# Comparison of Cost, Material and Time Usage in FDM and SLS 3D Printing Methods

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*Abstract* - **Additive manufacturing (AM) is the process of joining materials to make objects from Computer Aided Design (CAD) model data, usually layer upon layer, as opposed to using subtractive manufacturing methods. The use of rapid prototyping technologies has increased significantly in recent years. This paper represents an attempt to answer the questions of when 3D printing can be used efficiently and of choosing the appropriate technology on the basis of batch size, element size, complexity, and time requirements.**

*Keywords* - **Additive Manufacturing, Fused Deposition Modeling, Selective Laser Sintering, cost, time.**

## I. INTRODUCTION

Additive Manufacturing technologies refer to a group of technologies that build physical objects directly from CAD (Computer Aided Design) data. Synonyms used to refer to this technology include additive techniques, layered manufacturing, rapid prototyping, digital manufacturing, and solid freeform fabrication. Basically, these technologies work layer-by-layer with powder, liquid or sheet materials. Due to this, and keeping in mind the way how these technologies work, there are a number of interesting opportunities and advantages, as e.g. freedom of design, but there are some inconveniences or restrictions [1].

Compared to conventional manufacturing, such as machining, forging, injection moulding, casting, and other processes, AM has certain advantages. Firstly, AM can reduce environmental impact due to its avoidance of the tools, dies, moulds, and material waste associated with conventional manufacturing. Secondly, and most importantly for designers, this technology enables the manufacture of parts with novel geometric designs that would be difficult or impossible to achieve using conventional manufacturing processes. Thirdly, novel geometries enabled by AM technologies can also lead to environmental benefits or improved performance in a final product containing elements produced by AM [2-4].

Direct interaction between the producer and consumers becomes more important through the customization process. Producing goods on demand through AM also reduces inventories and the risks associated with oversupply and obsolescence.

## II. ADDITIVE MANUFACTURING TECHNOLOGIES

Although the term '3D Printing' is used by the media as a synonym for all additive manufacturing processes, there are actually many different processes which vary in their method of layer manufacturing. These processes differ depending on the material and technology used, and can be classified in a few categories (Table 1).

TABLE 1

| Technology | Related technologies |
|---|---|
| Vat photopolymerisation | Stereolithography (SLA), Digital Light Processing (DLP) |
| Binder jetting | 3DP (3D Printing) |
| Material jetting | Multi-jet modelling (MJM), PolyJet, Droplet on Demand (DoD) |
| Material extrusion | Fused deposition modelling (FDM) |
| Sheet lamination | Laminated object manufacturing (LOM), ultrasonic consolidation (UC) |
| Powder bed fusion | Electron beam melting (EBM), selective laser sintering (SLS), selective metal melting (SLM), direct metal laser sintering (DMLS) |
| Directed energy deposition | Laser Engineering Net Shaping (LENS) |

The AM processes can also be classified based on the state of the starting material used [1].

## III. SLS AND FDM DIFFERENCES

Today, one of the mostly used technologies is FDM (Fused Deposition Modeling), due to countless companies produced cheap 3D printers. FDM creates 3D prototypes by heating and extruding a filament of plastic material by

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the extrusion nozzle, which moves over the build platform in X and Y directions. This “draws” a cross section of an object onto the platform. When this thin layer of plastic cools and hardens, it immediately binds to the layer beneath it. Once a layer is completed, the base is lowered, making way to add the next layer of plastic (Fig.1).

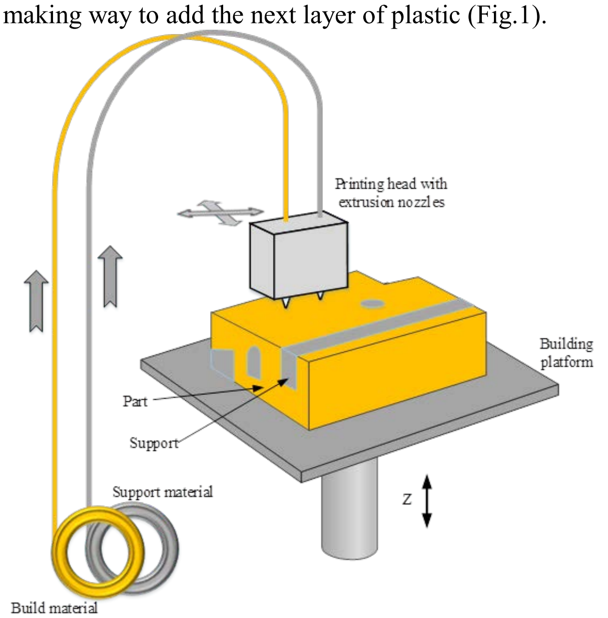


Fig.1 Fused Deposition Modeling method.

