Additive Manufacturing

Thinking about innovation

Feedback on implementation on Additive Manufacturing Technics
For designing and manufacturing of definitive mechanical parts, since 1995
When could I use additive manufacturing? Where could we find some informations? Who could help?

http://www.iphc.cnrs.fr/
Additive Manufacturing

Thinking about innovation

1- two complementary approaches
specific contexts

2- main additive manufacturing technics in use
processes, machine manufacturers, partners, ...

3- achievement example
geometrical optimization in an IPHC project,
some research and development examples in several domains

4- some 3D printers

5- Outlook

6- workshop - CAD presentation
workshop - topological optimisation / slicing

7- Conclusion

Annex : complementary informations

Summary
Additive Manufacturing

Thinking about innovation

1- two complementary approaches

specific contexts
1- two complementary approaches

Traditional method

Operational office

Definition drawings

Machining process

Implementing of machinings
And other mechanical operations

Manufacturing by Machining

Machining
Metal cutting

elasticity, plasticity rupture, Strain, stress

Raw material

Source: http://www.sandvik.coromant.com/
1- two complementary approaches

- **Traditional method**
  - Operation office
  - Definition drawings
  - Machining process
  - Implementing of machinings
  - And other mechanical operations

- **Numerical method**
  - Scanner
  - Engineering
  - Points cloud
  - Catia V5 workbenches: Atelier STL, Part Design, GSD, QSR, DSE
  - CAD Modeler CATIA V5
  - FEM specific files ANSYS, COMSOL, autres
  - CAD part geometry
  - CAM

Manufacturing by Machining
1- two complementary approaches

**COMPLEMENTARY TECHNOLOGIES WITH LIMITED OVERLAP**
**MAXIMUM BENEFIT DERIVED BY EMBRACING BOTH TECHNOLOGIES**

**Traditional method**

- Definition drawings
- Machining process
- Implementing of machinings
  And other mechanical operations

**Numerical method**

- Points cloud
- CAD Modeler CATIA V5
- CAD part geometry
- CATIA V5 workbenches:
  Atelier STL, Part Design, GSD, QSR, DSE
- FEM specific files
  ANSYS, COMSOL, autres
- CAM

**Manufacturing by Machining**

- Operational office

**Manufacturing by Additive Manufacturing**

- scanner
- engineering
- CATIA V5 workbench
  CATIA V5
- STL workbench
  CATIA V5
- AM specific file
- stl file
- Sending to 3D printer

**Different Materials!**
1- two complementary approaches

Metal powder and laser...
Direct manufacturing

Manufacturing by Additive Manufacturing

less material waste
create products that is impossible to make
with existing machining techniques.

ESIPAP - European School of Instrumentation in Particle and Astroparticle Physics - Archamps 7-3-2017
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1- two complementary approaches : numerical method

Base principle

Additive Manufacturing (AM) is defined by ASTM norm under the name ‘Fast Manufacturing’

‘3D printing’ is the common name to describe all the process which use AM.

Invention of stereolithography begins in 1980’s, in a chemical school in Nancy (France). Industrialisation begins in 1986 in USA by 3D Systems society.

Aim : to stack layer upon layer

Material of support : specific resin or fine mechanical structure needed by supporting part during manufacturing process
Material of part (anisotropical material) : plastic, metallic ou composite
1- two complementary approaches : numerical method

the revolution ...
1- two complementary approaches: numerical method

the revolution ...

production
1- two complementary approaches: numerical method

Main existing printing processes...

FDM = Fused Deposition Modeling
SLS = Selective Laser Sintering / DMLS = Direct Metal Laser Sintering
SLA = stereolithography

1- two complementary approaches : numerical method

Inseparable items...

- Own Material
- Own process
- Parameter setting
- Part
- Cleaning
- Maintenance
- Rapid Prototyping Machine
- manufacturer
2- main additive manufacturing technics in use

processes, machine manufacturers, partners, ...

Main : industrial use, make durable and accurate parts, with well known material
2- Main direct fabrication technics in use

**Stratoconception** (hybrid principle: stack of machined plates or cutted sheets: glued, welded or screwed together)

Using of traditionnal machining technics
Halfway between machining and AM
Fused Deposition Modeling at CEMES laboratory (CNRS, Toulouse)

_machines DIMENSION and Stratoconcept (manufacturer : STRATASYS)_

Soluble resin and part material (ABS) are deposed together.

_L'I3D du CEMES propose un parc de machines mutualisées…_  
_http://www.i3d.cemes.fr/_
Fused Deposition Modeling

What’s coming out of the printer?

