

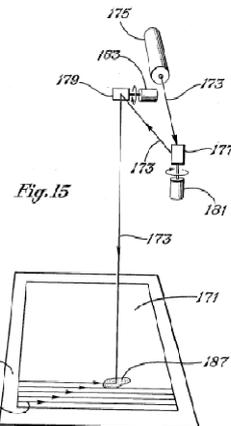
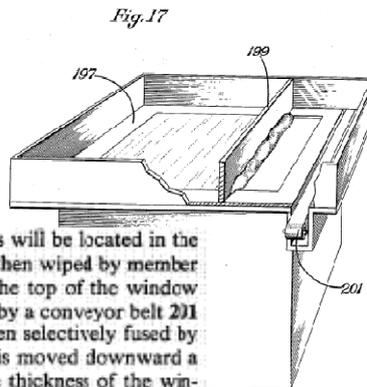
# Metals powder bed Additive Layer Manufacturing The good, the bad... and the ugly

Carl Brancher  
ILAS July 2009



## Metals Powder bed ALM- 30 years new

Ross Housholder US patent 4,247,508  
Issued 1981



**197.** A mound of fusible particles will be located in the window on the bottom **193** and then wiped by member **199** to a thin layer, level with the top of the window **197**. Excess material is removed by a conveyor belt **201** for reuse. After the layer has been selectively fused by the laser beam, the bottom **193** is moved downward a distance corresponding with the thickness of the window **197** and a second layer of particles deposited on the first layer. The second layer is selectively fused by the laser beam and the process repeated until the solid article is formed in the container. The unfused particles are removed leaving the finished article.



## What has metals powder bed ALM got to offer?



## The promise of metals powder bed ALM

- "...Highly complex geometries are created directly from 3D CAD data, Fully automatically, in just a few hours and without any tooling. It is a net-shape process, producing parts with high accuracy and detail resolution, good surface quality and excellent mechanical properties."

[<http://www.eos.info/en/products/metal-laser-sintering.html>]

To what extent is this 'promise' met?



## Our metals powder bed ALM 'Mission'

- Developing capabilities
  - Process, Materials, QA requirements...
  - Design-for and economics-of manufacture
  - Develop matching skills in existing supply chain
  - In customers' choice of materials
- Pilot a (new) supply chain
  - Develop manufacturing & QA systems
  - Drive a cost model for mass uptake



**Materials Solutions**

Helping you overcome the most demanding challenges

## Status of metal powder bed ALM now

- ALM produces 'castings' designs in certain materials with ~forged properties relatively quickly, at a cost viable in certain situations for certain geometries.
- ALM can also produce some integrated structures not otherwise possible without joining techniques.

This is **good!** Our job is to...

- Find these applications,
- Develop the demand-side knowhow and
- Inform the supply-side of the equipment, QA and materials technology and cost needs, thereby

Expanding the applications, develop the technologies and lower the costs



**Materials Solutions**

Helping you overcome the most demanding challenges

## The Economic Promise

- “...Highly complex geometries are created directly from 3D CAD data, Fully automatically, in just a few hours and without any tooling...”



**Materials Solutions**

Rapid Response to manufacturing challenges

## Economic Promise- comments

- “...Highly complex geometries are created
  - *Can be, but not ‘any’ geometry; there is a need to understand the process limitations*
- directly from 3D CAD data, fully automatically in just a few hours
  - *No! A new skills-set in file manipulation to be learnt*
  - *Days not hours to build a complex fist sized object*
- and without any tooling.”
  - *Yes, but, most parts need support structures designed, built and subsequently removed and*
  - *tooling is frequently used for holding complex shapes for the necessary finishing processes*



**Materials Solutions**

Rapid Response to manufacturing challenges

## The Technical Promise...

- "...It is a net-shape process, producing parts with high accuracy and detail resolution, good surface quality and excellent mechanical properties."



