HEI MAKERS

LESSON #7
DESIGN FOR 3D PRINTING

Technical creativity in 3D printing module

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OUTLINE OF THE LESSON #7

- Topic 7.1. Design for Additive Manufacturing concept
- Topic 7.2 Examples of rules of design for 3D Printing
- Hands-on activity
- Further learning
- Tasks for reflection

TECHNICAL CREATIVITY IN 3D PRINTING MODULE

DESIGN FOR 3D PRINTING

- In this lesson you will learn about the importance of knowing and applying design rules for obtaining a good 3D print.
- Expected learning outcomes: knowledge on how to design a part so that to benefit the advantages of 3D Printing.

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

7.1. DESIGN FOR ADDITIVE MANUFACTURING CONCEPT (1/7)

- Design for Additive Manufacturing (DfAM or D4AM) is defined as “the practice of designing and optimizing a product together with its production system to reduce development time and cost, and increase performance, quality, and profitability.” [Thompson, CIRP2016]

- DfAM means to adapt the design of additively manufactured parts or assemblies so that “to eliminate manufacturing difficulties and minimize costs” [Rosen, 2014].

References:

- Thompson, M. K., Moroni, G., Vaneker, T., Fadel, G., Campbell, R. I., Gibson, I., Bernard, A., Schulz, J., Graf, P., Ahuja, B., and Martina, F., 2016, “Design for Additive Manufacturing: Trends, Opportunities, Considerations, and Constraints,” CIRP Ann. Manuf. Technol., 65(2), pp. 737–760.
- Rosen, D. W., 2014, “What Are Principles for Design for Additive Manufacturing?, ”First International Conference on Progress in Additive Manufacturing (Pro-AM), Singapore, May 26–28, pp. 85–90

7.1. DESIGN FOR ADDITIVE MANUFACTURING CONCEPT (2/7)

- DfAM is part of the DfMA (Design for Manufacturing) framework, which is also a subset of Design for X (DfX)

- Examples of rules of design in DfX:

  - Design for casting: “Fillet All Sharp Angles”

  - Design for assembly: “Minimize the number of parts”, “Use symmetrical parts when possible”

  - Design for disassembly: “Use fasteners instead of adhesives”

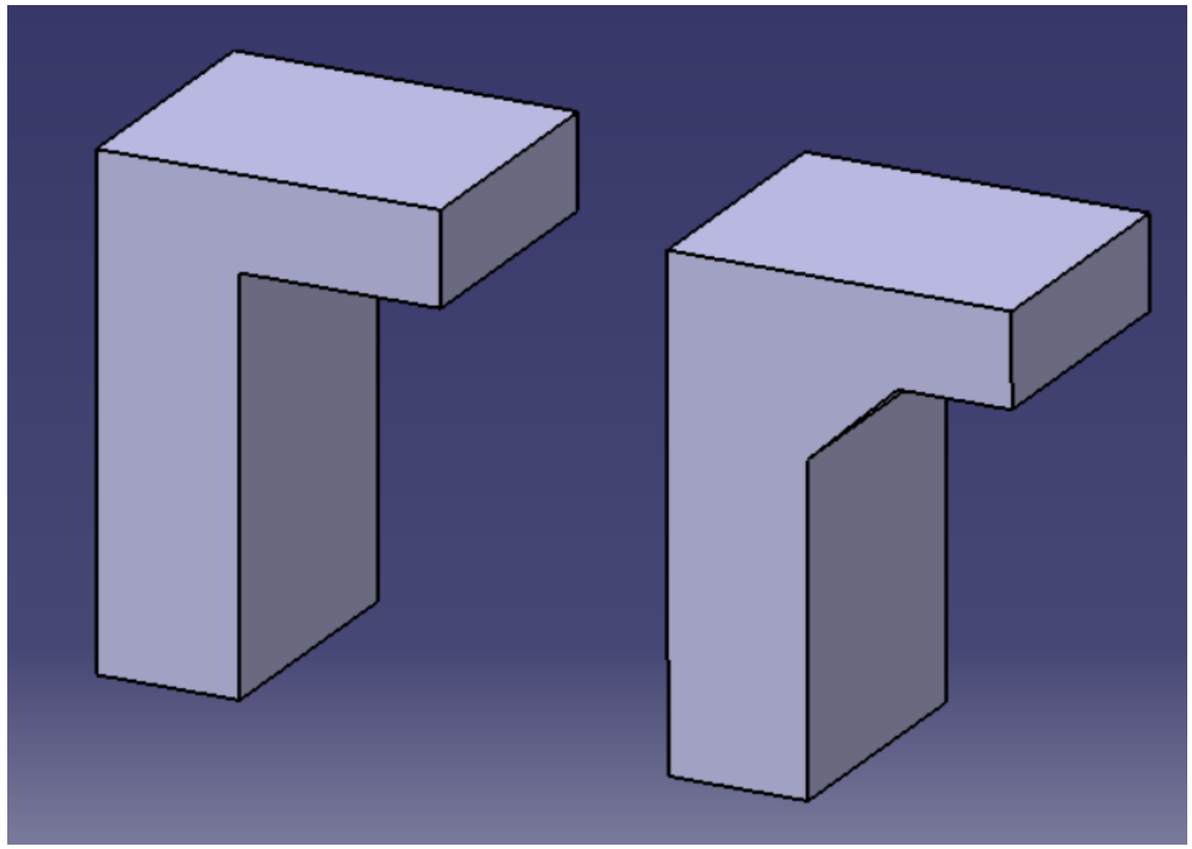
  - Design for injection molding: “Avoid sudden changes in wall thickness for not creating stress concentration areas”

