Economic aspects of Additive Manufacturing

Luca Beltrametti
(Università di Genova)

Nanoinnovation 2017
Rome, September 28th, 2017

Beyond prototyping

- 3D for prototyping have been around since 30 years. Even today prototyping is the the most important use of Additive Manufacturing (AM)
  - Shorter "*time to market*"
  - Early error detection
  - Early training for workers
  - Lower prices from suppliers

- But today: a twofold "revolution"
  - Better 3D printers➔ final production
    - 3D printers:
      - Print bigger objects
      - Are faster
      - Are more accurate
      - Use new, more interesting, materials
  - Cheap and open source 3D printers ➔ "makers"

I’ll focus on AM for final production
Main topics:

1. From “the less material I remove, the less I spend” to “the less I add, the less I spend”
2. More freedom of geometry ➔ more efficient shapes
3. Produce if/when/where needed
4. New materials/alloys
5. Re-fitting of used parts
6. Are economies of scale over?
7. How big is the market?

From:

- “the less material I remove, the less I spend”

to:

- “the less I add, the less I spend”

- Less material (almost no waste)
- Less machine time

Freedom of geometry ➔ more efficient shapes

1. Different shape ➔ less of the same material ➔ lighter objects ➔ more efficiency over the life cycle
2. Different shape, less of a different material ➔ more efficiency
3. Different shape, same resilience with different (cheaper) material
4. More efficient shapes, same material (weight is not the issue)
5. Other

Freedom of geometry ➔ more efficient shapes 1-3

1. Different shape ➔ less of the same material ➔ lighter objects ➔ more efficiency over the life cycle
   – E.g. rotating ring in a packaging machine ➔
      a. No bearings
      b. No lubrication
      c. Less energy (less inertia)

2. Different shapes, less of a different material ➔ more efficiency
   – No waste ➔ more costly materials become economically sustainable (e,g. titanium instead of steel)
   – e.g. safety belt buckle: steel, 155 g , aluminium120 g, titanium 70 g ➔ about 300 kg less in a plane ➔ €2 millions savings over the life cycle of the plane

3. Different shapes, same resilience with different (cheaper) material
   – E.g. reticular, nest structure ➔ plastic instead of steel

4. More efficient shapes, same material (weight is not the issue)

A. Molds with conformal refrigerant circuits; e.g.:. Biticino: -35% in time, - 30% production costs)

B. Hot air blower in a packaging machine

- Gets closer
- Optimized internal circuit ➔ homogeneous temperature along the blower working lenght
- No welding (5 before)
- See next picture

5. Other examples in which AM enhances efficiency

- Aerospace:
  - turbine blades: better internal cooling + less production failures
- Medical:
  - hip prosthesis (size and custom): better fitting with the patient body
  - Dental crowns (custom): lower cost
  - Plastic models supporting surgical operations (custom)
    - ➔ Better programming ➔ shorter operation
    - ➔ Less anesthesia
    - ➔ More productivity
    - ➔ More informed consensus from the patient ➔ less litigation

More on shape and efficiency

- It is wrong to compare the cost of the <u>same object</u> made with traditional technologies and made with AM
- We must compare the cost of the old object made with traditional technologies with the cost of the <u>**new**</u> object made with AM (re-engineering).
- Must take into account:
  – A "life-cycle" perspective
  – The new shape and the new material

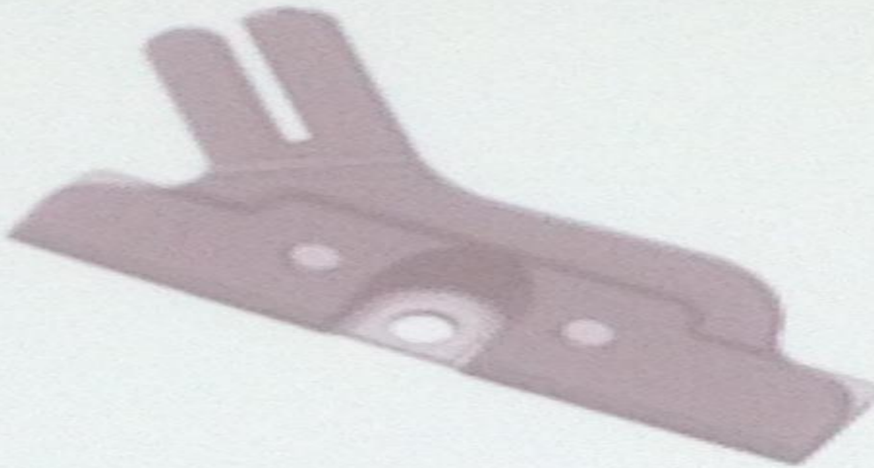
Additive Manufacturing is a game changing technology!