In powder-bed SLS, a layer of powdered material is laid down by a leveler on the build tray, and then a laser sinters the cross-section of the part. Subsequently, the platform drops another 0.1 to 0.2 mm and the process repeats. Process chamber are filled by nitrogen and heated.

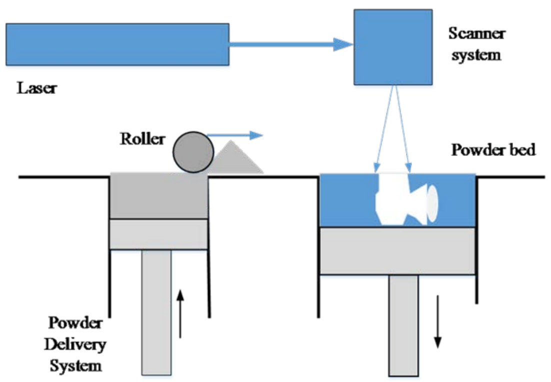


Fig.2 The selective laser sintering (SLS) process.

In FDM printers, resolution is a factor of the nozzle size and the precision of the extruder movements (X/Y axis). The precision and smoothness of the printed models is also influenced by other factors: warping, misalignment of layers, shifting of layers, shrinking of the lower parts. These compromise the precision and surface smoothness.

SLS printers consistently produce higher resolution objects and are more accurate than FDM printers, because the resolution is primarily determined by the optical spot size of the laser. Moreover, during printing less force is applied to the model. This way, the surface finish is much smoother. SLS prints show details a FDM printer could never produce, and it is possible very complicated parts in one process without need of use glue, due to fact that powders works as a support structure for printed parts.

As a quick summary, FDM is the dominant technology in the consumer-level 3D printing market due to the relatively low cost (a few hundred to a few thousand dollars) but does have it’s technical limitation, while SLS 3D printers are typically seen in professional or industrial settings due to the cost of the machines (tens of thousands of dollars), which is balanced by the high quality and technical capabilities.

## II. Material, Cost and Time

The Department of Manufacturing Systems, Faculty of Mechanical Engineering and Robotics, AGH, conducted a study to determine power, cost and time usage in the production of parts using SLS and FDM technology. To do this, for SLS a platform was prepared, including 2 parts multiplied 12 times, for a total height of 20 mm for an EOS Formiga P100 (Fig. 3).

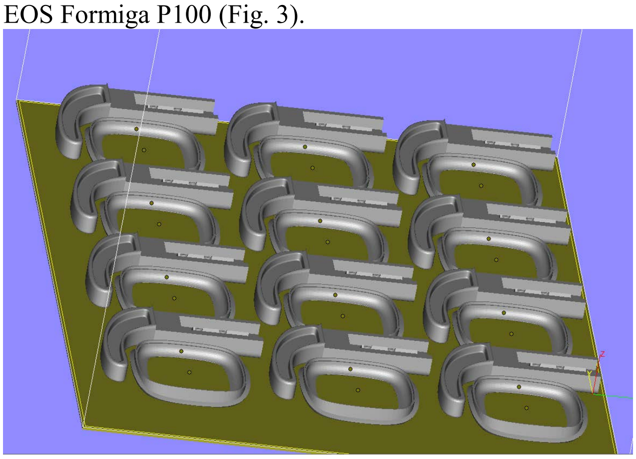

Fig.3 Prepared platform for the test job: 24 parts, 20 mm total height, 2:20 printing time.

Before printing was started on the test job, the work and removal chambers, heaters and air channels were cleaned and the optics and pyrometer were checked. Parts were positioned using Magic’s software (Fig. 3), and, after the arrangement was completed, the parts were merged and exported as one STL file. The volume of this part was 87651,816 mm3; it was located in a bin with the dimensions 200×250×20 mm. After some calculation it can be determined that the useful portion of this volume is approximately 9%. We can observe, that in the building volume was a lot of free space, but for this tests it not was filled by others elements.

