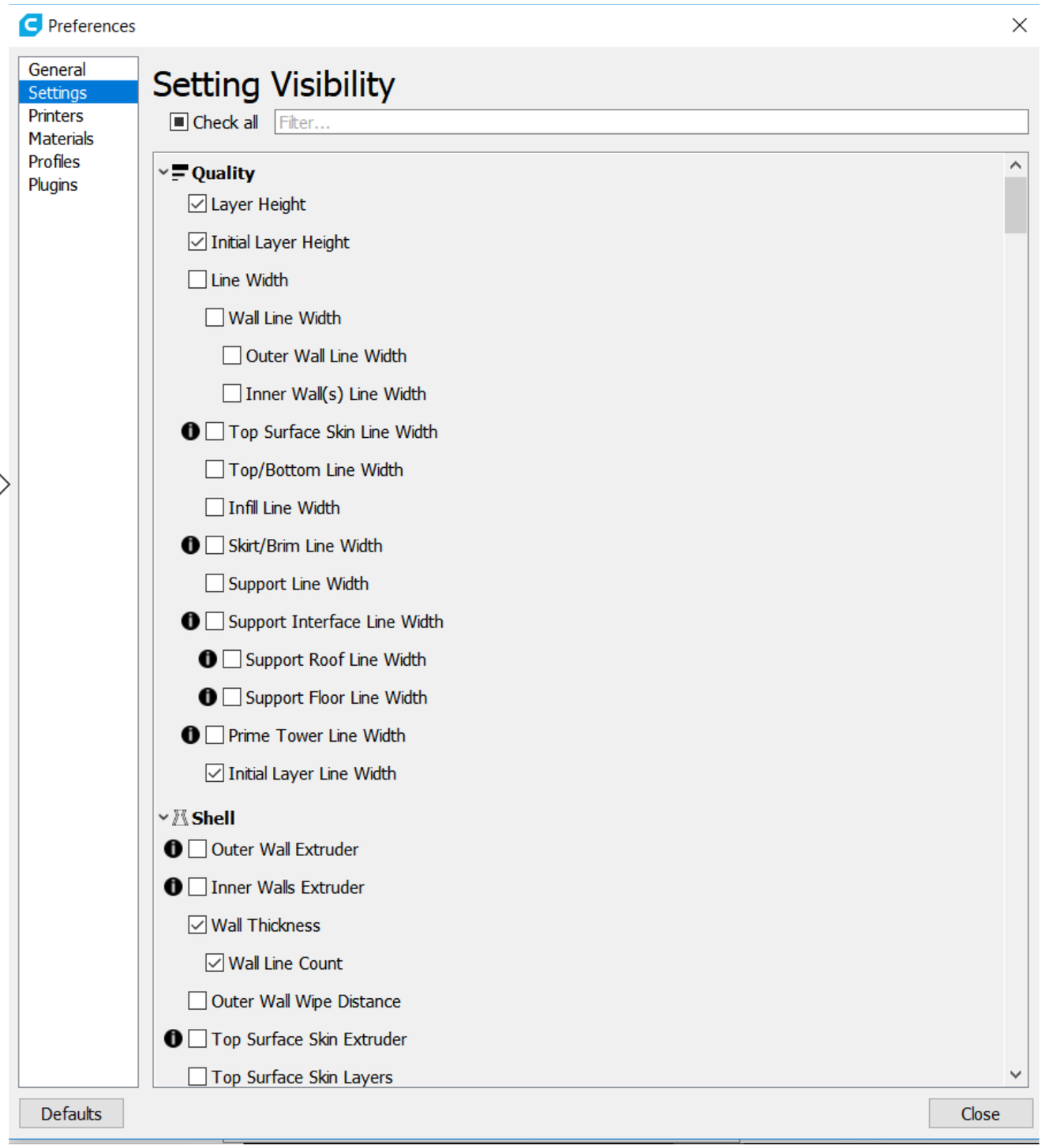
- Layer thickness/height
- Nozzle diameter/bead/road width
- Acceleration
- Flow rate
- Deposition speed
- Infill

Main slicing parameters:

- Raster orientation/angle
- Raster pattern
- Air gaps (raster to raster, perimeter to raster)
- Number of contours/ perimeters (contour width)
- Top thickness
- Bottom thickness;

3D PRINTING PROCESS PARAMETERS (4/18)

Some of the parameters that can be set in Cura software



3D PRINTING PROCESS PARAMETERS (5/18)

- *Layer height* – represents the height of each successive layer deposited/superposed. E.g. 0.06mm, 0.2mm, 0.4mm.

- Layer thickness and *nozzle diameter* are dependent parameters. A 0.4mm nozzle (most common) → 0.2mm layer height.