7.1. DESIGN FOR ADDITIVE MANUFACTURING CONCEPT (3/7)

- As there are many AM processes, DfAM is applied differently so that to take into accounts the constraints specific to each process and building material.
    - SLS: Resources: https://www.3dhubs.com/knowledge-base/how-design-parts-sls-3d-printing#design, https://www.shapeways.com/tutorials/design_rules_for_3d_printing
    - FDM, Resources: https://cdn2.hubspot.net/hubfs/340051/Design_Guides/Xometry_DesignGuide_FDM.pdf , https://ultimaker.com/en/resources/22015-designing-for-printability , http://forerunner3d.com/fdm-part-design-guide/ , https://www.printmypart.co.uk/fdm-3d-printing-design-guidelines , https://www.3dhubs.com/knowledge-base/how-design-parts-fdm-3d-printing
    - SLA, Resources: https://www.3dhubs.com/knowledge-base/how-design-parts-sla-3d-printing#designing-for-sla-printing , https://en.wikipedia.org/wiki/DFM_analysis_for_stereolithography

7.1. DESIGN FOR ADDITIVE MANUFACTURING CONCEPT (4/7)

- As there are many AM processes, DfAM is applied differently so that to take into accounts the constraints specific to each process and building material.



- 45deg rule for FDM process is not applied to SLS process, for instance

7.1. DESIGN FOR ADDITIVE MANUFACTURING CONCEPT (5/7)

- A distinction can be made between design rules that are geometric features specific (how to prescribe a part wall thickness or the clearance value between the components of an assembly, for instance) and rules or guidelines on using the technology (how to orient the part so that to increase its tensile strength, for example).

- Part orientation is discussed in relation to surface quality, mechanical properties, support structure, cost and manufacturing time. These issues are related to DfAM in the idea of designing geometrical features and establishing manufacturing conditions so that to obtain parts that satisfies the quality requirements.

7.1. DESIGN FOR ADDITIVE MANUFACTURING CONCEPT (6/7)

- In FDM, based on process characteristics, materials and hands-on experience, recommendations for holes, cavities, wall thickness, overhangs, assembly gaps/clearances, supports are established in literature. These recommendations consider the both the features dimensions, process parameters and building orientation.