Cleaning by immersion: support material is soluble
! two different materials
IPHC 3D fdm printer
‘Makerbot Replicator 2X’

Direct 3D printing or through SD card storage

goal:
good Design and final parts

Maximum printing size:
150x250x150 mm

Layer thickness: 0.1, 0.2 or 0.3 mm

Printing time:
0.5 – 25 hours / peace

Used material: ABS (several colors)

Used with raft and support: ABS

Price: ~3000 € HT
Test review: https://www.3dhubs.com/3d-printers/replicator-2x
Seller: http://www.machines-3d.com/
IPHC 3D fdm printer ‘ZORTRAX M200’

Direct 3D printing or through SD card storage

goal:
good Design and final parts

Maximum printing size:
200x200x180 mm

Layer thickness: 0.09, 0.14 or 0.19 mm

Printing time:
0.5 – 72 hours / peace

Used material: ABS (several colors)

Used with raft and support: ABS

Price: ~2000 € HT
Test review: http://www.lesnumeriques.com/imprimante-3d/zortrax-m200-p22789/test.html
Seller: http://www.machines-3d.com/
Photopolymer with UV curing with CADINDUS Society (Mulhouse, F) and pôle ORTECH from LpoDeck (Guebwiller, F)

EDEN machine by OBJET Society

Unremovable parts: bearing, Tête d'impression, Plateau support, spring.
Photopolymer UV curing

Cleaning: water jet and scraper

! resin support and part: same chemical base
3D printing with EDEN 330, viewed by electron microscope ESEM (IPHC)

Sample fabrication
10mm x 10mm x 1mm

Layers thickness: 16µm

©IPHC / DEPE / ESEM: Environnemental Scanning Electron Microscope
Source: http://en.wikipedia.org/wiki/Environmental_scanning_electron_microscope
Selective laser sintering (sls)
PA parts production at LpoDECK and 3DPROD (France)

Ofen temperature: 170°C + laser
Layer thickness: ~100 μm

EOS Formiga P100: Polyamid (PA) printing
metal or ceramic possible on other machine

Image source: http://3dprinting.com/
3D printing with EOS FORMIGA 100, viewed under ESEM (IPHC)

Powder grain size less than 100 µm
Partially melted on surface

©IPHC / DEPE / ESEM : Environnemental Scanning Electron Microscope
Scale effects

Source: http://www.sculpteo.com/fr/help/

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**Stereolithography (SLA)**

Photo-solidification: 3D printing patent (1986)
Using of a vat of liquid ultraviolet curable photopolymer and ultraviolet laser

Source: http://en.wikipedia.org/wiki/Stereolithography
Direct Metal Laser Sintering (DMLS)

Today, the way to produce metal parts...

Laser: ~200 W
Layer thickness: ~20 μm

Laser cladding (CLAD)

DMG MORI
LASERTEC 65 AM
special manufacturing machine

- Laser CLADDING
- Machining
- Repairing
- Coating

2- Main 3D additive manufacturing technics in use

1- **fdm process** (fused deposition molding) : thermoplastic fused deposition / extruder hole diameter ~ 0,4 mm

2- **Objets 3D printers** (Objet.com ; polyjet printing) : thin layers (less than 30 µm)
   - Remove with spatule, remove support material with water jet
   - Clear the tray with spray / Build tray is ready for the next model

3- **voxeljet** (voxeljet.com)
   - Poudre and binder jet
   - Parts complete curing after 24 h standing
   - Make vax parts for lost wax casting
   - Layer thickness 0,006 inch
   - Depoudering station to remove the pouder by hand to prevent damage
   - Final curing process : low temperature for 5 h
   - When curing is complete, remaining excess pouder is removed with low pressure air jet
   - Final step : quick dip in vax to seal the part
   - A heater can as used to remove the excess vax from the surface

4- **stratoconception**
   - Cutting parts in thin hard or soft plates (foam, wood, plastic, metal, ...)
   - Stack the pieces to construct the whole geometry

5- **stereolithography** (materialise.com ; SLA = StereoLytography Apparatus)
   - Pieces are produced in liquid polymer, with a same material builded supporting structure.
   - The polymer is solidified layer by layer : during the process, the pieces supporting tray go down in the polymer.

6- **polyshape process** (SLS = Selective Laser Sintering ; DMLS = Direct Metal Laser Sintering, SLM = selective laser melting)
   - Pouder layers with selective laser melting or sintering, layer by layer (plastic or metal)
   - The support, the pouder and the pieces are cooled before cleaning

7- **CLADDING** :
   - Simultaneous metal powder projection and melting by laser : the melted powder solidifies and forms the part layer by layer. The support can be curved.

Sources : http://www.industrie-techno.com/sept-facons-de-fabriquer-en-3d.23174
2- Main direct fabrication technics in use

Several machine manufacturers ...

Source: http://reprap.org/
2- Main direct fabrication technics in use – Who could make the part?

