White Paper

Introduction to the Plastic Manufacturing Industry

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Introduction

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Plastic is one of the most versatile and inexpensive materials available for consumer products and manufacturing industries. This whitepaper contextualizes the fabrication of parts and components using plastic through a variety of technological processes.

It will describe briefly the most common Conventional Manufacturing processes for plastic fabrication, brushing through the variety of technologies available on the industry at the moment. It will continue to describe more in depth the technologies related to additive Manufacturing, the technology that creates a plastic print by adding layers of materials.

This paper aims at giving a solid background on the different industrial technologies for plastic manufacturing. It is the necessity and the goal of a business that indicates which technology better suits the business needs. Lead time, budget, final product properties and product use will determine the plastic and fabrication process used for the manufacturing.

1.1 Introduction to the Plastic Manufacturing Industry

Plastic fabrication is the design, manufacture or assembly of plastic products through a manufacturing process. The properties of plastic determine the method of manufacturing and by the processing parameters. There are plenty of technologies to fabricate a plastic part, and the choice is made based on the requirements of the final application, the number of parts to be produced and the available budget.

In the following graph, the most important Plastic Manufacturing Processes used in the industry today are shown:

PLASTIC MANUFACTURING PROCESSES	
Conventional Manufacturing Processes	**Additive Manufacturing**
Molding	FFF
Extrusion	SLA
Calendering	DLP
Substractive Manufacturing	SLS
	Material Jetting
	Binder Jetting

Additionally, different polymers will exhibit a diverse variety of properties:

- ***Plasticity***, which defines the ability to irreversibly deform without breaking.
- ***Photosensitivity***, refers to the level of UV-light influence on the other plastic properties.
- ***Thermal Resistance***, is the resistance of the material to let heat flow through itself.
- ***Malleability***, is the ability to be extended or shaped by pressure.

Conventional Manufacturing Technologies

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These type of processes involve changing the shape of the raw material to create the model, using hard tools to mechanize the material or moulds.

Moulding

Moulding is a technology that produces plastic pieces with the form of a mould. There are several types of Moulding Manufacturing Processes:

- **Casting:** Consists of a liquid material introduced into a mould with the desired shape. It is then left to cool down and solidify to obtain the final solid model.
- **Injection Molding:** Consists of injecting molten plastic into a mould. Material for the part is fed into a heated barrel, mixed, and injected into a mould, where it cools and hardens with the final shape.
- **Blow Molding:** Consists of inflating a hot and hollow plastic preform (a part of plastic with a hole in one end to introduce the compressed air) inside a mould. The air is blown into it through the hole to push the plastic out to match the mould. Once the plastic has cooled and hardened the mould opens up and the part is ejected.
- **Rotational Molding:** Involves a heated mould which is filled with raw material. It then starts to rotate, causing the softened material to disperse and stick to the walls of the mould.
- **Compression Molding:** A plastic is placed into a heated open mould, it is softened by the heat and then a pressure is applied to form the shape of the mould while closing it.
- **Thermoforming:** A plastic sheet is heated over an open mould. The heated sheet adapts slowly to the desired shape.

Extrusion

Is a process in which plastic is gradually melted and mixed inside an extruder. Some turning screws help to heat up the material and push it through a die that gives the shape of the section.

Caldering

A mass of plastic material is forced to pass through two counter-rotating rolls to transform them into thin films.

Subtractive Manufacturing

Subtractive manufacturing is a process which cuts material away from a solid block of raw material to construct a 3D model. Although it can be done manually, it is most typically done with a CNC Machine.

Additive Manufacturing Technologies

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While traditional methods involve shaping or carving plastic ino order to obtain the final object, additive manufacturing creates models by adding thin layers of material. There is a wide range of 3D Printing Technologies and each one of them has its own variety of applications, like prototyping, end-use parts, design iteration, etc.