  - "Layer height should not exceed 80 % of the nozzle diameter"

  - Nozzle diameter affects the level of details in horizontal plane, printing time

3D PRINTING PROCESS PARAMETERS (6/18)

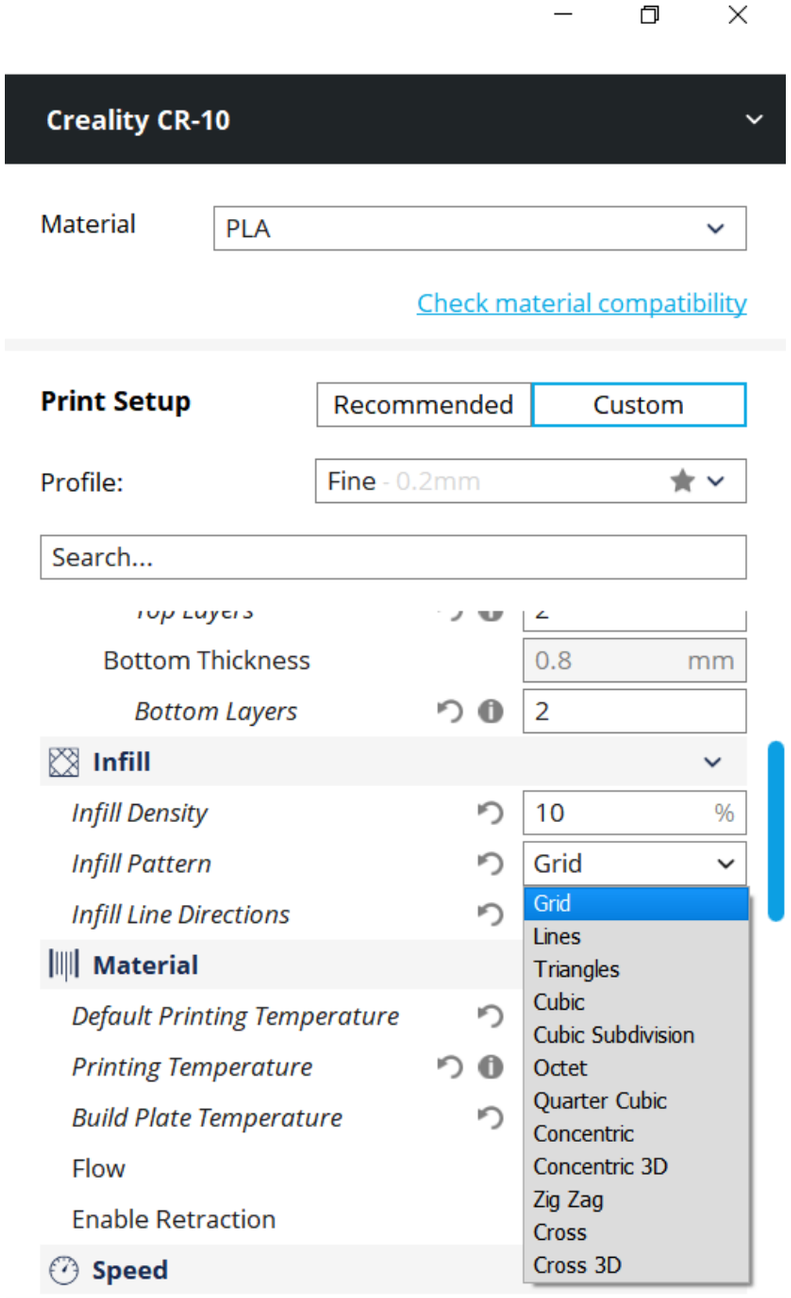
Figure 2.2.2. Comparison of layer height. Source: flickr.com

3D PRINTING PROCESS PARAMETERS (7/18)

Figure 2.2.2. Comparison of layer height and details accuracy. Source: flickr.com

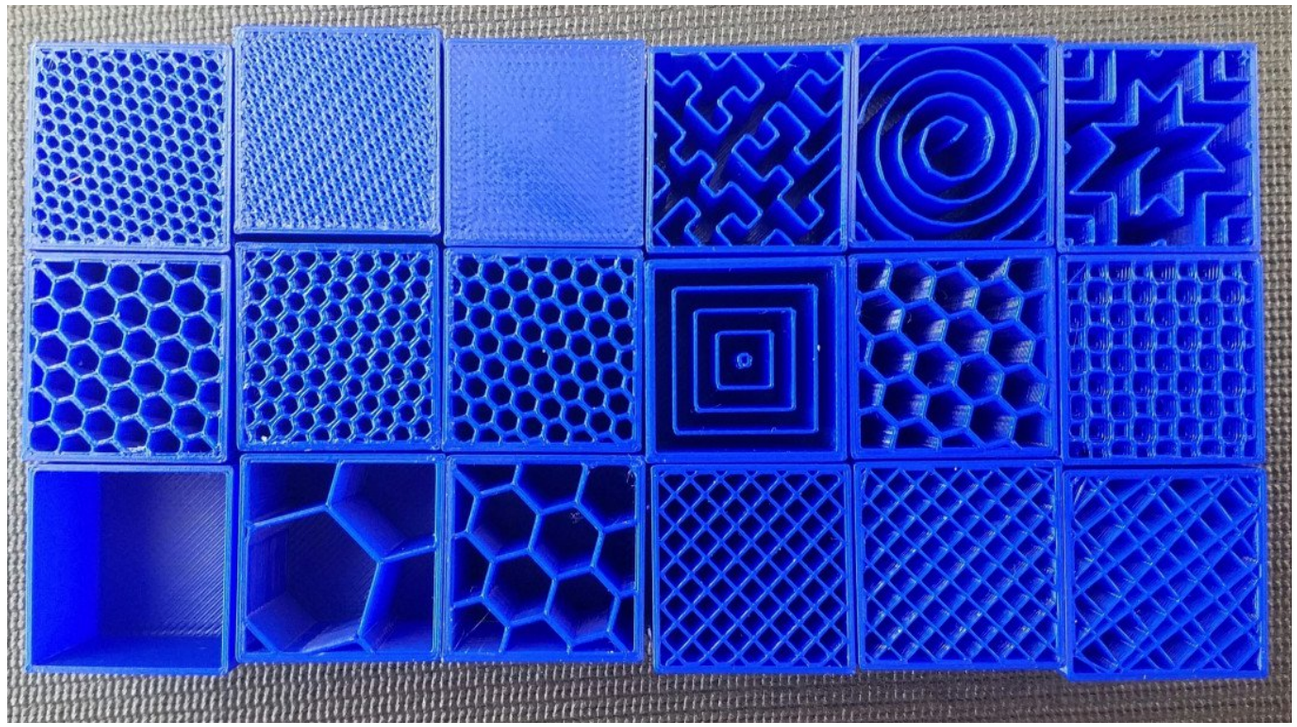
3D PRINTING PROCESS PARAMETERS (8/18)