- **SLS polymer and metal, finishing**
- **SLA (simple ou bimatière), finitions**
- **FDM**
- **Frittage PA et photopolymère**
- **UGV, Electroérosion, MMT, scanner 3D**

**Additive manufacturing machine manufacturers**

**IPHC-ORTECH collaboration**
Additive Manufacturing

Thinking about innovation

3- achievement examples

generical optimization in an IPHC project,
Quick overview of
some research and development examples in several domains
Numerical method at IPHC

Imaging System

AMISSA
developed and used at IPHC

3D images superposition
Acquisition by $\mu$TEMP and $\mu$CT
(skeleton, flesh and localisation of cancer in mouse)

Cloud of points
**Numerical method at IPHC**

3D CAD volume

After treatment with CATIA V5 (skull and head of a rat)

.stl printing file

Impression 3D

55mm

Very fine details and fragiles, 
Vivus and humidity sensibility

Produced by LpoDECK

Rat skull printing

©IPHC/ImaBIO

Cloud of points

©IPHC/ImaBIO

©IPHC/ImaBIO
Mouse supporting during scanning time

Requests:
- General Anesthesia
- Mechanical supporting of mouse (40 gr)
- Material optimization around the mouse
- Possibility of hot air circulation

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FDM on STRATASYS/DIMENSION (at CEMES Toulouse):
ABS thread / layer thickness = 0.254 mm
Photopolymer support by OBJET 250

Material evolution, in water immersed part and leave in sun shine

Thickness wall = 0.4 mm

Unused part

Totally removed supporting resin
Total in water immersion
Solar UV ray exposition

After 3 days:
- Deformation
- Hardening
Requests:
- General Anesthesia
- Mechanical supporting of rat (800 gr)
- Material optimization around the mouse
- Possibility of hot air circulation

Rat supporting during scanning time
CADVISION / IPHC manufacturing test
Mesurements on fdm produced part
on Fortus 250 Stratasys machine, with layer thickness of 0,178 mm

Differences between several numerical dimensions and real produced dimensions are between 0,04 and 0,2 mm.

ABS fdm part
- Height 73 mm
- Thickness plate 12 mm
- Cylindrical part thickness 4 mm

Part produced by Cadvision
Contact : Stefka BARZAKOVA / stefka@cadvision.fr

Photos : ©IPHC.cnrs.fr
Techno flower

Printed by OBJET connex

multimaterial 3D printing

Inflatable structure

Source: http://www.industrie-techno.com/fleurs-de-techno.27541
Building 3D printing – concrete masonry unit -1-

Extrusion of high performance concrete
Strength: 3,000 to 10,000 psi

Source: [https://www.youtube.com/watch?v=ehnzfGP6sq4&list=PLwZuNacIKo6a3C1tavZ5hnS2WABYSGbJv](https://www.youtube.com/watch?v=ehnzfGP6sq4&list=PLwZuNacIKo6a3C1tavZ5hnS2WABYSGbJv)

NASA development

Source: [http://www.contourcrafting.org/](http://www.contourcrafting.org/)
Building 3D printing – concrete masonry unit -2-

Source: https://www.youtube.com/watch?v=EfbhdZKPHro&list=PLwZuNacIKo6a3C1tavZ5hnS2WABYSGbJv
Robot 3D printing

Source: http://www.dvice.com/2013-5-22/material-anti-gravity-3d-printer
Architecture models

How it was...
How it could be...

Source: http://www.hp3dprinting.co.uk/applications.htm

Source: http://www.midwestmodel.com/pagesroot/pages/ProjectDetails.aspx?ProjectId=339&DetailsType=ATOZ
Automobile Design

research and development department
Combination of manufacturing technics
First Asian 3D Print Fashion Show

2013
First fashion meeting with 3D printed wears, organized by Materialise, belgian company.

Source: http://www.numerama.com/magazine/26298-un-defile-de-mode-pour-l-impression-3d.html
“The clothing was modeled as it would be if it were knitted with thread inside the 3D software,” Ono told 3DPrint.com.

Source: https://3dprint.com/149870/3d-printed-amimono-woven-fashion/
Nike Debuts First 3D-Printed Football Cleat

Source: http://mashable.com/2013/02/27/nike-3d-printed-cleat/
MADE IN 3D challenge - 2011

This strange parts supports an Iphone and emplify sound coming out the phone.

To make a 3D ready printing design is the main goal.

This part is called the ‘Mush’ and was designed with CATIA V5 by a young designer.

http://www.3dvia.com/blog/made-in-3d-challenge/
3D Printing Pen (Sculptures drawing)
February 19, 2013

Source: http://www.thisiscolossal.com/2013/02/the-worlds-first-3d-printing-pen-that-lets-you-draw-sculptures-in-real-time/
A kid drawing converted into 3D part

Edible prints

Although these ideas are only being experimented in labs for now, it’s thrilling to know that these innovations might be very soon a part of our daily consumption.

Source: http://blsciblogs.baruch.cuny.edu/yomara89/?p=7
Food

Food Ink enterprise

Source: http://www.lesimprimantes3d.fr/limprimante-3d-fabrique-chocolat/

Chocolate 3D printing
Meat 3D printing

How Cultured Meat Works

1. Biopsy a small number of cells
2. Multiply using an animal-free growth serum
3. Print sheets of cells using a 3D printer
4. Layer sheets to create cubes
5. Grind cubes, then add flavor and nutrients
6. Cook product and package for resale

Source: http://veganvine.blogspot.fr/2013/08/you-can-take-meat-out-of-animal-but-you.html

Source: http://www.peta.org/issues/animals-used-for-food/meat-wastes-natural-resources/
Industry news

Renault Trucks enterprise prints their motors

Source: https://www.industrie-techno.com/renault-trucks-imprime-ses-moteurs-en-3d-metal.47535

1/2017

Michelin and Fives enterprises wants to be leaders in metal additive manufacturing

