Additive Manufacturing or 3D prototyping

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Definition

Additive Manufacturing is defined in ASTM F2792-12 as an assembly process of successive thin layer of materials by using numerical data's issued from a 3D CAD model.



Additive Manufacturing is a complement to the subtractive manufacturing (milling, turning, etc...)



Base conditions

3 parameters are necessary for additive manufacturing

- ✤ Materials⁻
 - Energy
- Specific to the additive manufacturing technology
- Numerical model (CAD file)

Materials

They can have various state, liquid, powder, wire and thin film.

Energy

Melting, sintering, polymerization or reticulation process require energy for the part manufacturing. The energy is supplied by a laser, UV or IR light, electron beam or heating source for the most common systems

Numerical model

CAD file are generally convert to a specific exchange format file such STL, IGES, STEP.

Recently a new format AMF has been define and publish by ASTM (ASTM F2915-12) to improve the resolution, the size and the data integrity. This new format will be implement gradually by the 3D equipment manufacturer's and the CAD software editor's.

STL vs AMF: STL files -> volume define by flat triangles, AMF files -> volume defined by curved triangles



Existing Technologies

7 technologies are actually available on the market:

- **SLM -> Selective Laser Melting**
- EBM -> Electron Beam Melting
- **SLS** -> Selective Laser Sintering
- MM -> Multijet Modeling (3 versions)
- **FDM** -> Fused Deposition Modeling
- SLA -> Stereo Lithography Apparatus

LOM -> Laminated Object Modeling



Materials

Each technology have is specific range of materials.

Only SLS/SLM can fulfill the requirements for using plastic, liquid, metallic or ceramic materials.

All metallic additive manufacturing melting processes are using powders except the LOM who needs thin sheet metal

The size of the particles have a strong influence for the precision and the surface aspect of the manufactured parts

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| Manufacturing Method | | | SLS | MM | FDM | SLA | LOM | | | | SLM/SLS | EBIV |
|----------------------|--------|-----------------------|-----|----|-----|-----|-----|--------|-----------|-------------------------------|---------|------|
| Plastics | Base | ABS | | | х | | | Metals | Ti Base | Ti (G2, G3) | х | x |
| | | PA12 | x | | | | | | | Ti6Al4V (G5 et G23) | х | x |
| | | PC/ABS | | | х | | | | Fe Base | DS20 Acier+Ni | x | x |
| | | PC | | | x | | | | | DSH20 Acier + CrNiMoSiV | x | x |
| | | PEEK | Х | | | | | | Stainless | 1.4540 | Х | X |
| | | PEI | | | x | | | | Steels | 1.4542 | х | x |
| | | PPSU | | | Х | | | | | 1.2709 | Х | X |
| | | PS | Х | | | | | | | 1.44XX | Х | X |
| | | PVC | | | | | Х | | Ni Base | Inconel 625 | Х | X |
| | Others | ABS Like | | Х | | | | | | Inconel 718 | Х | X |
| | | PP Like | | Х | | | | | Co Base | CoCrMo SP2 | Х | X |
| | | Rubber Like | | Х | | | | | | CoCrMo MP1 | Х | X |
| | | Polyepoxyds Resins | | x | | x | | | Cu Base | Bronze DM20 | х | x |
| | | Elastomeric Resins | | x | | x | | | Al Base | AlSi10Mg | х | x |
| | | Wax | x | x | | | | | Others | Та | | x |
| quid | | Sand | Х | X | | | | | | W | | Х |
| owders | | Ceramics | Х | X | | | | | | Cu | | X |
| 'ires/Sheets | | Paper | | | | | Х | | | Nb | | X |
| | | Aluminium | | | | | X | | | Hard Metal | | Х |



Selective Laser Melting SLM

- Various metallic materials
- Very good mechanical resistance (>95% density of the original material)
- Melting under gas protection (Ar or N2)
- Heating temperature: 40-60°C
- Part tolerances : +/- 0.05 à 0.15mm















Selective Laser Sintering SLS

- Plastic, metallic, ceramic/sand materials.
- Mid to good mechanical resistance (~70-80% of the original density)
- Melting, sintering under gas protection (Ar or N2)
- Heating temperature (only for plastics) : ->150-180°C (PA) up to ->300°C (PEEK)
- Parts tolerances: +/- 0.15 à 0.3mm







Electron Beam Melting EBM





Multijet Modelling (1)

Actual existing technology denomination: Multijet Modeling (Polyjet) or Jetted Photopolymer

- Acrylic, polyepoxyd, wax, elastomeric base materials.
- Low to medium mechanical resistance.
- Very good density (>99%)
- Materials very sensitive to day light or UV exposure. Decrease of performance after some weeks/months
- Possibility to mix colors or materials.
- Part tolerances: +/- 0.05 à 0.25mm





Multijet Modelling (2)





Multijet Modelling

Samples of parts manufactured by Multijet Modeling or Jetted Photopolymer technology





Fused Deposition Modeling FDM





Stereolithography Apparatus SLA

- Polyepoxyd UV laser cured materials.
 - Low to medium mechanical resistance
 - High sensitivity to UV and daylight.
 - Very good density (>98%)
 - Part tolerances: +/- 0.03 à 0.15mm







Laminated Object Modeling LOM





3D prototyping@EPFL

- Need to offer a centralized service for rapid manufacturing
- Complementary service with the Technical Workshop Platform (PAT) (mechanical workshops, PCB manufacturing unit)
- Opportunity to have a strong interaction with existing infrastructures and services for such heavy equipment
- Investments opportunities for 3 additive manufacturing technologies offering services for research and education (Full operational for Q1/2014)
- Skills and competencies rationalization in 3D manufacturing with dedicated staff for support and manufacturing









EPFL equipment

Multijet Modelling MM

- > Manufacturer: OBJET Geometries Ltd
- Model: Connex 500
- Available materials (liquids):
 - ABS-like (ivory)
 - Rubber-like base (black) ->27ShA
 - PC-like (semi-transparent)
- Mixing of materials, hardness and grey shades inside the same part/assembly
- Tolerances: +/- 0.05 à 0.15mm
- Maximum part size:
 - L:490x W:390x H:200mm

Fused Deposition Modeling FDM

- Manufacturer: Stratasys Inc.
- Model : Fortus 400mc
- Available materials (wires):
 - ABS (ivoire)
 - PC-ABS (noire)
 - PC (blanc)
 - PPSU (beige)
- Tolerances: +/- 0.13 à 0.20mm
- Maximum part size:
 - L:406x W:355x H:406mm

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Selective Laser Sintering SLS

- Manufacturer: EOS GmbH
- Model : EOSINT P395
- Available materials (powders):
 - PA 12 (white)
 - PA 12+ Aluminum (grey)
 - On demand
 - PA 12+ Carbon Fiber (black)
 - PA 12+ Glass Fiber (white)
- Tolerances: +/- 0.13 à 0.25mm
- Fusion/sintering under temperature (160-180°C) and control atmosphere (N2)
- > Maximum part size:
 - L:340x W:340x H:620mm





Questions / Sources

Thanks for your attention

Sources:

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