- *Infill* – represents the structure that is printed inside the layer. Usually, it is characterized by:
  - Density
  - Pattern
  - Line Directions



3D PRINTING PROCESS PARAMETERS (9/18)

- Infill influences:
  - Part mechanical strength
  - Building time
  - Cost
- Examples of infill patterns

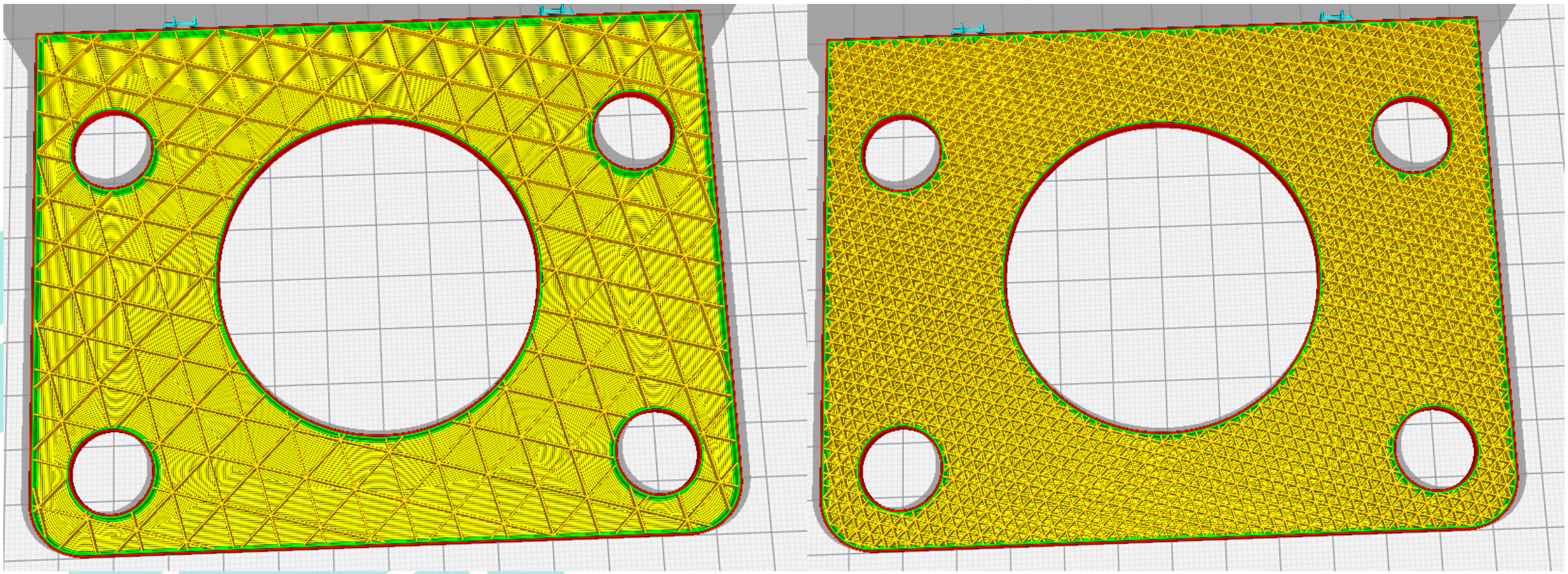


3D PRINTING PROCESS PARAMETERS (10/18)