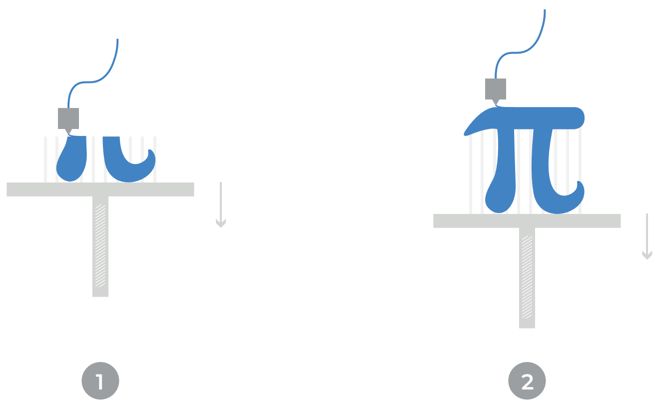
3.1 Extrusion FFF

FFF is the most spread additive manufacturing process. It builds objects by depositing melted material layer-by-layer, using thermoplastic polymers as raw material.

How does it work?

The extrusion path is pre-calculated to design all the layers of a model. Then, the printer takes a filament of a thermoplastic material and pushes it to the print head using gears. The print head will melt the filament at an adequate temperature and will depose it through a nozzle along the XY-plane to create one layer. Once the layer has cooled down, the platform moves down the height of one layer and deposits the path of material to build the second layer. In some printers, the platform remains fixed always at the same height, and the moving part along the Z-axis is the print head. The process continues until the full model is completed.

In case of having overhangs, some support structures may be required to avoid filament falling down. Professional FFF Printers use to have Dual Extrusion technology, which means that are able to use water-dissolvable supports to hold the hanging structures.



Post-processing

- Dissolve support structures or mechanically remove support structures.
- Parts can be processed to improve the surface finish.

Main Application

- Visual aids and prototypes.
- Functional parts for a wide range of applications. A broad variety of compatible materials to fulfill all requirements.
- Manufacturing aids.

Advantages	Disadvantages
Fast printing speed.	Visible layer lines.
Allows creation of end-use parts.	Lower level of detail.
Large range of compatible materials.	

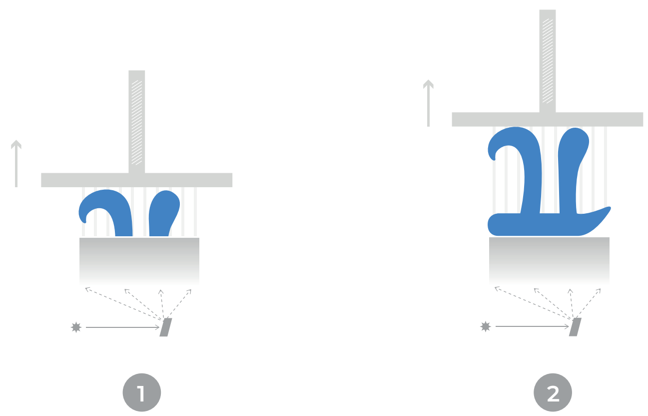
3.2 Vat Polymerization - SLA

SLA is an additive manufacturing process that selectively photo-polymerizes a liquid curable resin from a vat to create solid models.

How does it work?

The UV laser path is pre-programmed to design all the layers of a model and the build platform lowers down to contact the bottom of the vat. Photopolymers are sensitive to UV light, so the first layer of these materials will solidify when the UV light draws the first path of the design. The first layer will be the one contacting the bottom of the vat. This light is directed by scanning mirrors, to heat and harden precisely the polymer.

Vertical build platform and horizontal tank movement separate the cured layer from the bottom of the tank, to let fresh resin flow below. After this, the printer moves the platform upwards and draws the second one, continuing the process until the full model is created.



Post-processing

- Post Curing in a UV oven to completely polymerize.
- Mechanically remove support structures.
- Parts can be processed to improve the surface finish.