**Materials Solutions**

Rapid Prototyping to meet your most demanding challenges

## Technical Promise- comments

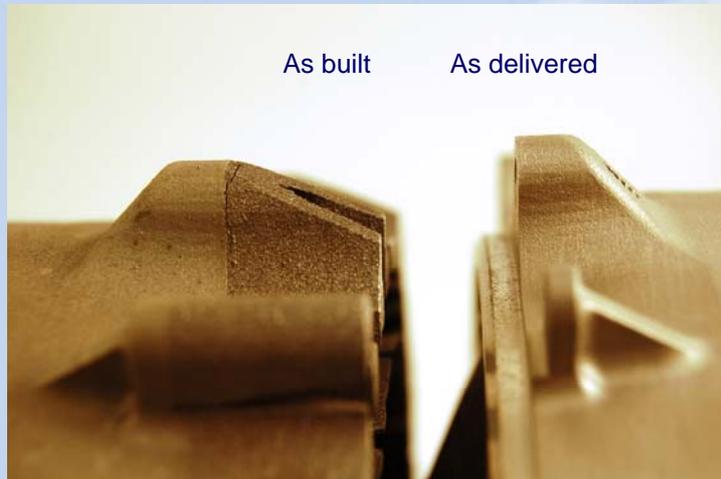
- "...It is a net-shape process,
  - *Geometry dependent capability*
  - *Need to remove supports*
- producing parts with high accuracy and detail resolution, good surface quality
  - *Anything <0.1mm, probably machined*
  - *But very repeatable and can 'dial in' better accuracy*
  - *Geometry dependent, 3-5 $\mu$  Ra Top & Vertical, ~9 $\mu$  Ra undersurface/30° typical*
- and excellent mechanical properties."
  - *Yes, in some materials ~forged and near isotropic after heat treatment*



**Materials Solutions**

Rapid Prototyping to meet your most demanding challenges

## “Net-shape” ... to an extent



Support structures + machining/hand finishing needed



**Materials Solutions**  
Rapid development to meet your challenges

## ...but this is still pretty good

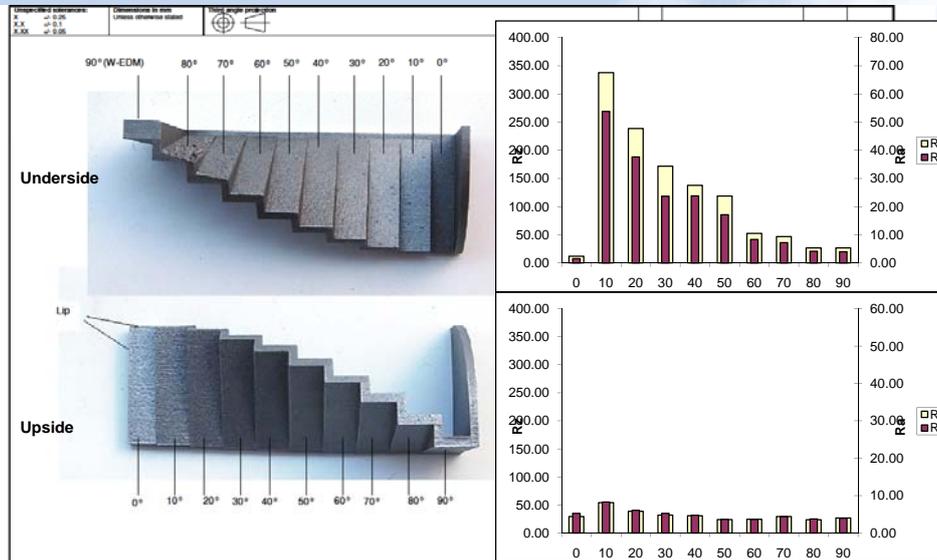


- It's unfair to expect a new method of manufacture to make net-shape parts designed (explicitly or implicitly) for other methods of manufacture
  - Therefore part of the new 'art' is to design for manufacture by this process



**Materials Solutions**  
Rapid development to meet your challenges

# Surface Quality- geometry dependent

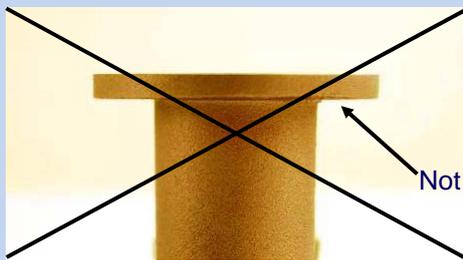


2 things you need to know to understand the process



# 1. Metal MUST wet to underlying surface

- Process requires a build plate (and stress dictates a thick one), and  $\sim 30^\circ$  to horizontal limit for geometries
  - Process cannot built any/all geometries
    - Design changes may be required
    - Build orientation must be considered
    - Support design, building and subsequent removal WILL be required for all practical geometries



**Materials Solutions**  
Rapid Prototyping to meet your most challenging

## $\sim 30^\circ$ to horizontal limit



Support +  
'wetting  
surface'-  
Stress  
evident!