- Examples of infill densities

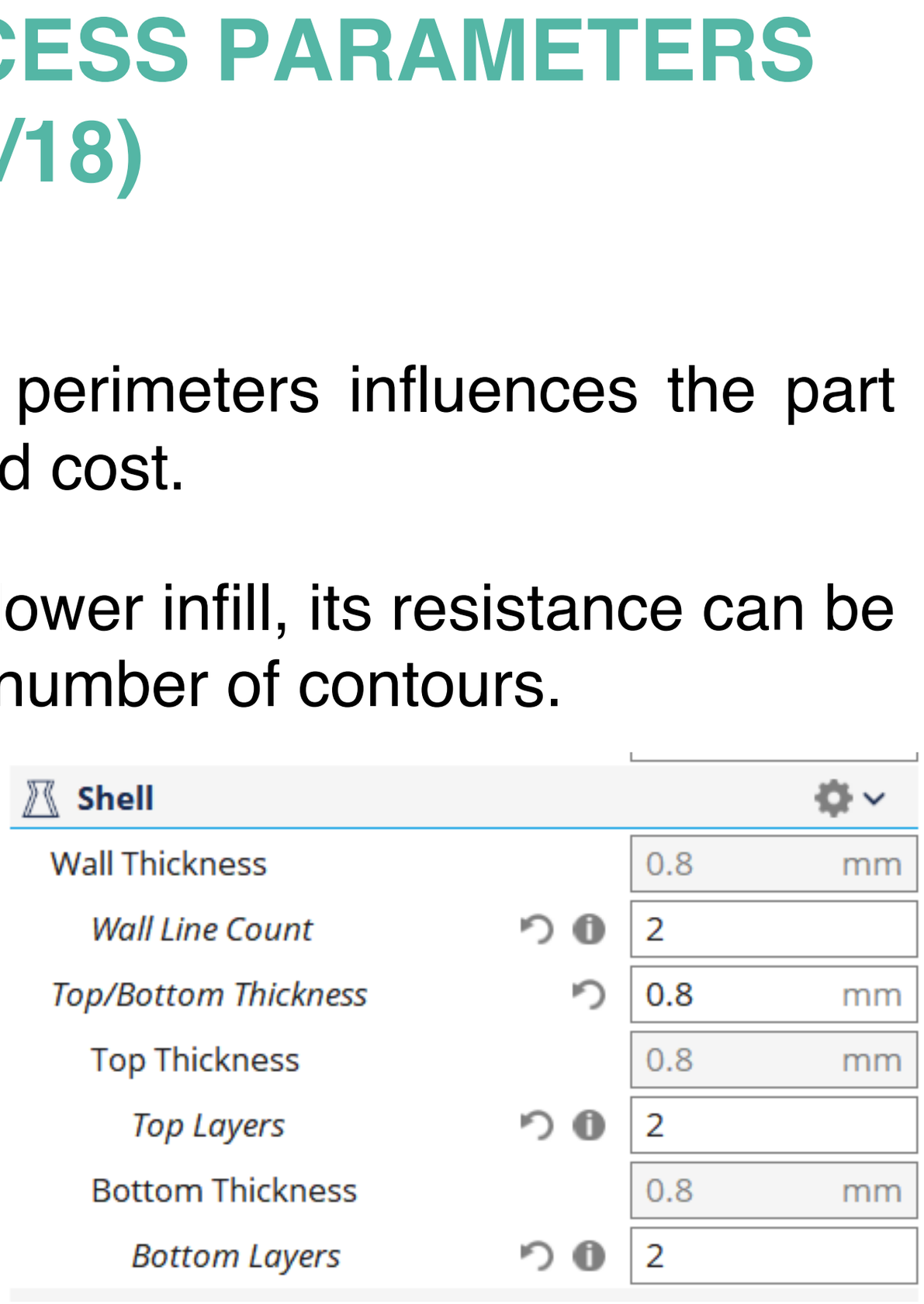
15%

55%



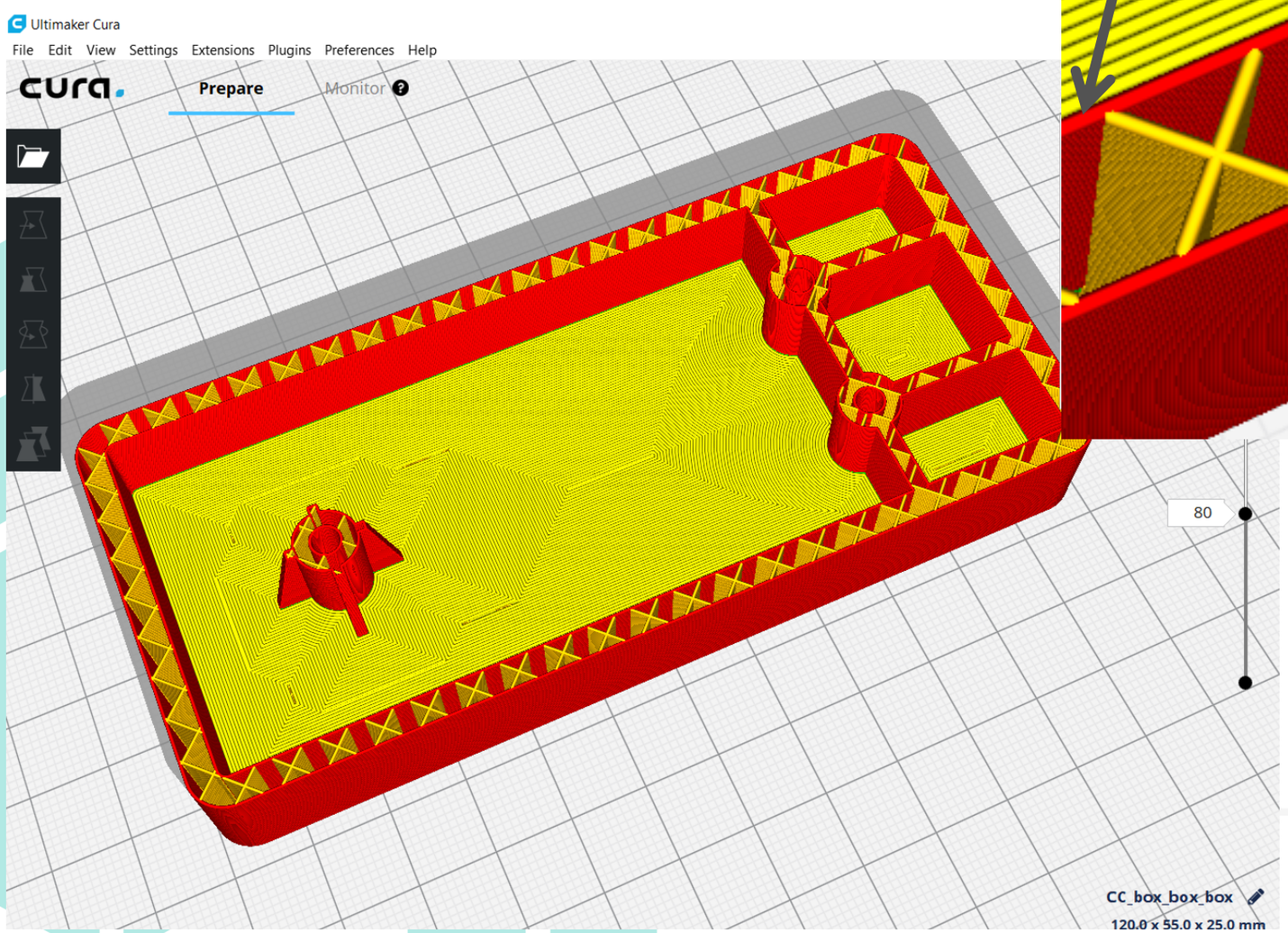
3D PRINTING PROCESS PARAMETERS (11/18)