Source: https://www.industrie-techno.com/impression-3d-metal-michelin-et-fives-se-positionnent-sur-le-marche.39690

9/2015

BeAM enterprise adds its technology in Fives 5 axis production machines

Source: https://www.industrie-techno.com/fabrication-additive-beam-integre-sa-technologie-aux-batis-5-axes-defives.38970

1/2015

-> CLAD printing process (IREPA Laser)
See machines by DMG MORI

-> http://www.beam-machines.fr/
Leap Fuel Nozzle

Aviation développement:
Problem of nozzle: cooking with carbon deposition
Function: Spray fuel into combustor

- The temperature increases up to 3000°C -

Solution with DMLS:
Efficiency
engine durability (X5)
18 parts in one single piece
Weight -25%
Better than casting, machining, welding,...
Production speed x20

Source: http://www.youtube.com/watch?v=I0SX1kmzyw
Numerical method
CAD – DMLS – PLASTIC INJECTION

Industry news

Printing maraging steel parts
Source: http://www.incept3d.com/metal--dmls.html

Printing completed with machining
Source: http://www.3ders.org/articles/20120918-shell-makes-complex-structures-with-3d-printing.html

Printing Titanium bike frame
Source: http://inhabitat.com/empire-cycles-unveils-the-worlds-first-ultralight-3d-printed-titanium-bike/

Printing Nylon bike
Implants

Custom Prosthetics

ESA : 3D Printing Metals on earth and in Space

The AMAZE project team printed its logo in titanium as an intricate net shaped to millimeter-level precision to demonstrate what metal 3D printing can do. The project is working with materials that can withstand temperatures up to 3500 °C and involves 28 industrial and educational partners across Europe.
(Source: ESA-N. Vicente)

Source 2013 : http://www.esa.int/Our_Activities/Human_Spaceflight/Research/3D_printing_for_space_the_additive_revolution
NASA-funded research by University of Southern California professors Behrokh Khoshnevis, Madhu Thangavelu, Neil Leach, and Anders Carlson is exploring how structures on the moon can be made using the Contour Crafting robot. Under NASA’s Innovative Advanced Concepts program, the researchers aim to develop methods for creating infrastructure, such as roads and landing pads, to support human settlement on the moon. The technology can create structures in situ from local materials, which is especially important for long-term, continuously expanding operations on the moon. For example, the team is exploring a nozzle system that heats lunar soil into a cement-like paste. In this visualization by Behnaz Farahi and Connor Wingfield, a lander descends on a pad fabricated by the Contour Crafting robot.

(Source: University of Southern California/Contour Crafting)
Additive Manufacturing

Thinking about innovation

4- some 3D printers
4- some 3D printers

**Stratasys uPrint SE**

ABSPlus thermoplastic thread
With soluble resin support
Oven temperature : 260°C
Layers thickness between 0,12 and 0,25 mm
Geometrical precision ~0,2 mm
Production 3D array 152 x 203 x 152 mm
~20 k€

Source : http://www.u-print.fr/
4- some 3D printers

UP MINI 3D PRINTER
ABS with thread
layers 0.15 to 0.40 mm
3D array: 140 x 140 x 135 mm
~3k€

Source: http://modeler3d.fr/
4- some 3D printers

A2 V2

3 nozzles
ABS, PLA, NylonCarbon, PC, PC-ABS, PETG, ... thermoplastic thread
With soluble resin support (SSU01)
Regulated oven temperature : 80 °C
Max nozzle temperature : 410 °C
Max plate temperature : 135 °C
Minimum layer thickness : 0,05 mm
Resolution : 0,015 mm
Geometrical precision ~0,2 mm
Production 3D array 620 x 350 x 490 mm
~25 k€

Source : http://www.3ntr.eu/a2/
4- some 3D printers

Apium P 155

High performance polymers
PEEK, POM-C, PVDF, PEI Ultem 1000 ...
thermoplastic thread
Specific regulated oven temperature
Max nozzle temperature : 520 °C
Plate temperature : up to 120 °C
Minimum layer thickness : 0,1 mm
Machine resolution : X Y 0,0125 mm / Z 0,05 mm
Product resolution : X Y 0,5 mm / Z 0,1 mm
Production 3D array 145 x 135 x 148 mm
~35 k€

Source : http://apiumtec.com/
4- some 3D printers

3D Roboze One+400

High performance polymers  
PEEK, Carbon Pa, PC, PMMA, ...
thermoplastic thread  
Specific regulated oven temperature  
Max nozzle temperature: 520 °C  
Plate temperature: up to 150 °C  
Minimum layer thickness: 0,1 mm  
Machine resolution: 0,05 mm  
Production 3D array 200 x 200 x 200 mm  
~40 k€

Source: http://www.primante3d.com/kreos-roboze-20160520/
4- some 3D printers

**Objet30 Pro**

Polyjet printer
3D array : 294 x 192 x 148.6 mm
Layers thickness 28 microns
Layers thickness 16 microns with VeroClear material
Resolution: 600 x 600 x 900 dpi
Precision about 0.1 mm
7 different photopolymers (indépendant printings)
With resin support material
~20k€