Main Application

- Visual aids and prototypes, as this technology offers good accuracy and surface finish.
- Casting moulds.

Advantages	Disadvantages
Excellent accuracy and precision	Parts are degraded to sunlight
Smooth surface quality	Low mechanical properties
	Mechanical removal of supports

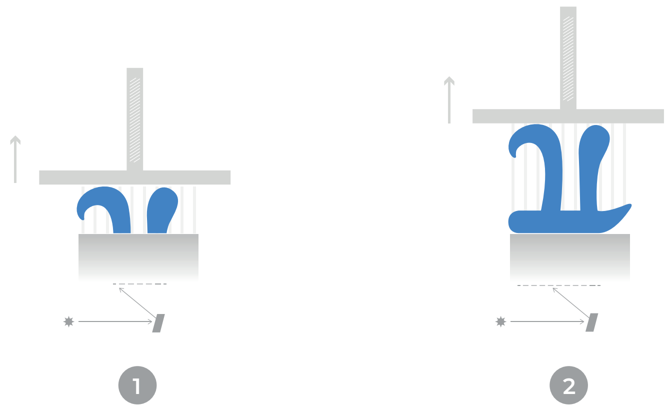
3.3 Vat Polymerization - DLP

DLP is an additive manufacturing process that selectively photo-polymerizes a liquid curable resin from a vat to create solid models.

How does it work?

DLP is a technology similar to SLA, as they both use curable resins as raw material. The main difference between them is the type of light source used to cure the photopolymer. While in SLA the light comes from a UV laser, in DLP it comes from a digital light projector screen, creating only a single image per layer.

All the images of layers will be pre-programmed and the build platform lowers down to contact the bottom of the printing platform (called vat). Once the light is projected into the layer of material at the bottom of the vat, it will solidify to create the desired geometry. The light is directed using a digital micromirror device (DMD). A DMD contains micromirrors that create the pattern of a layer. Then, the printer separates the cured layer from the bottom of the tank, to let fresh resin flow below. Then, the printer moves the platform upward the height of one layer and projects the second image, continuing the process until the model is created.



Post-processing

- Post Curing in a UV oven to completely polymerize.
- Mechanically remove support structures.
- Parts can be processed to improve the surface finish.

Main Application

- Visual aids and prototypes, as this technology offers good accuracy and surface finish.
- Casting moulds.

Advantages	Disadvantages
High accuracy and precision	Parts are degraded to sunlight
Smooth surface quality	Low mechanical properties
	Mechanical removal of supports

3.4 Powder Bed Fusion - SLS

SLS is an additive manufacturing process that selectively sinters powdered plastic materials with high power lasers.

How does it work?

As previous 3D printing technologies, SLS requires a previous stage of calculating the laser path all over the layers of the model. Inside the printer, there is a tank full of plastic powder and a build platform. The platform lowers down the height of one layer and a roller takes the raw material from the tank and coats all the printing surface. Then, a laser impacts on the layer of material following a pre-calculated path to create the model. The platform moves down again the same height as before and the roller fills the space with new plastic powder. The process continues to complete the full part.

In this technology there is no need to generate any structure for hanging built part. This is because the non-sintered powder that remains in place works as support for the sintered parts.

Post-processing

- Cleaning the non-sintered powder with compressed air.
- Parts can be processed to improve the grainy standard surface.

Main Application

- Prototyping and functional testing.
- Manufacturing aids.
- Production of small series of parts.