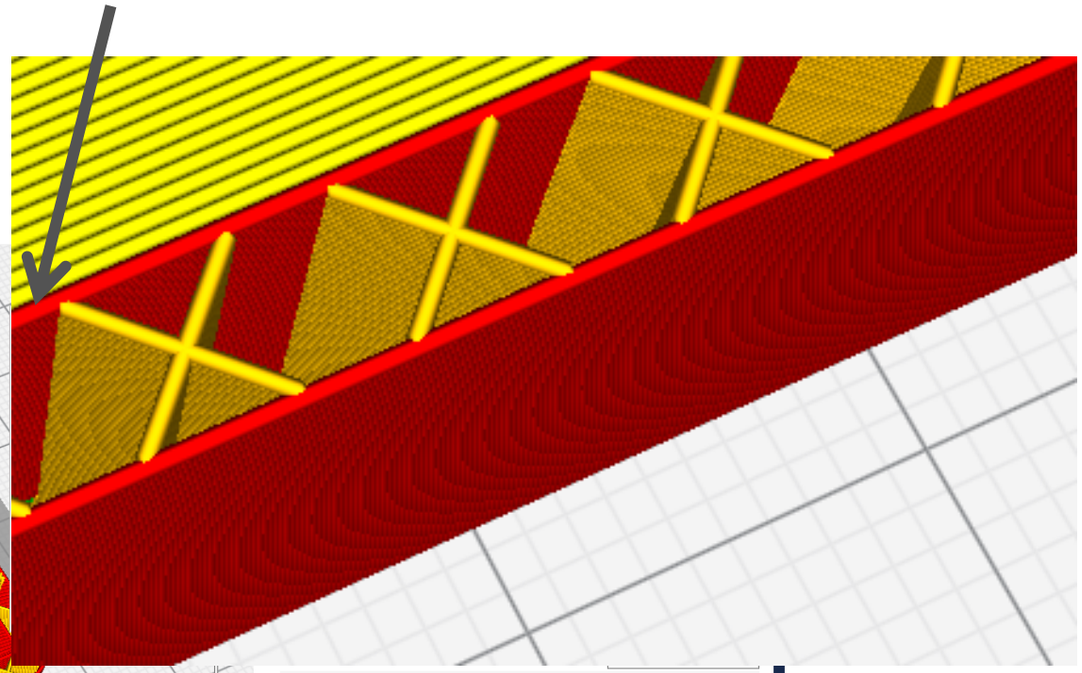
- The number of contours or perimeters influences the part strength, 3D printing time and cost.
- If a part is 3D printed with a lower infill, its resistance can be increased by increasing the number of contours.

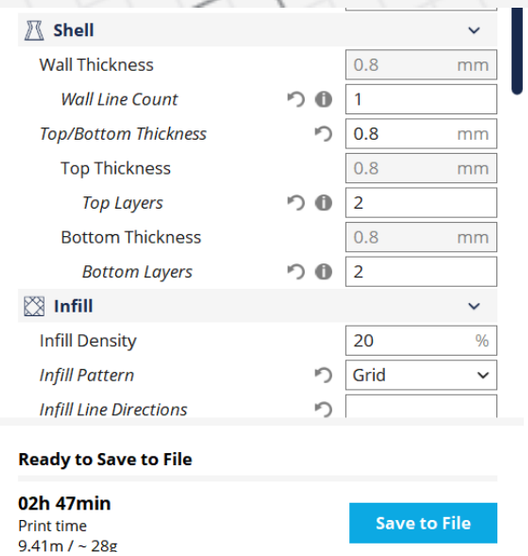


3D PRINTING PROCESS PARAMETERS (12/18)

