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Smart Additive Manufacturing – an AM Intelligent Platform

D4.2 Generic Process Model for AM

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CHANGE HISTORY

Version	Date	Reason for Change	Sections / Pages Affected
0.1	2021-03-15	First draft version.	All
0.2	2021-08-23	Added introduction	Section 1
1.0	2021-08	First Version	All

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1 INTRODUCTION

By it's nature, the additive manufacturing (AM) process is somewhat different from traditional manufacturing processes. Given the context of the SAMUEL project, it is imperative to have a good understanding of this process. This document details a generalized AM process chain, gives an overview of the different AM techniques and presents figures to illustrate the process.

2 AM PROCESS CHAIN

Additive manufacturing (AM) almost never is a standalone process but is typically part of a whole process chain including other manufacturing technologies and assembly to come to a final product, even in case it is merely prototyping. The focus here is on the production of one part and even there, a lot more should be taken into consideration than just AM. When a new AM-project (part) is introduced, typically, the following steps are followed, often with some iterations between the first two steps in order to select the correct solution:

i)   Material selection. This might seem an odd thing to decide first. Most of the time however it is immediately clear what material the part should be made of.

- It can be imposed by the industry or individual customer.

- The environment in which the part will live: mechanical loads, chemical environment, temperatures, expected life-span, etc.

ii) AM-process selection.

- First of all, it should be decided if AM is the best solution. Most parts can be produced in traditional ways, better and cheaper. There should always be a good reason to turn to AM. (Time can also be a reason.)

- Secondly, the specific AM-technology needs to be selected. This choice is depending on the material as well as the geometry of the part (overall size, detail size, accuracy requirements, etc). Some designs are even better adapted to the specifications of the chosen process.

- Thirdly, the process parameters need to be determined.

iii) The design (CAD-file) needs to be pre-processed and made ready for printing.

a. Necessary provisions need to be made to ensure a good fit as specific printing processes have different tollerances.

iv) The printing itself. This is pretty obvious. During the printing, the process is monitored through a wide variety of sensors and cameras. The readings of these sensors are logged and can provide already quality information about the part. This part of the process will be handled and described separately.

v)   The part needs to be taken from the machine. This can include a cooling down phase and removal of excessive powder and/or support structures. . On some technologies extra baths, UV curing or additional baking is required to give the parts their final strength.

vi) Post-processing steps. This again depends on the previous steps. The possibilities here are endless. They can range from basic sanding over painting, coating, post-milling, polishing to even HIP (Hot Isostatic Pressing) and WIP (Warm Isostatic Pressing).

There are many different AM-processes. There is a standard on the classification of the different types of processes both by ISO and ASTM (ISO/ASTM 52900:2015). There are 7 categories of AM technologies defined:

1) Binder Jetting: AM process in which a liquid bonding agent is selectively deposited to join powder materials.

2) Directed Energy Deposition: process in which focused thermal energy is used to fuse materials by melting as they are being deposited.

3) Material Extrusion: AM process in which material is selectively dispensed through a nozzle or orifice.

4) Material Jetting: AM process in which droplets of build material are selectively deposited.

5) Powder Bed Fusion: AM process in which thermal energy selectively fuses regions of a powder bed.

6) Sheet lamination: AM process in which sheets of material are bonded to form a part.

7) VAT Photopolymerisation: AM process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization.

All AM technologies can be classified into one of the categories above. Within the SAMUEL project however, there are only 2 categories actively used:

1) Material Extrusion: This is by far the most used technology, mainly because the low-end, home 3D-printers also belong to this category. Both Cr3do and Materialise extensively use the (high-end) FDM (Fused Deposition Modeling) machines from Stratasys in this category. The use case on build-time estimation is on this technology. Figure 1 shows how FDM works.

2) Powder Bed Fusion: These are more advanced technologies. Within SAMUEL, LS (Laser Sintering) and Laser Melting (LM) are used by Materialise and some of the Canadian partners. Figure 2 shows how LS works (schematically).

All technologies above are the so-called layer-based technologies and allow for a common generic process description (to a certain extent). The starting point is a CAD-file of the part. The standard used in AM is a mesh-based format (STL) so often a conversion needs to be done from a traditional CAD-format. Figure 3 gives the generic flow.
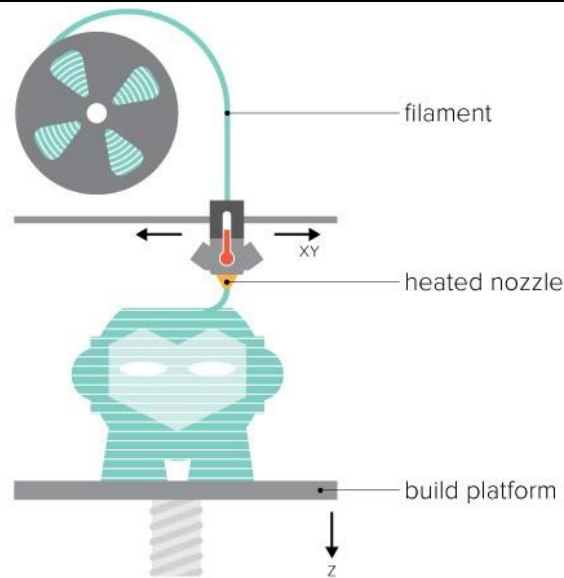
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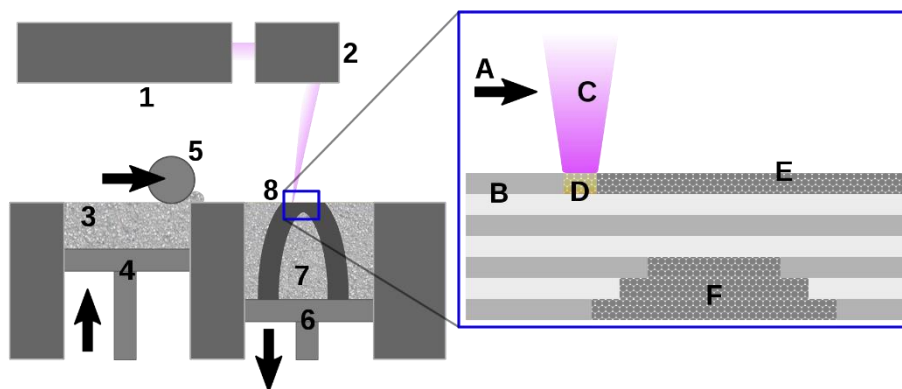
Figure 1: FDM concept

