Making products without tools

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Loughborough University

The Sunday Times
University of the Year
Loughborough University: Strength in research

- Our research generates nearly half of the University's income
- Rated World Class for Research by the Sunday Times 2006 for:
  - Built Environment
  - English Language and Literature
  - Geography
  - Sociology
  - Mechanical, Aeronautical and Manufacturing Engineering
  - Electrical and Electronic Engineering
  - European Studies
  - Library and Information Management
  - Sports-related Subjects
- Awarded the highest level of funding per grant of any UK university by the Engineering & Physical Sciences Research Council
Rapid/Additive Manufacturing Research Group

- Part of the Department of Mechanical and Manufacturing Engineering.
- Research rated as “world leading” by WTEC and EPSRC international reviews
- Annual turnover more than £1m
- Numerous £1m+ projects
- Total RMRG staff/full-time PhD’s ~ 50 (4 in the “TCT 25”)
- Undergraduates/MSc’s focussed on RM ~ 20
- Undergraduates/MSc’s in direct contact with RP ~ 200
- 1000+ visitors to the RMRG lab / year
- Consortium
Rapid/Additive Manufacturing Research Group

- Some current partners
  - Boeing
  - Siemens
  - Burton Snowboards
  - New Balance
  - Adidas
  - UK Sport
  - Most RP/T/M vendors

- Some former partners
  - Lotus Cars
  - Rover
  - Volvo
  - Perkins Engines
  - DaimlerChrysler
  - Alstom
  - Jaguar
Rapid/Additive Manufacturing fundamentals

- Also known as…
  - Direct Digital Manufacturing
  - Solid Freeform Fabrication
  - Layer Manufacturing*
  - Personalised Manufacturing

*note our definition is not restricted to layer based approaches
Definition:

“the use of a CAD based automated additive manufacturing process to construct parts that are used as finished products or components”
Rapid/Additive Manufacturing fundamentals

- Stereolithography
Rapid/Additive Manufacturing fundamentals

- Stereolithography

http://www.turkcadcam.net/rapor/otoinsa/uyg-medikal-conjoined-twins.html
Rapid/Additive Manufacturing fundamentals

- Selective Laser Sintering
Rapid/Additive Manufacturing fundamentals

- Selective Laser Sintering
Rapid/Additive Manufacturing fundamentals

- Ink Jet (3D) Printing
Rapid/Additive Manufacturing fundamentals

- **Ink Jet (3D) Printing**

http://www.objet.com/Case_Studies/Entertainment/
- High Speed Sintering
Rapid/Additive Manufacturing fundamentals

- High Speed Sintering
Rapid/Additive Manufacturing fundamentals

- Other polymer processes:
  - Fused Deposition Modeling
  - Plastic Sheet Laminate Object Manufacturing
  - Flash curing processes
  - Various others drifting in/out
Rapid/Additive Manufacturing fundamentals

- **Benefits:**
  - Elimination of tooling (cutting or forming)
  - Geometry freedom
  - De-centralised manufacture (in the West)
  - Cost effective for small volumes
  - De-risking of projects
  - Increased material utilisation compared with cutting
  - etc
Rapid/Additive Manufacturing fundamentals

- Problems (know as “research opportunities” in academia):
  - Equipment / material cost
  - Process speed
  - Small range of materials
  - Properties and repeatability require improvement
  - Perception by engineers
  - etc
The first “RP” part to be used as an end use product was an electrical housing made using selective laser sintering on the international space station.

Taken from “Rapid Manufacturing: An industrial revolution for the digital age”
Rapid/Additive Manufacturing history

- Study from 2000 (Hopkinson and Dickens, 2003)
Rapid/Additive Manufacturing industry status

- ~10 years old
- Sintering of Nylon 12 dominates
- Almost exclusively short volume production
- Some high volume “one-off” production
- Difficult to quantify market size
- System level benefits of RM are important but difficult to quantify
- Economics of RM $\neq$ economics of RP
Rapid/Additive Manufacturing industry status

- Hearing aids

- SLS User Group 2002, Martin Masters from Siemens quotes manufacturing cost of hearing aid shells as...

  “about a buck”

Source: Siemens
Rapid/Additive Manufacturing industry status

- Boeing identifying “system level” benefits

Source: Boeing / 3D Systems
Rapid/Additive Manufacturing industry status

- Series manufacture in the low thousands....

Source: FoC
Rapid/Additive Manufacturing for running shoes

- Personalised sprint spikes at Loughborough University
- Film commissioned by the UK Institute of Engineering and Technology

- IET video
Rapid/Additive Manufacturing for running shoes

- Personalised sprint spikes at Loughborough University

Source: Sunday Times
Rapid/Additive Manufacturing for running shoes

- Elite athletes will allow us to understand how to provide personalised sports footwear
- ...they will also provide high profile
- By 2012 we are aiming to have personalised footwear available to the public.

© Brian Bell Photography
Rapid/Additive Manufacturing outlook

- Machine / material cost
- Process speed
- Repeatability
- Surface finish?
- Feature resolution
- Material choice
- etc
Rapid/Additive Manufacturing outlook

- High Speed Sintering
High Speed Sintering: Build speed projections

- 300mm x 300mm x 300 bed:
  - Parts per level = 105, number of levels = 72 => Parts per build = 7560
  - Build time = 20 seconds x 2800 + 3 hours = 66800 seconds = 18.5 hours
  - Build rate = 8.80 seconds per part
High Speed Sintering: Build speed projections

- 1000mm x 1000mm x 1000 mm bed:
  - Parts per level = 1250, number of levels = 247 => Parts per build = 308,750
  - Build time = 20 seconds x 9800 + 3 hours = 206800 seconds = 57.4 hours
  - Build rate = 0.67 seconds per part
  - (At 30 second layer cycle, build rate = 0.99 seconds per part)
This is more difficult than calculating build time projections, please bear with me on assumptions!

Ruffo cost model applied to 300x300x300mm machine assuming:
- Machine cost (£250,000) = £29 per hour
- Material cost ~ £30/Kg assuming 50% recycle rate

Machine cost per build = £29 x 18.5 hours = £536.50
Material cost per build = £30 x 15.56Kg = £466.80
Total cost per build = £1003.30

Cost per part = £1003.30 / 7560 = £0.13
Rapid Manufacturing outlook

- Still niche solutions in high added value applications
- But……
- Space shuttle / station
- Formula 1
- Personalised sports footwear
- Personalised Hearing aids
- Aerospace ducting
- Lamp shades
- Electrical connectors

Niche

Niche?
A plug for our book and conference!

Rapid Manufacturing
AN INDUSTRIAL REVOLUTION FOR THE DIGITAL AGE

July 14-15 2010
Sir Dennis Rooke Conference Centre
holywell park
loughborough university
united kingdom