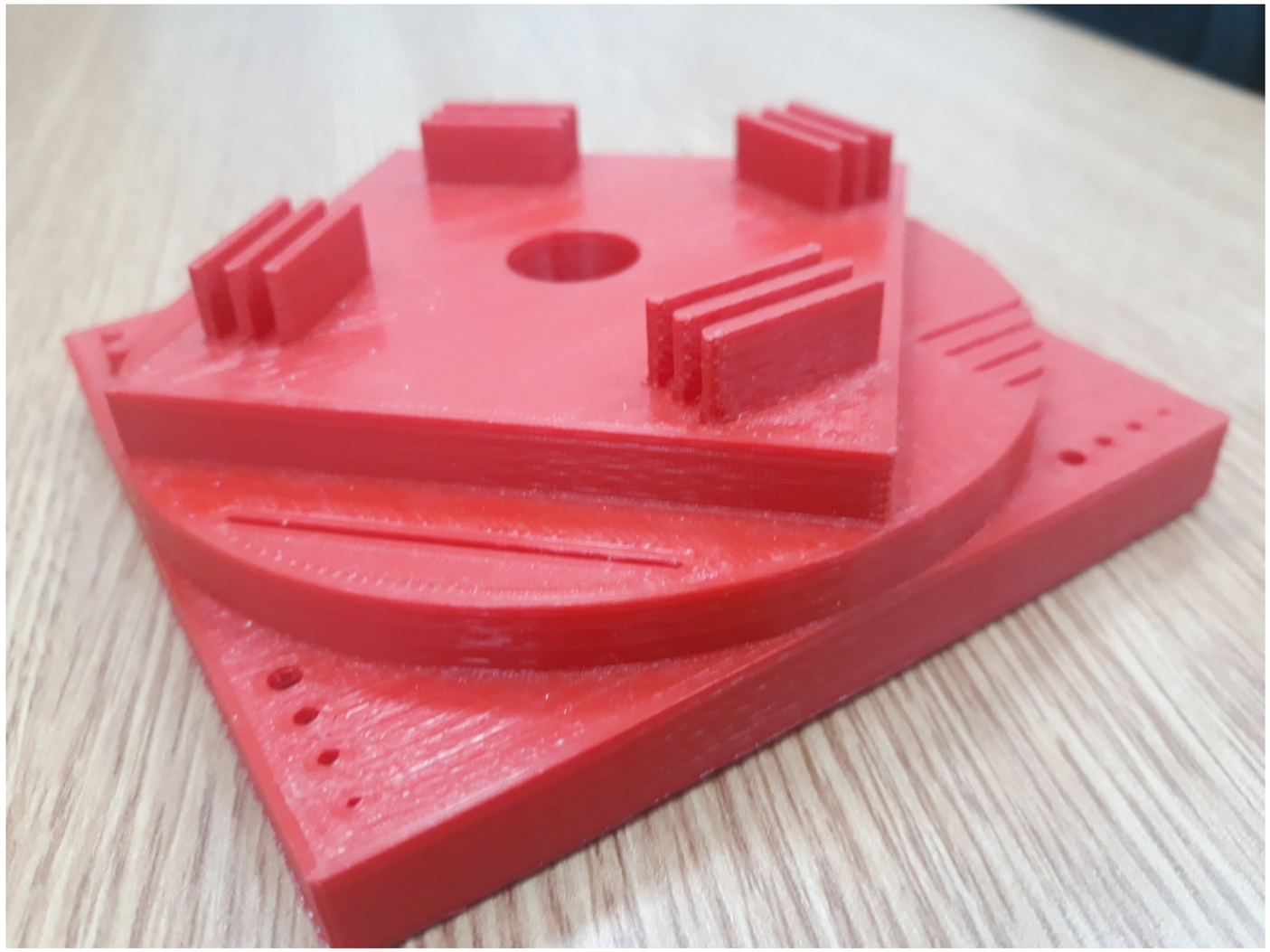
- Issues regarding objects quality such as surface finish, distortion, shrinkage or post-processing are also considered in a design for 3D printing approach.

- In order to examine how different AM processes and materials influence the ability to obtain certain geometric features, benchmarking activities are performed. Test parts (benchmarks) usually contain standard geometries (parallelepipeds, cylinders, cones, spheres, overhangs, stairs, angled planes, pins, slots, holes, etc.) with different sizes and placed in different positions.

7.1. DESIGN FOR ADDITIVE MANUFACTURING CONCEPT (7/7)

- Examples of a benchmark part

- Dimensional and form accuracy can be thus analyzed



7.2. EXAMPLES OF RULES OF DESIGN FOR 3D PRINTING (1/2)

As FDM/FFF (Fused Deposition Modeling/Fused Filament Fabrication) is the most well known, affordable and used additive manufacturing process, the focused is put next on design rules specific to it.

- It is recommended that the horizontal wall thickness to be not less than 1 mm
- A vertical wall thickness below 0.2 mm it is hardly obtained in the FDM process. Moreover, Stratasys specialists recommend that this value to be not less than 1.52 mm.
- If possible, it is also recommended to prescribe a wall thickness as an exact multiple of the thickness of the deposited filament, thus avoiding the formation of internal voids.
- In FDM, the diameters of the holes are generally below their nominal value.

7.2. EXAMPLES OF RULES OF DESIGN FOR 3D PRINTING (2/2)

- FDM/FFF design rules:
  - Special attention should be paid to the design of FDM parts so that the support structures built to be removed at the end of the building process, i.e. not to remain blocked/trapped inside the part. This is especially important when using the break-away type support, which requires access space for the tools necessary to detachment the supports.
  - Given that the FDM can directly build assemblies of parts, it is recommended that in the xy plane the clearance between parts to have a value at least equal to the layer width, in z-plane the clearance value being equal to the layer thickness

FURTHER LEARNING (1/2)

Design for 3D printing
https://support.3dverkstan.se/article/38-designing-for-3d-printing

Mistakes to avoid when designing for 3D printing
https://i.materialise.com/blog/en/5-mistakes-to-avoid-when-designing-a-3d-model-for-3d-printing/

