The rise of 3D Printing as a Digital Fabrication approach

Diginova Meeting, Centi, 4 March 2013

Contents

- The concept of 3D Printing (Additive Manufacturing / Digital Fabrication)
- Why it’s important
  - Why does it change the way we think about stuff?
- The importance of design
  - Lightweighting, functionality
- What the future holds….
Additive Manufacturing

- Effectively “3D Printing”
  - Emerged from Rapid Prototyping type techniques (SL, LS, etc)
  - Conceptually simple – belies significance
  - AM is very different to RP – even if same systems are used

- Dedicated manufacturing systems beginning to emerge
  - Plastics
  - Metals (increasingly useful)

- Principal advantage?
  - No mould tooling
  - Unparalleled Geometric freedom

Where it’s being used

- Increasingly being used in demanding applications
- Ideal for Complex, High Value, medium-low volume, customised products
Why is it important?

2. Maximising design complexity & flexibility
3. Increasing part functionality
4. Product personalisation
5. Reducing environmental burden
6. New business models and supply chain realignment

Identified as Key to UK:
- One of 22 TSB Core Technology Competences
- One of 12 EPSRC Centres for Innovative Manufacturing
- Identified by DSTL as strategic technology for defence and security
- UK currently leading AM / 3DP research domain
  - Innovation is important
    - needs underpinning with world-class research
  - Pipeline of activity
  - Needs translation and exploitation
  - Skills shortage a significant issue
    - Technician to PhD
The importance of design

- Processes are just enablers
- The real potential of AM comes from the *Design & Implementation* areas
  - Design possibilities unlocked by AM capabilities
- AM can print from lots of data sources
  - scanning, CAD, MRI, CT
- We can print almost anything with no cost penalty
  - Designers greatly restricted with traditional manufacture
  - There are lots of funky design examples

Areas of interest (to me….)

- Biomemetics
  - Optimisation, Biological structures
- Customisation
- Micro level design
  - Textures, textiles & foams
- Design possibilities / restrictions
  - Polymers, metals, multifunctional systems
- All of these require new Design Tools to maximise potential
Problem with CAD*

- CAD is seen as a great enabler, but……
  - Current CAD developed to suit traditional manufacturing techniques
  - AM able to produce virtually any complexity of parts
  - CAD not suitable for geometrical freedoms of AM
  - New design tools required

* Computer Aided Design

Design Optimisation / Lattices

- Use of Optimisation / lattices to minimise material usage
- Potential for skeletal designs (minimisation of materials)
  - Common in construction industry due to fabrication
  - Not generally used in product manufacturing
Incorporation of stochastics: fast determination of optimum

Both solutions have same compliance of 1.87mm/N and volume fraction of 0.5

Intelligent iterative mesh refinement
Aesthetic Topology Optimisation: Walking Aid Example
Aerospace bracket example

Original mass: 285g

Optimised mass: 148g

reduction: 48%
Flow optimisation

Flow optimisation
Flow optimisation

Flow optimisation
Design for Low Carbon

40% weight saving over original component design
Example – conceptual heat exchanger

3D Conformal Textiles

- Currently relatively easy to produced flat sheets
3D Conformal Textiles

- Entirely different matter when moving to fitted apparel

And now a reality....
End Goal

- Customised Personal Protective Equipment, incorporating intelligent design, novel materials and integrated sensors

Structure of Polymeric Foam

- Characteristic compressive behaviour due to cellular structure

  **Closed cell foam**
  - Cell walls form between struts
  - Isolated cells of gas
  - Walls, struts and gas contribute to compressive behaviour

  **Open cell foam**
  - Cell walls receded into struts
  - Gas moves freely through structure
  - Struts alone contribute to compressive behaviour

An open-cell arrangement of struts forming a Kelvin structure

File size a genuine limitation in the generation of lattice structures

IARMS – Straight Strut Design

- Same underlying structure with a helical strut applied to it
- Very large file sizes
- Helix utilised to increase the length of the strut, making the structure more flexible

IARMS – Helical Strut Design
Straight Strut Compression

Further Work

- Auxetic IARMS
Conventional modelling techniques (e.g. CAD) are inefficient at generating lattice structures.