Advantages	Disadvantages
Ideal for complex geometries	Considerable high cost
Produces small series of parts	Grainy surface and porosity

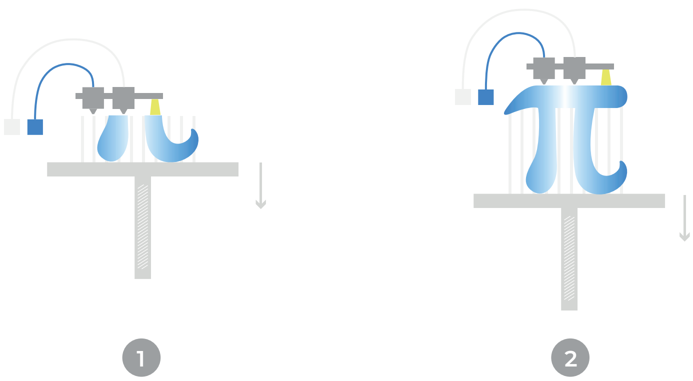
3.5 Material Jetting

Material Jetting is an additive manufacturing process that deposits and cures droplets of material using photopolymers sensitive to UV light.

How does it work?

The first step is to pre-calculate the deposition and cure path. The build platform is placed at a height of one layer from the nozzle that drops material. The print head deposits the droplets onto the platform following the deposition path to create a layer of one model. The material is only dispensed when needed, not following a continuous path. Using thermal or piezoelectric actuators, the print head changes the pressure within the nozzle and the material falls down. Then a UV light attached to the print head cures and solidifies the material. The build platform moves down the height of one layer and the further layers are built up on top following the same method.

These types of printers allow for different materials to be printed in a single model. It means that support structures can be produced with a different material than the object itself. However, the use of droplets limits the range of compatible materials due to their viscous properties.



Post-processing

- Removing support structures with chemical solutions.
- As the print is coloured during the print, the post-processing is limited.

Main Application

- Prototyping.
- Casting moulds.

Advantages	Disadvantages
Full-color prototyping	Low material properties
Excellent surface quality	Limited range of materials
High accuracy and level of detail	

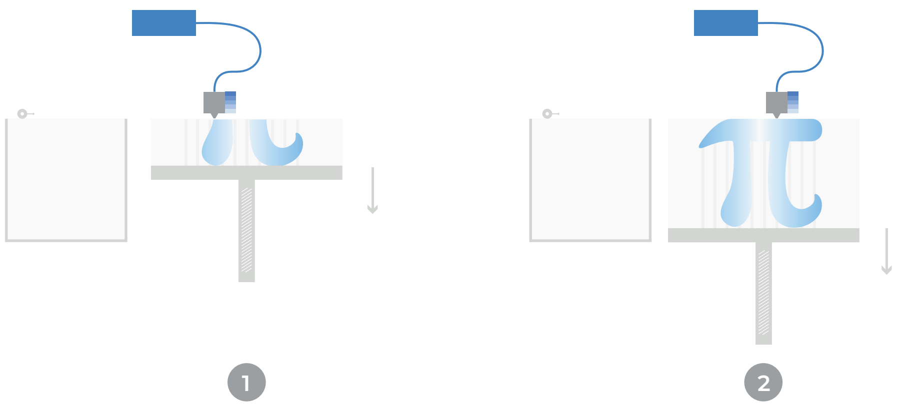
3.6 Binder Jetting

Binder Jetting is an additive manufacturing process that uses a liquid bonding material to bind parts of a powder bed.

How does it work?

As is the case in other technologies, the printhead path is pre-calculated. The printer leaves a space of one layer between the print head and the build platform. This space is then filled with a powdered material to create a homogeneous surface. After that, the print head draws the path and deposits the bonding agent which binds the powdered parts. It is now possible to create full-coloured parts using the same technology as a traditional inkjet printer. The Binder Jetting printer can add and combine colour pigments to the bonding agent (black, white, cyan, yellow and magenta). Once the layer is finished, the build platform moves down the height of one layer and refills the space with new powder. New binder agent is added and the process continues to create the full model. Once finished, the object is left inside the non-bonded powder and is cured.

The obtained part is in "green state", it means the model has high porosity and low mechanical properties. There are some post-processing stages to improve mechanical properties.