- 0.2mm layer height, 2 top layers, 2 bottom layers, 20% grid infill. 60mm/s printing speed, 1 perimeter,
  - 2h47min printing time

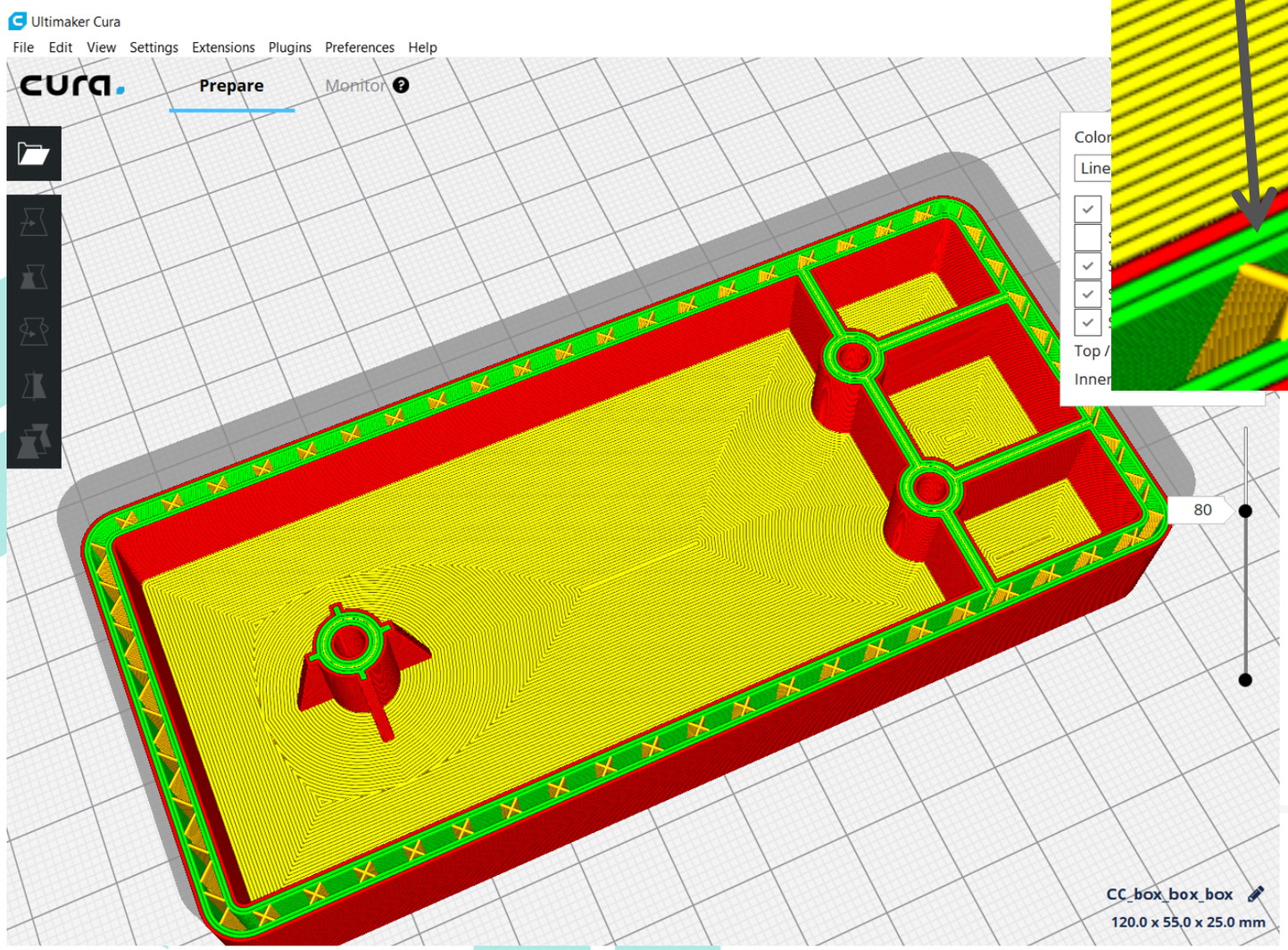


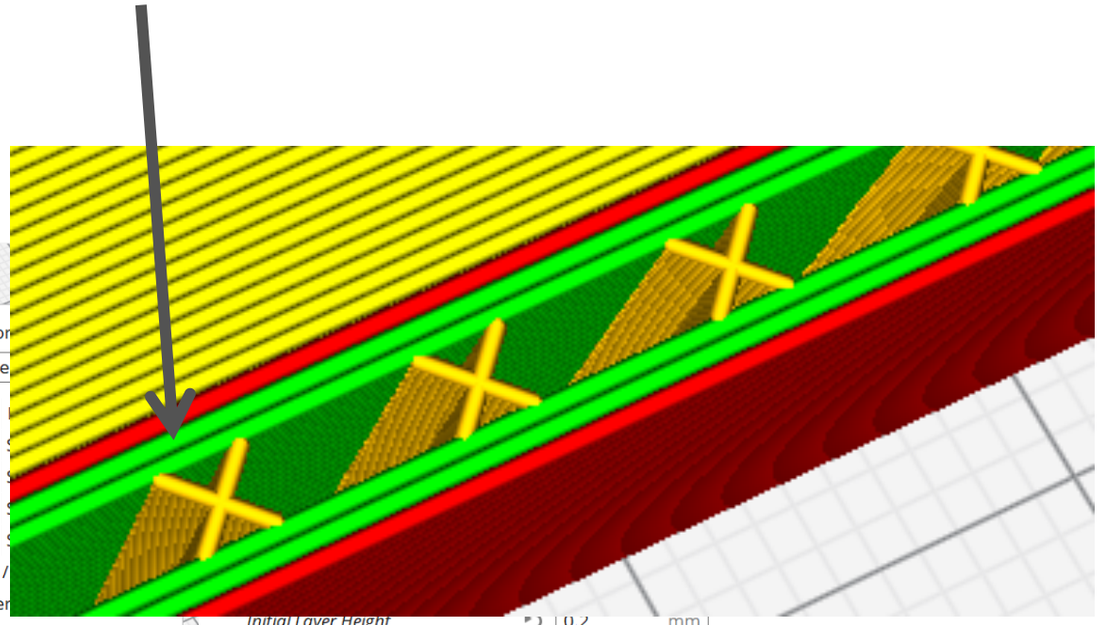




3D PRINTING PROCESS PARAMETERS (13/18)