Figure 2: LS concept: 1 Laser, 2 Scanner system, 3 Powder delivery system, 4 Powder delivery piston, 5 Roller, 6 Fabrication piston, 7 Fabrication powder bed, 8 Object being fabricated, (see inset) A Laser scanning direction, B Sintered powder particles (brown state), C Laser beam, D Laser sintering, E Pre- placed powder bed (green state), F Unsintered material in previous layers

Obviously, the AM-parameters, the slicing, hatching, printing, cleaning and post-processing are different for each technology but the idea behind them is similar. For example in FDM, the cleaning consists mainly of support removal while in LS, this is cooling down and powder removal.

In each step of the process flow, an error can occur. The CAD-file might not be watertight and consequently cannot be meshed into a closed, unambiguous STL-file. The detail size might be too small so the slicing and the hatching might fail. The printing, cleaning and post-processing are physical manipulations so there is a wide variety of things that can go wrong. These are obviously depending heavily on the specific process used.
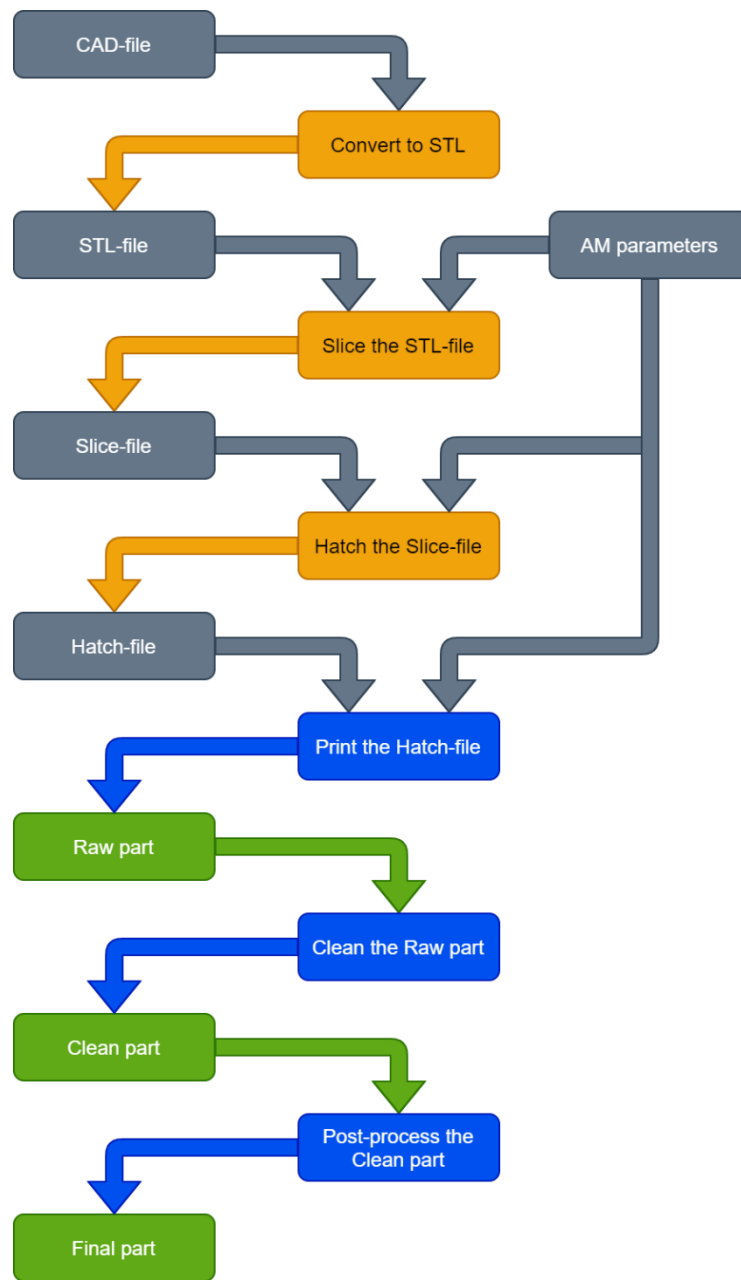
Figure 3: A workflow for (layer-based) AM