Post-processing

- Remove the non-bonded powder with compressed air.
- Sintering stage to reduce porosity.

Main Application

- Full-colour prototyping.
- Casting patterns.

Advantages	Disadvantages
Full-colour models	Limited mechanical properties
Good surface quality	Fragile and brittle parts

Conclusions

04

This paper has brushed through the plastic manufacturing industry, describing both conventional and additive technologies. Lead time, price and accuracy are important elements to take into account when deciding which technology should be incorporated into a manufacturing workflow.

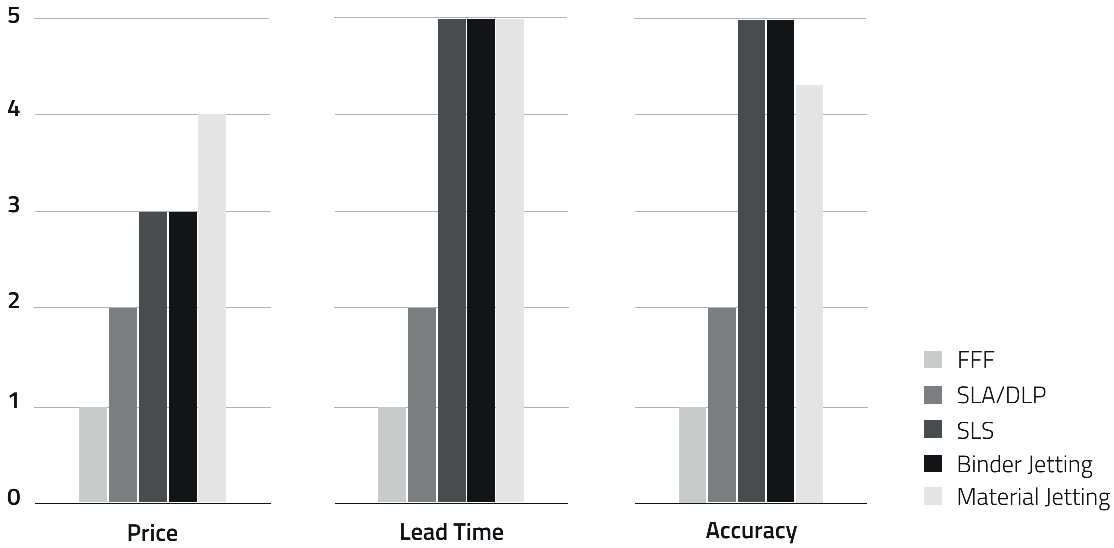
Technology	Advantages
Additive manufacturing	Producing a low number of parts at low cost and short lead times.
	Complex geometry that cannot be produced with any other technology.
Subtractive manufacturing	Producing medium-volume batches of parts (>100) at low cost.
	Simple geometries that require high accuracy and high mechanical properties.
Traditional manufacturing	High-scale production (>1000) at low cost.
	Simple geometries with good mechanical properties.

While traditional manufacturing offers a large scale production at low cost, the costs are high if the aim is to produce low quantities. Scaling up through a traditional manufacturing process also means longer wait times and production times, as moulds are based on prototyping and the process can be prone to error and delays in obtaining a final mould. Opposite to this, additive manufacturing will render inexpensive low batch productions and short lead times but will not be as cost effective when scaling up production.

Conclusions

Similarly, additive manufacturing offers the ability to produce complex geometry tailored to every single produced piece, while traditional manufacturing will require more simple geometries.

Additive manufacturing allows creating a great range of producible range of shapes that would not be possible to manufacture in a single print using traditional technologies. When the requirements are high accuracy and low amounts, the most suitable technology is additive manufacturing. If, however, the need is to obtain a deliverable that must be mass produced, then the traditional manufacturing technologies would be better suited for this job.



Conclusions

If you want to know more about Additive Manufacturing Processes and how to implement them into your workflow, contact us at info@bcn3dtechnologies.com.

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