Software is being developed that generates lattice structures that conform to a volume.
Lattices: Research into efficient generation and optimisation
Bracket example

Original mass: 285g
Optimised mass: 148g
reduction: 48%

Lattices
Lattices

Example – Heat dissipation surfaces
5. Life cycle sustainability

- Product lifecycle improvements in economic and environmental sustainability
- Reduced raw material consumption
- Efficient supply chains
- Optimised product efficiency
- Lighter weights components
- Reduced lifecycle burden
Environmental benefit over product lifecycle

- Example based on 90M km (Long haul) application

<table>
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<tr>
<th>Process</th>
<th>Raw Materials CO₂</th>
<th>Manufacture CO₂</th>
<th>Distribution CO₂</th>
<th>Usage CO₂</th>
<th>Life cycle Kg CO₂</th>
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<td>2 Kg</td>
<td>20,339 Kg</td>
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So how do our lifecycle CO₂ compare

**Scenario 1** – Machined from solid (100%)

**Scenario 2** – Selective Laser melted lattice (37%)

**Scenario 3** – Selective Laser melted optimised design (46%)
Applied Topology Optimisation: Approx. Weight Savings

We can tailor parts to consumers
We can save materials
We can set-up new businesses that are as cost effective in the west as the east
AM makes manufacturing attractive, funky and topical in a digitally connected world

Why does 3D Printing change the way we think?
So where is 3DP / Additive Manufacturing going?

Larger machines with higher throughput
Consistent and improved mechanical properties

(Data Courtesy of Liverpool University)

Home Printing: MakerBot – the ‘market leader’

- Less than 3-years old
- Business based on open source
- 6700 machines sold in 2011
- $1,749 per machine
- $10M VC investment Q4/2011
- Loyal customer base of Beta Testers – V3 model
MakerBot are not alone

Start-up: BigRep, SUMPPOD, Fablicator, Origo
Growing: MakerGear, Solidoodle, Ultimaker
Established: Cubify, Botmill, Bits From Bytes

Printing systems could get very complex........
What will the future look like?

This is the future....
EPSRC CENTRE FOR INNOVATIVE MANUFACTURING

In ADDITIVE MANUFACTURING

- **Liquid Metal Engineering** - Brunel (Birmingham, Oxford)
- **Industrial Sustainability** - Cranfield (Cambridge, Loughborough, Imperial)
- **Ultra Precision** - Cranfield (Cambridge, NPL)
- **Through-life Engineering Services** - Cranfield (Durham)
- **Regenerative Medicine** - Loughborough (Nottingham, Keele)
- **Intelligent Automation** - Loughborough (Cranfield)
- **Additive Manufacturing** - Nottingham, Loughborough
- **Emergent Macromolecular Therapies** - UCL (Imperial, LS Pharmacy)
- **Advanced Metrology** - Huddersfield
- **Composites** - Nottingham (Bristol, Cranfield, Manchester)
- **Photonics** - Southampton
- **Continuous Manufacturing & Crystallisation** - Strathclyde (Bath, Glasgow, Herriot Watt Loughborough, Edinburgh, Cambridge)
Centre Vision:
- To take AM beyond geometry and single materials to the “print” of multifunctional, multi-material components / devices / systems in one operation
- Ultimate exploitation of design freedom
  - Move from “passive” AM to multifunctional “active” AM

Our Partners
Challenges

- Based on existing AM philosophy, but not on existing equipment
  - Much process and material development
  - Underpinning design systems
- Ultimate exploitation of design freedom
  - Move from “passive” AM to multifunctional “active” AM
- Has a remit to also act as a National Centre
  - Outreach, coordination, dissemination
Additive Manufacturing (AM) is viable.
GE is transitioning AM into production.
Much work needs to be done, both internal to GE and external to the supply chain.
Collaboration and leveraging are necessary to move the technology forward.
AM is the future of manufacturing...

‘...in our lifetime, at least 50% of the engine will be made with additive technologies...’
Marcel’s metaljet