Source: http://fr.objet.com/

EDEN 260 at Pôle ORTECH (Lycée Théodore Deck, in Guebwiller, France)

http://www.lyceedeck.fr/poleortech/equip_eden.html
4- Some 3D printers

**FORMIGA P100**
sls PA 100µm
~200 k€
Maintenance ~2-4k€/an

FORMIGA P100 at Pôle ORTECH (Lycée Théodore Deck, in Guebwiller, France)

Source: http://www.eos.info/en

http://www.lyceedeck.fr/poleortech/Equip_EOS.html
Powder and binder jet
By Zcorp (3D System since 2012)

ZPRINTER 150 by ZCORP
monochrom (white)
Resolution : 300 x 450 dpi
minimal size : 0,4 mm
vertical creation speed : 20 mm/heure
fabrication maximal size : 236 x 185 x 127 mm
layer thickness 0,1 mm

Zprinter 150
Monochrom voxeljet ~15k€

Zprinter 250
Polychrom voxeljet ~25k€

Source : http://www.zcorp.com/
(this adress doesn’t work anymore)
Powder and binder jet
By VOXELJET

build space: **4000 x 2000 x 1000 millimetres**

Source: http://www.voxeljet.de/en/systems/vx4000/

- Powder = PMMA or SAND
- Print resolution x, y: 600 dpi
- Layer thickness: 120/300 μm
- Build speed: 15.4 mm/h (≈123 l/h)

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3Z MAX printer by SolidScape

Precision and High quality wax printing
For lost wax casting

Source: http://www.multistation.com/3Z-MAX
5- Materials

*Several possible materials used in 3D printing industry*
Several plastic materials by STRATASYS

Stratasys fdm production possibilities:


Source: http://www.stratasys.com/materials/fdm/compare-fdm-materials

Stratasys Polyjet plastic production possibilities:

Vero, Translucent Rigid, High Temp, Durus, Digital ABS, Digital ABS2, Tango (Rubber-Like / Flexible), Performance Digital, Rubber-Like Digital, Biocompatible


Source: http://www.stratasys.com/materials/polyjet/compare-polyjet-materials

http://www.stratasys.com/
Several plastic and metal materials by EOS

EOS SLS plastic production possibilities:

Alumide (polyamide aluminum filled), CarbonMide (polyamide carbon fiber-reinforced), PEEK HP3 (PEEK, polyaryletherketone), PA 1101 (PA11), PA 2015 (PA12), PA 2200, PA 3200, PrimeCAST 101 (PS, polystyrene),

Source : data sheet on
http://eos.materialdatacenter.com/eo/standard/main/ds

EOS DMLS metal production possibilities:

Aluminium AlSi10Mg, CobaltChrome MP1, CobaltChrome SP2, MaragingSteel MS1, NickelAlloy IN625, NickelAlloy IN718, StainlessSteel GP1, StainlessSteel PH1, Titanium Ti64


Source : http://www.eos.info/
Several materials by 3D SYTEMS

3D Systems SLA plastic production possibilities: Accura series
Accura 25, 55, 60, 48HTR, ABS Black (SL 7820), ABS white (SL 7810), Amethyst, Bluestone, Casto, Casto Free (SL 7800), CeraMAX Composite, ClearVue, ClearVue Free, e-Stone, Peak, Sapphire, SL 7840, Xtreme, Xtreme White 200

3D Systems SLS plastic production possibilities: CastForm PS and Duraform series
Duraform EX Black, EX Natural, Flex, FR100, GF, HST Composite, PA, ProX
Source: data sheet on http://www.3dsystems.com/materials/production

3D Printer plastic production possibilities: VisiJet series (27 different materials)
Source:
http://www.3dsystems.com/materials/professional

DMS metal production possibilities:
17-7 PH, Aluminium, Beryllium Copper, Brass, Carbon Steel, Copper, Nickel Alloys, Phosphor Bronze, Spring Steel, Stainless Steel, Titanium
Also some finishes: anodized, Heat Treated, Laser Welded, Painted, Powder Coated, ...
Source: http://www.3dsystems.com/quickparts/production/quick-sheet-metal
Source: http://www.3dsystems.com/
Material today in use or development in progress

**Plastics or ‘plastic like’**
ABS Acrylonitrile Butadiene Styrene
Nylon
PEHD
Polycarbonate
ULTEM (Stratasys)
PLA
Polyjet Resin
PMMA
PA
PEEK
PSU
Multicolor or not
...