For Formiga P100 8h total time of build this platform include 3h of preheating, 2h20m of build time and 2h 20m of cooling time. After this it is needed 20m of cleaning parts from unsintered powder. Material used in this process was Exceltec Innova Pa 1550 XS, characterized by reuse ratio new/old material in 25/75. This provides possibility to very low waste and case less cost of manufacturing parts, even in a low filling ratio. For printing job SLS material waste is close to constant and it is not significant dependent from building volume, so best utilization of the printer we can observe for preparation a big, high filled batches.

Printing single part was not performed on the Formiga P100 due to possibility to stacking parts and possibility to printing a lot of elements in one batch. Time of build one part will be close to time of build 12 parts, due to fact, that printing time is significant depend from height of build, and in this case we can observe a big waste of time and material.

The same part was printed on the FDM machine (Tiertime Up Box) using best quality and precision settings. Parts were printed once one by one and in second example in one setting. In contrast to used SLS machine, in this FDM process it is possible to change resolution of printing in Z direction, from 0.1 to 0.5 mm. Thicker layer leads to shortest time of build, but parts are very rough. For produce parts with good quality and with high precision, on the printer was applied best settings: 0.1 mm height of layers, fine printing speed. Unlike SLS in FDM process is possible to control process of filling parts. Less filling leads to less material usage, weight and inferior strength compared to more filled part. In must be mentioned, that strength in Z direction is worse then in X or Y direction. Also in some cases need of support structure lead to worse quality of surface, longer time of printing and more material waste. Additionally it contributes in not possibility to produce very complicated models.

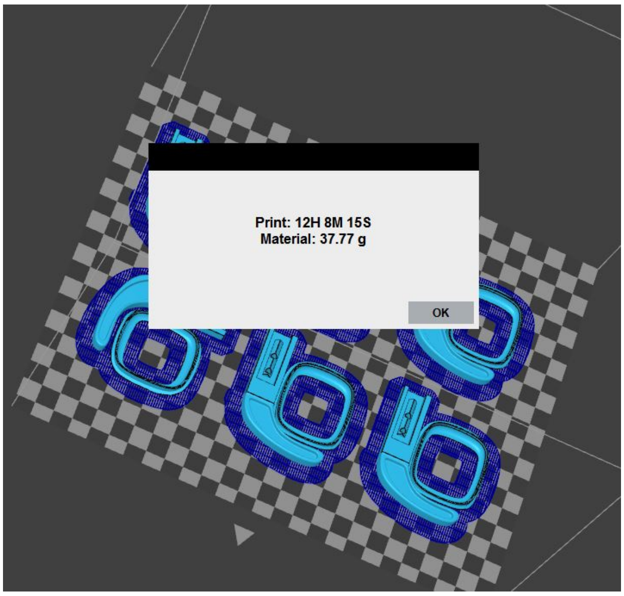


Fig.4. Prepared platform for the FDM test job.

Due to smaller platform compared to Formiga P100, in first case only 12 parts was printed (Fig. 4), which takes approximately 12h, so total time for print 24 parts will be 24h.

TABLE 2

| Process | SLS | FDM |
|---|---|---|
| Time / part | Depends on batch size, for high density time of printing per part is going down. | Constant. Not dependent for number of parts in one process. |
| Cost per part | Depends on batch size, for big prints and high density significant going down | Constant. Not dependent for number of parts in one process. |
| Material waste | Depends on batch size, for big prints and high density significant going down, but still there are some waste. | Constant. Depends on printing models, compulsion of support structures. |
| Strength | High. Not big anisotropy | Depends on filling methods and high anisotropy |
| Detail | It can be printed parts with high details, very complex, interlocking or enclosed parts | Low detail, not very complex elements, interlocking or enclosed parts are possible with soluble support material. |

## III. Conclusion

When we want to print one object with a low level of complexity, FDM is the best choice: it's quicker, cheaper, has a good result, only disadvantage is a quiet poor strength, especially in Z direction. But in the case many objects of the same model for SLS, the price will decrease per unit.

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