MILLING | **3D-PRINTING**

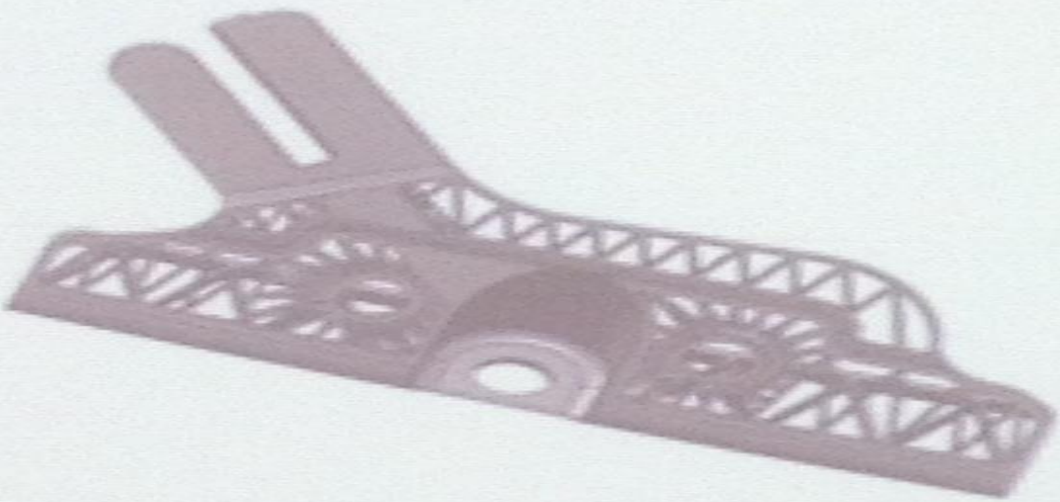
1.2 KG

0.6 KG

Weight saving potential between 30% and 70% for aircraft components!



bracket



Optimized lightweight bracket

"It is easier to ship recipes than cakes and biscuits" (J. M. Keynes, attributed to)

- Store bits, not atoms!
- 3D printers are "generic" and more flexible machines than numerical control machines:
  - They do not need specific setting/tooling for each job (tool path).
  - They can build simultaneously objects with different shapes.

Spare parts

- Build spare parts if, when and where you need them
  - Airbus:
    - 3,6 million spare parts + 120,000 tools; for over 60 years
    - Value of the stock: bw $20 and 30 bn; annual cost: 20%.
  - Mercedes Benz trucks
  - Even if the single object is more expensive, we must evaluate all costs:
    - Warehouse
    - Capital cost
    - Logistics
    - Waste (not-used pieces)
  - Reverse engineering (for vintage machines)

Nice to have a “B plan”

- You pay more but you avoid a huge incoming cost if something has gone wrong
- E.g.:
  - *Automotive*
  - A maker of industrial coffee machines (a small plastic recipient … big delay)

Print only if you need it (and where you need it)

- Cost **not** the central issue
  - Surgical tools in the *Army*
  - Space trips

New materials/alloys

- AM also is a way to get new, more efficient, materials

This topic goes beyond the scope of this presentation

Re-fitting of used parts

- E.g. new edges for used turbine blades

➔ Longer life for costly capital

Are economies of scale over?

- The cost of making 100 copies of the same object or 100 different objects is the same (i.e. the cost of variants is zero).
- **<u>BUT</u>**, this does **<u>not</u>** imply that economies of scale are over.

If you are bigger… you still are more efficient ➔there is room for service providers

- Training people
- People looking after the machines
- Until the working plane is full… returns to scale
- One machine for each material (switching cost are high)
- Market power on the market for powders
- Efficiency from variety of shapes

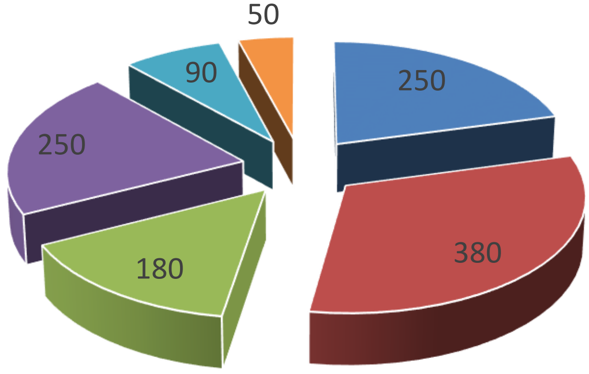
Is AM really part of "Industrie 4.0"?

- More "vertical" (like numerical control machines) and 30 years old ➔ 3.0?
- But:
  - Zero cost for variants ➔ mass customization enabled ➔ a technology that is a natural complement to IoT that you use for managing production and logistics
  - Using AM for embedding/attaching sensors (also in old staff) ➔
    - Predictive maintenance
    - IoT

HOW BIG IS THE MARKET FOR ADDITIVE MANUFACTURING?