**Soluble**
PVA
HIPS

**Metals**
Aluminium
Nickel
Tantale
Tungsten
Titanium (Ti-6A-4V)
Maraging steel
Stainless steel 316L
Inconel
Cr-Co alloy
Aluminium alloy
Gold, silver

**Alternative:**
Biological material: bone, lever, skin, ...
Meat,
Pizza,
Chocolate, sugar

**Other**
Ceramic (ZrO2, TiO2, SiC)
Sand
Wax
Alumid
Additive Manufacturing

Thinking about innovation

6- Outlook
5- Outlook

Fdm patent is already expired (in 2009)

Key 3D printing patent expired 28th of January 2014
Apparatus for producing parts by selective sintering
US 5597589 A
Abstract:
An apparatus for selectively sintering a layer of powder to produce a part made from a plurality of sintered layers. The apparatus includes a computer controlling a laser to direct the laser energy onto the powder to produce a sintered mass. The computer either determines or is programmed with the boundaries of the desired cross-sectional regions of the part. For each cross-section, the aim of the laser beam is scanned over a layer of powder and the beam is switched on to sinter only the powder within the boundaries of the cross-section. Powder is applied and successive layers sintered until a completed part is formed. Preferably, the powder dispensing mechanism includes a drum which is moved horizontally across the target area and counter-rotated to smooth and distribute the powder in an even layer across the target area. A downdraft system provides controlled temperature air flow through the target area to moderate powder temperature during sintering.

Even it’s a little different, but 3D printing using powder will explode in 2014
More possible materials!
5- Outlook

Source: http://www.3ders.org/articles/20130529-mckinsey-report-12-disruptive-technologies-by-2025-3d-printing-included.html
5- Outlook

Possibilities for innovation in physics developments

Without assembling or Assembling by glueing, bolting, screwing, ...

Multifunctionnal parts

Additive Manufacturing Machine

Geometries

New materials

integration

In existing manufacturing process

Where are the limits?

Some benchmarks:
- Service society: Specialized in additive manufacturing
- Possible plastics: ABS, PLA, PC, PA, Plastique ceramic charged, fibres or aluminium alloy charged, ...
- Possible metals: 316L, Ti64, TA6V, maraging steel, CR-CO, Bronze, Inconel, Nickel alloy, aluminium alloy, ceramics, ...

Including 3D wire screen (filter), Cooling channels, Volume optimisation

Plastics, Metals, Composites

EBM Electron Beam Melting

DMLS Direct Metal Laser Sintering

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Metal 3D Printing Services

I3DFG enterprise

Aluminium, titatium, stainless steel, maraging steel, inconel (IN718) or customer powder

Source: http://www.i3dmfg.com/industries/tooling/

Aluminum, Stainless Steel, and Titanium DMLS printing possibilities
Source: http://3dprintingcolorado.com/3d-metal-printing/

Smit Röntgen enterprise

Tungsten alloy parts

Source: http://www.smitroentgen.com/

Post treatment processes

5- Outlook

Be careful about copyright!

Where is the limit of 3D printing?

A lot of leaders: each in his domain ...
5- Outlook : questions...

When will I use 3D printing technology ?

What have I to do with it ? What can I do with it ?

Just think, simulate and print ...

5- Outlook : questions...

How will you use 3D printing?

5- Outlook : questions...

**Innovation : ears and guns produced by 3D printing**
Some steps were forgotten ...

And printing something between ears ?

Source : http://www.clubic.com/diaporama/photo-la-semaine-de-flock-enleve-les-bigoudis-de-l-actu-61890/
5- Outlook : questions...

Easy copy

We should be careful
About file protection

Source: http://textually.org/3DPrinting/2012/12/031489.htm
5- Outlook

**Futur is 3D printing**

Source: [http://www.3dprinter.net/3d-printing-the-business-opportunities](http://www.3dprinter.net/3d-printing-the-business-opportunities)
Additive Manufacturing

Thinking about innovation

Annex
Plastic printing services

Source: http://www.aniwaa.com/blog/the-best-3d-printing-services/
Direct metal laser sintering

Source: https://fr.pinterest.com/explore/direct-metal-laser-sintering/
Association Française de Prototypage Rapide :
http://www.afpr.asso.fr/

Assises Européennes de Prototypage Rapide :
http://code80.net/afpr/aepr/
National Additive Manufacturing Innovation Institute:
SOURCE: http://namii.org/resources/presentations/

77 members from 15 countries
Direct Metal Laser Sintering
About powder production...

Source: http://www.epma.com/
Some Fab Labs in Europe

Source: http://www.fabfoundation.org/
The Fab Charter

What is a fab lab?
Fab labs are a global network of local labs, enabling invention by providing access to tools for digital fabrication

What’s in a fab lab?
Fab labs share an evolving inventory of core capabilities to make (almost) anything, allowing people and projects to be shared

What does the fab lab network provide?
Operational, educational, technical, financial, and logistical assistance beyond what’s available within one lab

Who can use a fab lab?
Fab labs are available as a community resource, offering open access for individuals as well as scheduled access for programs

What are your responsibilities?
safety: not hurting people or machines
operations: assisting with cleaning, maintaining, and improving the lab
knowledge: contributing to documentation and instruction

Who owns fab lab inventions?
Designs and processes developed in fab labs can be protected and sold however an inventor chooses, but should remain available for individuals to use and learn from

How can businesses use a fab lab?
Commercial activities can be prototyped and incubated in a fab lab, but they must not conflict with other uses, they should grow beyond rather than within the lab, and they are expected to benefit the inventors, labs, and networks that contribute to their success

draft: October 20, 2012

Source: http://www.fabfoundation.org/fab-labs/the-fab-charter/
FABLABs around the world
A Fab Lab in Strasbourg...
### 3D printer prices