Key design considerations
https://www.3dhubs.com/knowledge-base/key-design-considerations-3d-printing#/rules

FDM part design guide
http://forerunner3d.com/fdm-part-design-guide/

FURTHER LEARNING (2/2)

Design for FDM production parts
https://grabcad.com/tutorials/designing-for-fdm-production-parts

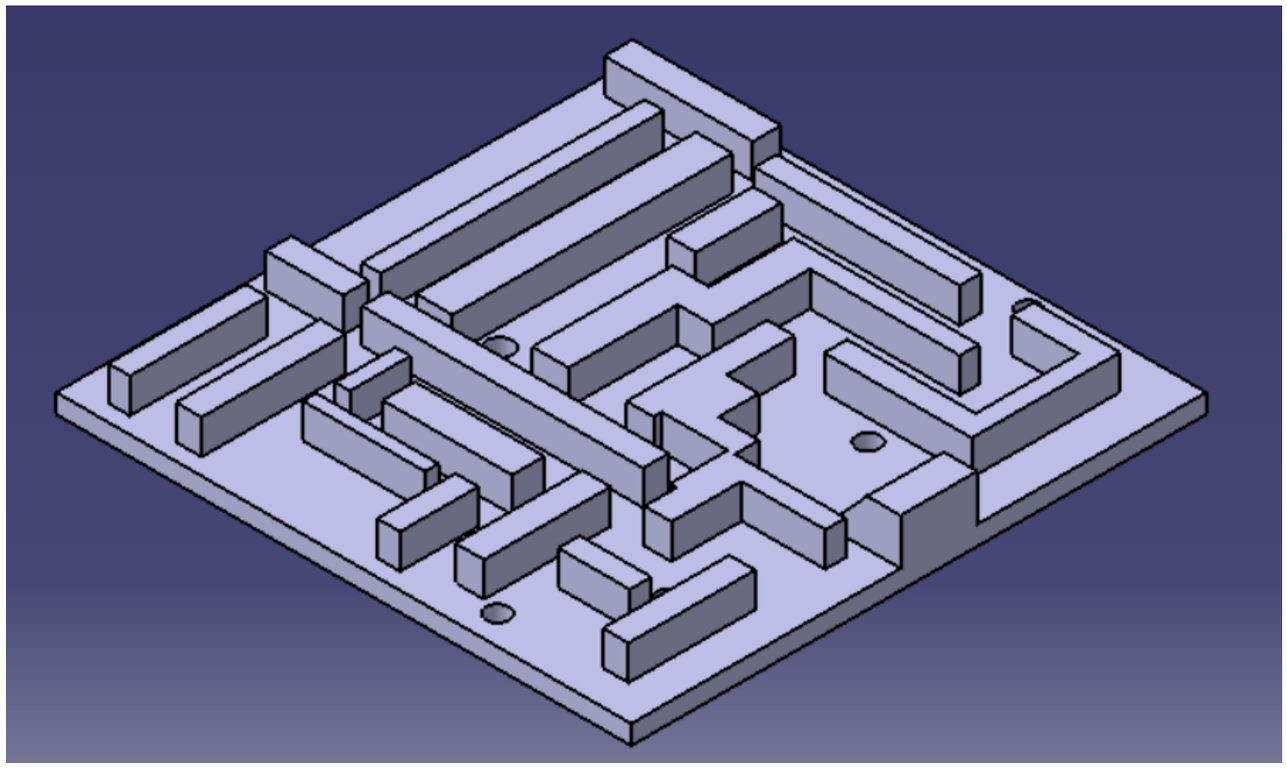
Design for printability
https://ultimaker.com/en/resources/22015-designing-for-printability

Design guide for FDM
https://cdn2.hubspot.net/hubfs/340051/Design_Guides/Xometry_DesignGuide_FDM.pdf

Design guide
https://i.materialise.com/en/3d-printing-materials/abs/design-guide

HANDS - ON ACTIVITY (1/2)

- Design a maze, see figure as model.
  - Prescribe and discuss values for wall thickness
  - Prescribe and discuss values for the holes
  - 3D print the maze and analyse the results: measure the maze, test it, take a look at the quality of the geometric features



HANDS - ON ACTIVITY (2/2)

- Design a product that should be 3D printed directly as an assembly
  - Prescribe different clearances between components in horizontal plane
  - Prescribe different clearances between components in vertical plane
  - 3D print the assemblies and analyse the results. Draw design conclusions

TASKS FOR REFLECTIONS

- Compile list of 3D printing design rules from the literature study.
- Think about the reasons why different AM processes have different design rules for prints
- Do the material type influences the design of the 3D print?