- 0.2mm layer height, 2 top layers, 2 bottom layers, 20% grid infill, 60mm/s printing speed, 3 perimeter
  - 3h31min printing time





3D PRINTING PROCESS PARAMETERS (14/18)

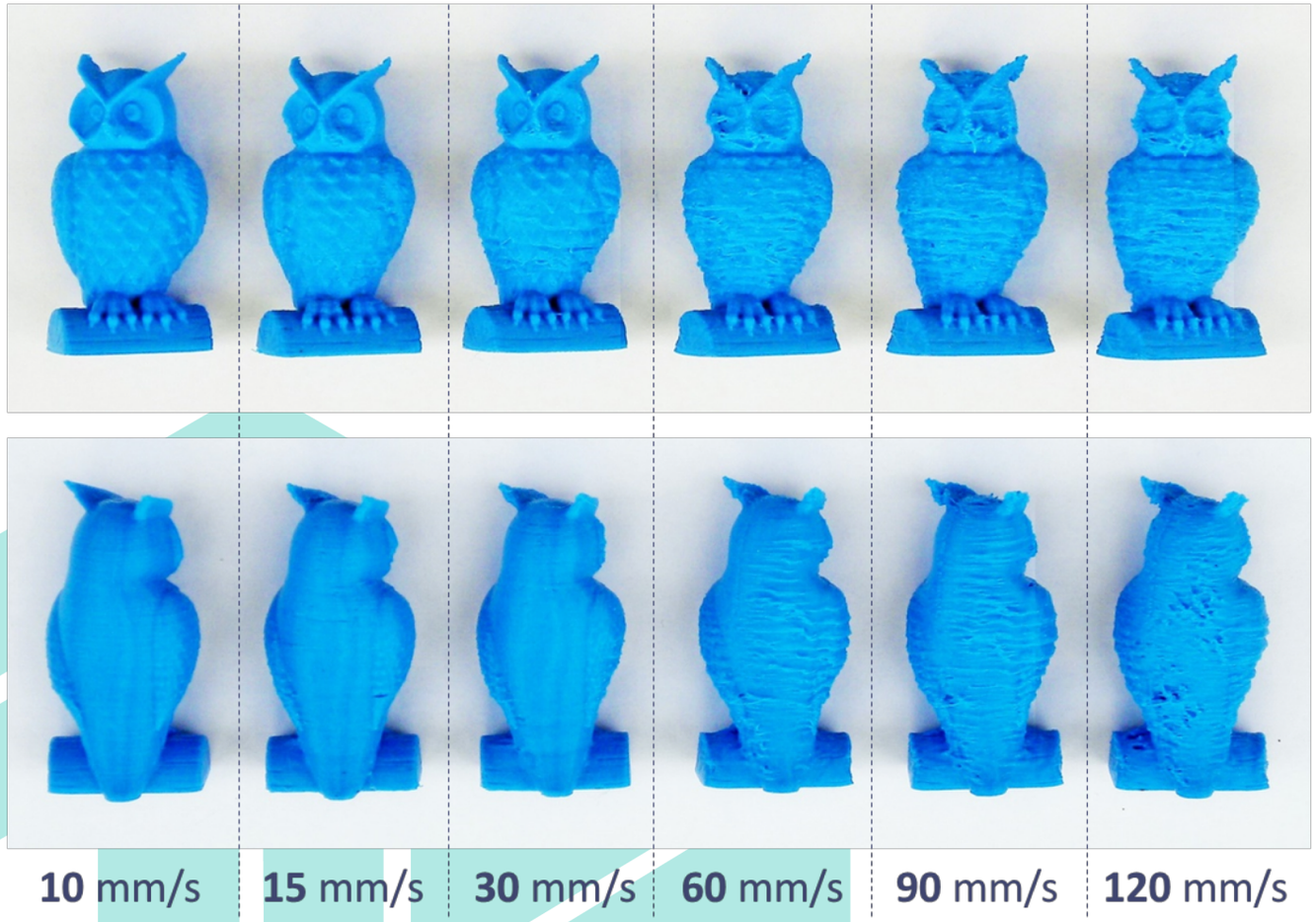
- *Number of top layers and bottom layers* – refer to the number of full layers forming the lower and the upper surfaces of the part.