<table>
<thead>
<tr>
<th>Model</th>
<th>Price</th>
<th>Build Volume</th>
<th>Layer Resolution</th>
<th>Material</th>
<th>Nozzle Diameter</th>
<th>Maximum Print Temp</th>
<th>Dimensions</th>
<th>Chassis</th>
<th>Body Type</th>
<th>Body Style</th>
<th>Build Platform</th>
<th>XYZ Actuation</th>
<th>Connectivity</th>
<th>Operating System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapide One</td>
<td>$2499</td>
<td>170x170x170mm</td>
<td>100um</td>
<td>PLA/ABS/PVA/Nylon</td>
<td>0.4mm</td>
<td>350C</td>
<td>332x445x345mm</td>
<td>Aircraft Grade Aluminum (CNC)</td>
<td>Fully Enclosed</td>
<td>Designer</td>
<td>Heated Aluminum</td>
<td>Water Resistant Bronze</td>
<td>USB, SD Card</td>
<td>Windows (7+) Mac OS X (10.6+) Linux (Ubuntu 12.04+)</td>
</tr>
<tr>
<td>Replicator 2</td>
<td>$2799</td>
<td>250x160x150mm</td>
<td>100um</td>
<td>PLA/ABS</td>
<td>0.4mm</td>
<td>230C</td>
<td>480x420x531mm</td>
<td>Powder Coated Steel</td>
<td>Open</td>
<td>Box</td>
<td>Heated Aluminum</td>
<td>Water Resistant Bronze</td>
<td>USB, SD Card</td>
<td>Windows (7+) Mac OS X (10.6+) Linux (Ubuntu 12.04+)</td>
</tr>
<tr>
<td>Cube X</td>
<td>$2799</td>
<td>275x265x240mm</td>
<td>100um</td>
<td>PLA/ABS</td>
<td>0.4mm</td>
<td>260C</td>
<td>515x515x566mm</td>
<td>Steel</td>
<td>Open</td>
<td>Box</td>
<td>Heated Aluminum</td>
<td>Linear Bearings</td>
<td>USB</td>
<td>Windows (7+)</td>
</tr>
</tbody>
</table>

# 3D printer prices

Source: Industrie et Technologies – May 2010

<table>
<thead>
<tr>
<th>Marque</th>
<th>Multi station</th>
<th>Solido</th>
<th>3D Systems</th>
<th>Zcorporation</th>
<th>Stratasys</th>
<th>Solid scape</th>
<th>Objet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nom</td>
<td>Extrud3D plastique</td>
<td>SD3000 Pro</td>
<td>V-Flash</td>
<td>Projet 3000 Dentaire</td>
<td>Zprinter 350</td>
<td>Zprinter 650</td>
<td>uPrint</td>
</tr>
<tr>
<td>Taille Objet</td>
<td>60 x 60 x 80 x cm</td>
<td>46 x 77 x 42 cm</td>
<td>56 x 69 x 79 cm</td>
<td>73 x 125 x 150 cm</td>
<td>20 x 25 x 20 cm</td>
<td>25 x 38 x 20 cm</td>
<td>63 x 66 x 78 cm</td>
</tr>
<tr>
<td>Résolution</td>
<td>400 μm</td>
<td>100 μm</td>
<td>220 μm</td>
<td>328 x 606 dpi</td>
<td>450 x 300 dpi</td>
<td>600 x 540 dpi</td>
<td>200 μm</td>
</tr>
<tr>
<td>Consommable</td>
<td>ABS</td>
<td>PVC</td>
<td>FTi230</td>
<td>Bimatériaux Support/résine</td>
<td>Poudre + liant</td>
<td>Poudre + liant</td>
<td>Bobine ABS</td>
</tr>
<tr>
<td>Principe</td>
<td>Extrusion fil plastique</td>
<td>Plastic sheet lamination</td>
<td>Type stéréolithographie</td>
<td>Ajout de couches</td>
<td>Jet d’encrage couleur sur poudre</td>
<td>Jet d’encrage couleur sur poudre</td>
<td>fused Deposition Modeling</td>
</tr>
<tr>
<td>Prix</td>
<td>1 000 €</td>
<td>7 950 €</td>
<td>9 900 €</td>
<td>70 000 €</td>
<td>22 000 €</td>
<td>50 000 €</td>
<td>11 999 €</td>
</tr>
<tr>
<td>Les plus</td>
<td>La moins chère</td>
<td>Faible coût impression</td>
<td>Prix peu élevé et simplicité</td>
<td>Wax up dentaire en continue</td>
<td>Proto couleur, faible coût impression (0.1 €/cm²)</td>
<td>Idem Z350 avec bac impression plus grand</td>
<td>Technologie nid d’abeille, moins de matériau</td>
</tr>
<tr>
<td>Les moins</td>
<td>Pas de détails très fins</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparatif Imprimantes 3D du marché - Source: Industrie et Technologies - Mai 2010

SOURCE: [http://p1.storage.canalblog.com/16/54/447324/54635666.png](http://p1.storage.canalblog.com/16/54/447324/54635666.png)