METAL 3D PRINTERS IN EUROPE (2016)

ITALY	250
Germany	380
UK	180
France	250
Scandinavia	90
Others	50
TOTAL EUROPE	1.200



Source: own data and elaborations

European market for metal powders ≈ 600 Tons

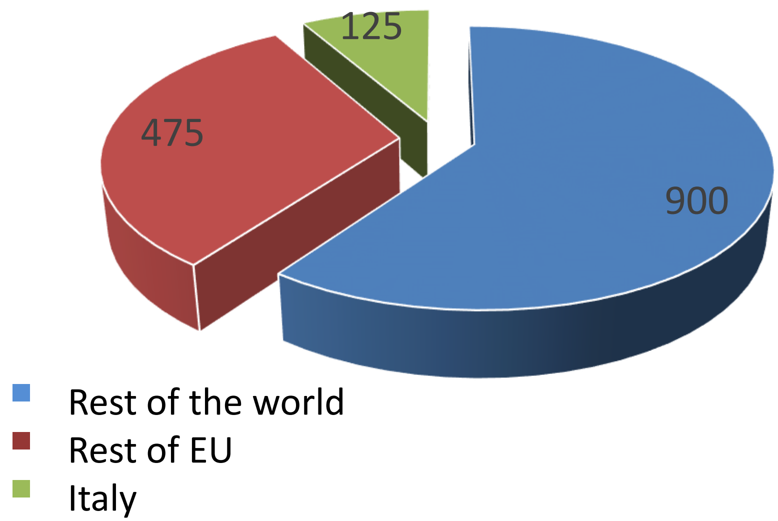
Considering the estimated average consumption of powder per machine (2016) :

World 3.000 printers → 1500 t

Europe 1.200 printers → 600 t

Italy 250 printers → 125 t

Consumption of metal powders 2016

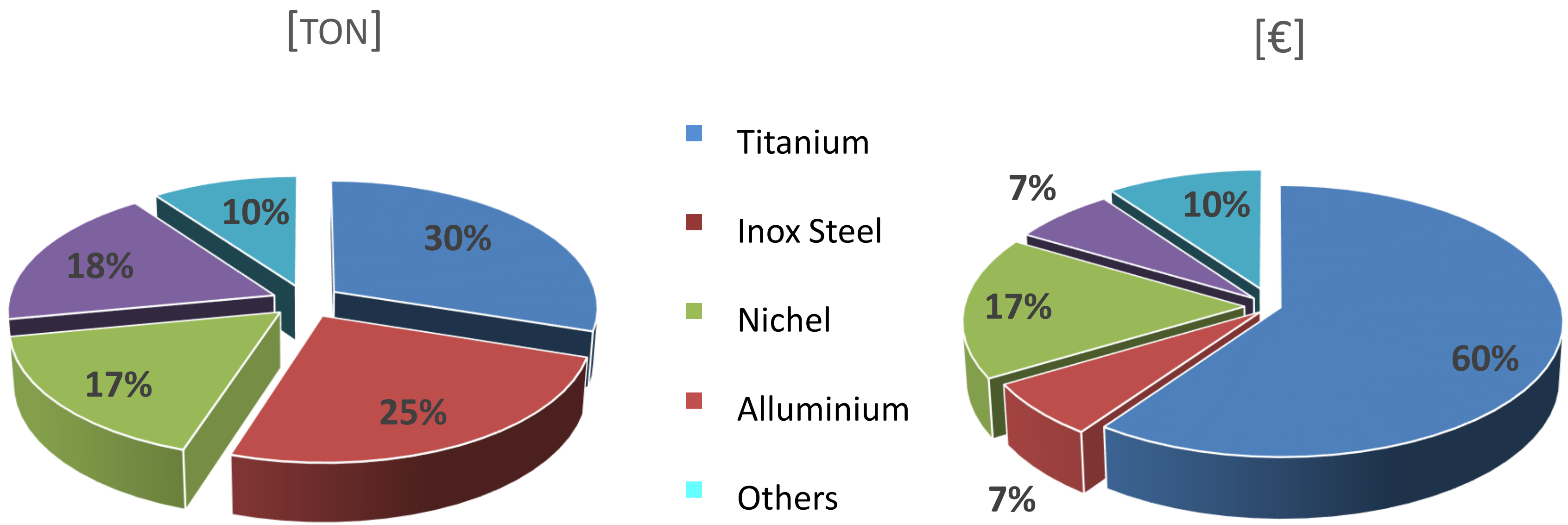


Italy: ~ 20% world market

Source: own data and elaborations

What metal?

EUROPEAN MARKET BY MATERIAL 2016



Source: own data and elaborations

In sum

- "Think additive", creatively re-engineering
- We need certification for both materials and processes
- A new economy with
  - Smaller factories, closer to final markets (a new geography of production)?
  - Radically smaller inventories ➔ better use of capital?
  - A more environmentally friendly impact?
- A significant, fast growing but still small market