- Similar to the number of perimeters, the number of top and bottom layers will determine the thickness of the base and the ceiling of the part if it is manufactured using a subunit fill ratio.

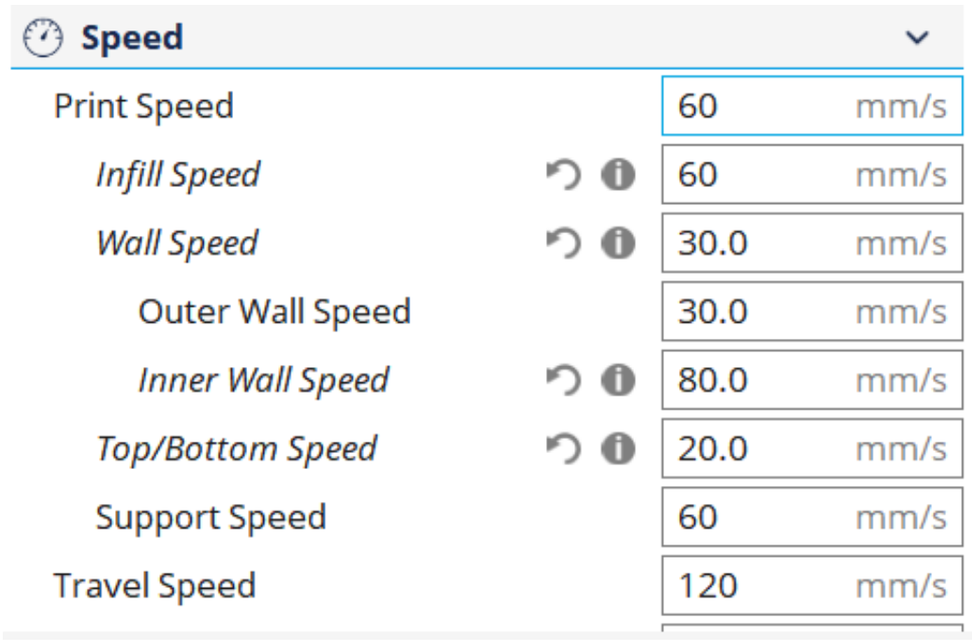
- Depositing molten filaments above the air gaps of small density infills, before solidification, the layer can deform under its own weight, generating concave surfaces instead of flat surfaces. Several layers of material may be used to correct the surface, since for each layer the filament support points above the air gaps are closer, decreasing the weight of the unsupported filament.

3D PRINTING PROCESS PARAMETERS (15/18)

- Speed:



Source: my3dmatter.com



- 3D printing with high speed reduces printing time, but negatively influences roads and layers adhesion.

3D PRINTING PROCESS PARAMETERS (16/18)

- 3D printing speed must be correlated with the temperature of the heating head, taking into account the characteristics of the material used.

- Acceleration is also an important dynamic process parameters, along speed. Depending on the constructive version of the 3D printer, optimal acceleration values may vary between 500mm/s^2 and 2000mm/s^2.

- Improper speed or acceleration values determines defects or deformations due to temperature accumulation.

3D PRINTING PROCESS PARAMETERS (17/18)

- Temperatures:
  - Extrusion temperature
  - Platform/bed temperature
  - Environment temperature
- Incorrect temperature settings can determine total prints failure or defects.

3D PRINTING PROCESS PARAMETERS (18/18)

- Platform/bed temperature – determines part adhesion to the platform, as well as layers and road fusion.
  - Recommendation:
    - PLA – around 70C
    - ABS – 90C
    - PVA – around 40C
    - PETG – around 60C

FURTHER LEARNING

What are the main 3D printing parameters
https://3dprinting-blog.com/tag/3d-printing-parameters/

Quality in FDM 3D printing
http://blog.zmorph3d.com/quality-in-fdm-3d-printing/

Selecting the optimal shell and infill parameters
https://www.3dhubs.com/knowledge-base/selecting-optimal-shell-and-infill-parameters-fdm-3d-printing

How to find optimal 3D printer settings
http://www.3dprintmaterials.guru/talk/how-to-find-optimal-3d-printer-settings

3D PRINTING PROCESS PARAMETERS HANDS-ON

- Analyse the effect of different process parameters settings over the printing time using Cura software
- 3D print a part on your printer using cold platform and then hot platform. Analyze the results
- 3D print a simple cube with different travel speeds and check the resulted prints quality
- 3D model a handle or download it from an online repository. Use different infill densities and check its resistance using different weights
- 3D print calibration or test parts on your printer and analyze the effect of process parameters over the print quality

TASKS FOR REFLECTIONS (1/2)

- What parameter you consider the most important in obtaining good features resolutions of 3D printed parts?
- Do you think that infill patterns influence the part mechanical properties?
- Is there a relationship between layer height and part strength?
- Is printing temperature influencing part strength?

TASKS FOR REFLECTIONS (2/2)

- Is 3D printing building orientation influencing the quality of parts' surfaces?
- Is printing speed influencing parts' mechanical properties?
- Think about how the nozzle diameter affect layer thickness and raster width.