Additive Manufacturing

Thinking about innovation

6- Workshop
Workshop

Metal powder and laser...
Direct manufacturing

Scanner

Engineering

Points cloud

Catia V5 workbenches:
Used workbenches: STL, Part Design, GSD, QSR, DSE

CATIA V5 CAD Modeler

FEM specific files
ANSYS, COMSOL, other

CATIA V5

CAD part geometry

Numerical method

STL workbench
CATIA V5

AM specific file

Sending to 3D printer

stl file

Manufacturing by Additive Manufacturing

less material waste
create products that is impossible to make with existing machining techniques.
Workshop

1- CAD (presentation)
2- Topological optimisation
3- stl file slicing

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Numerical method from cloud to simulation

Cloud of points in **CATIA V5 environment**...

DSE

QSR

Part Design

Analysis and Simulation

Importation
Filtration
Reparation

Automatic Surface construction

solid

Exportation Simulation

~80cm

ESIPAP - European School of Instrumentation in Particle and Astroparticle Physics - Archamps 7-3-2017
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Workshop

1- CAD (presentation)
2- Topological optimisation
3- stl file slicing

Where should be the material to optimise the piece response?

http://www.altairhyperworks.com/product/solidThinking-Inspire

SolidThinking/University Products:

Altair contact:
Julien Grezolle, Application Engineer, jgrezolle@altair.com
Static analysis

Topological optimisation
Show/Hide

Store/Recall Views

Switch to Perspective Projection

Rotate to closest principal axes

Fit Selected (f)

Add/Edit Section cuts
Workshop

Topolical optimisation of a Cantilever beam

width 10 mm x height 20 mm x length 100 mm
Steel AISI 304 (E = 195.10^9 N/m^2)
Support fixed
Force = 100 N
Mesh size = default value

Theoretical Beam deflection: without shear effect
\[ d = \frac{F.l^3}{3EI} = \frac{100.0.1^3}{(3.195.10^9)(10.20^3)/12} = 3.08.10^{-4} \text{ mm} \]

Finite Element deflection: with shear effect, \( d = 2.65.10^{-2} \text{ mm} \)
With default values  \[ \text{deflection} = 2.65 \times 10^{-2} \text{ mm} \]
With default values
Évolution de la topologie
PolyNURBS solution

-> export to STEP file
PolyNURBS solution \( \Rightarrow \text{deflection} = 5.58 \times 10^{-2} \text{ mm} \)
Main steps
With default values

\[
\text{deflection} = 2.65 \times 10^{-2} \text{ mm}
\]

Topological optimisation

\[
\text{deflection} = 5.58 \times 10^{-2} \text{ mm}
\]
THE INSPIRE 2017 WORKFLOW

Generating the ideal part concept in Inspire is quick and easy. View the Inspire 2017 workflow below. Click on each step to see a quick video demo.

1. Sketch or Import a Part
2. Defeature the Part
3. Define Fasteners, Joints, and Contacts
4. Assign Materials and Loads
5. Generate Ideal Shape
6. Refine using PolyNURBS or Export to CAD
7. Verify Performance
8. Manufacture

Workshop

1- CAD (presentation)
2- Topological optimisation
3- stl file slicing
Workshop

1- CAD (presentation)
2- Topological optimisation
3- stl file slicing

ON YOUR DESKTOP

Makerbot Desktop 3.7

Seller:

Makerbot Replicator 2X
Makerbot Desktop 3D printing settings
Makerbot Desktop 3D printing custom settings
Makerbot Desktop 3D printing custom settings
Makerbot Desktop
3D printing custom settings
Makerbot Desktop 3D printing custom settings
Makerbot Desktop 3D printing exportation

⇒ .x3g
Makerbot Replicator 2X specific file exporting
Makerbot Desktop 3D printing printing preview
First raft layer

First piece layer

Raft

Piece (here, without support)

Makerbot Desktop
3D printing printing preview
First specific layers
General FDM 3D printing run problems
some solution

Incomplete bottom layer -> add additional bottom layers

Hanging strands -> change layer thickness and cooling (fan or ambient temperature)

Too small holes -> use offsets

Burn marks on model -> clean or change nozzle

Irregular walls or material deficiency -> clean, change extruder cable or PCB, or change extruder

Layer shifting during print -> tighten screws on polleys

Unfinished part -> possible problem origins = material tangled on spool, material running out or material blocked in the extruder

Extrusion problem -> change extruder cable, or change thermocouple and heater

Wrapping (raft doesn’t stick to the platform) -> adjust distance between nozzle

Delamination of layers (layers split apart)
-> use material with low shrinkage level, print at a temperature more than 20°C.
7- Conclusion
6- Conclusion

1- Complementary manufacturing processes: machining and 3D printing

2- New items in 3D printing:
   CAD, STL and AMF file format, design, topological and process optimisation,
   Finite Element simulations, Slicing, printing settings, safety, file protection,

3- New Additive Manufacturing machines with increased performances,
   new materials (plastic or metallic) and New services
Thanks for attention!

Source: http://www.ufunk.net/en/techno/3d-printed-flowers/