Build orientation consideration leading to  
support design and build... and removal



**Materials Solutions**  
Rapid Prototyping to meet your most challenging

## 2. Tensile stress in as-built parts

- Hot metal + cold process = high tensile stress in as-built parts
  - Geometry dependent build distortions and artefacts and ultimately build failures
  - Heat treatment required of most parts [whilst still attached to the base plate to avoid distortion]
    - Base plates therefore cannot be reused as-is
  - Mismatch of parts and base plate materials... stress complications
  - Tensile stress in larger built parts bends the base plate- parts removal 'complicated'



**Materials Solutions**

Specialist equipment to overcome the most demanding challenges

## Tensile stress demonstration



Test bars processed under differing conditions- then the top layer cut to allow residual stress to mechanically relax



**Materials Solutions**

Specialist equipment to overcome the most demanding challenges

## Stress related build artefacts



Witness mark geometry related stress driven movement during build



**Materials Solutions**  
Rapid Response to manufacturing challenges

## Making the Unmake-able



**Materials Solutions**  
Rapid Response to manufacturing challenges

## Complex geometries

- Can build geometries that cannot be cast or machined, but...
  - The part needs to be designed for this process and this requires
  - Confidence in the ALM process, materials and cost model - before the necessary skills are invested in design and the manufacturing route is committed to this process because
  - There is no going back if not possible by other methods



**Materials Solutions**

Helpful Advice to support your manufacturing challenges

For ALM to be a useful manufacturing process it must be understood, stable, verifiable and economic



**Materials Solutions**

Helpful Advice to support your manufacturing challenges

## Equipment specification & control

- Large number of process variables
  - Not all known, let alone controlled
- Inevitable change in machine spec. over time
  - Software, lasers, galvometers...
- Equipment is not standardised
  - Variability between same make and model of machine in same room/operator/ procedures let alone between different installations or different vendors



**Materials Solutions**  
Rapid Response to manufacturing challenges

## Materials specification & homogeneity

- Sources & Suitability
  - Need to know what you need
  - Can present approvals problems
- Powder reuse can change everything
  - Chemistry
    - Oxidation/ Nitridation
  - Surface condition/contaminants (including water)
  - Powder morphology, size and size distribution
    - Measurement method dependent

Powder reuse is assumed but needs verification  
Particularly relevant to the 'buy to fly ratio' justification



**Materials Solutions**  
Rapid Response to manufacturing challenges

## Supporting software limited

- 'Auto Support' generation software is very limited
- Parts shrinkage and stress- could be compensated for by software tools- if we had them
- 'Best recipe' could be automatically selected using expert software- if it existed

Needs a better process understanding, stable and larger market to justify development costs

- Until then, great expertise needed to use ALM effectively



**Materials Solutions**

Helping you overcome the most demanding technical challenges

## Expectations

- 'Overselling' the technology can lead to problems of over-inflated expectation
- The powder bed process is not a replacement for conventional metals processing
  - it is a new tool that sits within the existing toolbox and needs new skills to successfully exploit it
  - We are developing that skill set



**Materials Solutions**

Helping you overcome the most demanding technical challenges

## Conclusion

- Some ALM equipment/processes are robust
- Economically viable applications do exist
- To use effectively, ALM need a new skills set
- ALM equipment and the (potential) supporting software needs further development
  - To justify this a large stable market is needed
  - To create this we need to create value from the existing equipment- to stimulate that market

## Thanks is due to

- Our Customers
- Advantage West Midlands
  - particularly Ivan Buckley
- DTI...TSB
- Xinhua Wu at the University of Birmingham
- EOS

## About Materials Solutions- Organisation

- Not-for-profit start-up, Sept 2006
- Independent of technology providers and users
- Grant supported by AWM and TSB



## About Materials Solutions- Operation

- Delivering novel capabilities to manufacturing
  - Technology + supply chain solution (source, cost)
    - Consulting & technology capability development
    - Early stage manufacturing to ~TRL6 ["Process optimised for Capability and Rate using production equipment"]
- First technology is metals powder bed ALM
  - Continuously evaluating 'what's next' since Jan '06
    - haven't yet found anything even close...
    - ...So, we're entirely focussed upon ALM... for now



## Our Rapid Manufacturing 'Vision'

- **Increase manufacturing speed and flexibility**

- ~2 week lead time, no 'first-off' costs
- Low carried costs (inventory, tooling)
- Economic 'batch of 1' for complex parts
  - 'ideally 'Right first time'
- Increased design complexity
- Reduced parts count/fasteners
- In the customers' choice of material (**RM** not RP)

- **Manufacturing- ready technology & operations**

- Repeatable- over time/across machines
- Traceable/auditable



**Materials Solutions**  
Rapid Manufacturing as a Service