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ADDITIVE MANUFACTURING
State of Art

(source: innovation community)

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Technology Overview

Additive Manufacturing (AM) is a computer-driven manufacturing process used for producing the final product starting from a digital model by laying down successive layers of material. It is considered a disruptive technology in the way of producing, improving, repairing parts. It consists in adding material just where it is needed (near net shape) instead of removing not needed material from a thick semi-finished or to produce it as a cast.

1. AM begins with a digital model of the object. Depending on the input available (geometry, coupling surfaces, tolerances, loads, etc) and the improvements pursued on the part, the "geometric model" of the object can be created directly through solid modeling CAD software (for totally new parts or when drawings of original part are available) or built through a reverse engineering process starting from a 3D laser scanning of an existing part. A further phase is the mechanical verification of the part and, in some cases, the thermo-mechanical fluido-dynamic ones (e.g. Finite Element Model analyses). To optimize the part for AM ("design-for-additive" concept) sometimes the model undergoes a topologic optimization through dedicated software. The final output of this complex phase is a "close surface model", usually in *.stl format. Once created, the model can be digitally archived and shared for further uses.
2. The model is then processed in order to make it suitable for the manufacturing technology/ material/ process. In the model are included the placing, the supports – if needed – and the model is properly sliced. Most of these actions are supported by a CAD-CAM software that includes and considers the AM machine characteristics and parameters. The result is a sliced model (slice thickness related to the physical layer thickness) that includes the laser path, speed and power (as a function of hatching distance, laser spot size and, for some technologies to the powder/wire feed rate). The produced file is uploaded in the AM machine.
3. The input file is used by the machine for the part production/repair. After the manufacturing process, the part is removed from the machine, cleaned to remove overhung material, polished and machined with subtractive processes and subjected to thermal treatment (if needed). After Non Destructive Tests and Quality Checks it is ready for use.

Aerospace, automotive and medical industries are expected to account for half of 3D printing market by 2025, the global additive manufacturing market in 2018, including hardware, software, materials and services, generated $9.3 billion revenues after growing 18% in one year. Some of the main growth drivers are the strategic importance placed on additive manufacturing by large multinational corporations (chemical and materials, developers of traditional machine tools and industrial lasers) and the efforts of the industry to focus on applications, especially ones that provide growth that is largely complimentary, not competitive, with existing manufacturing processes and machine tool.

From a general point of view, there are different business models available to exploit AM potential:

In-house: The manufacturer has the in-house capability as well as the infrastructure to manufacture components using AM technology (Example: General Electric, Engie);

Contract Manufacturing Model: A 3D manufacturer who contracts with a firm to manufacture components using 3D manufacturing, an outsourcing model. (Example: Rapid PSI, BeamIt);

3D Printing as a Service: Online business model where the orders are received online and the finished products are mailed to the customers. (Example: Shapeways);

Retail 3D Printing: Portable 3D printers available in the retail market which can be used to manufacture products at home (Example: Cubify).

The main **advantages** of the additive technologies are:

Possibility to increase geometrical complexity without increasing cost;

Customization and optimization of parts (no more designed for conventional manufacture but for their optimized functionality and lifecycle cost)

Possibility of trabecular structures, optimized lattices, internal cooling paths and the possibility to reduce the number of single components for usually-assembled parts

Possibility to produce small lots without significant economic penalizations in realization costs;

Properties of additive materials (hardness, strength, fatigue) and more efficient use of those material (more sustainable process);

Improvement of logistics;

For what concern metal additive manufacturing three main technologies are available on the market (further are available yet). Each one has specific points of strength:

Selective Laser Melting (or Powder Bed) consists of progressively laying thin layers of metal powder and melting just the object section (relevant to that layer or slice) by laser source, so that, the solid part(s) produced is eventually drowned in a box of powder.

Electron Beam Melting technology, similar to Selective Laser Melting, with an electron beam used to pre-heat the powder (de-focused beam) and melt the metal powder (focused beam).

Metal Laser Deposition (or Direct Energy Deposition) consists of melting the metal powder/wire by laser directly on the substrate (a plate or semi-finished part for brand new objects, a machined used part for repairing). In this case, the powder is fed directly in the laser spot (in the deposition head).

Powder bed technology is in particular convenient for very complicated shapes and for small dimensions (bigger working volumes exceeding 40x40x40 cm are a target of machines producers, but they are still facing some technological constraints). The technology is generally not suitable for repairing. Many companies have in their portfolio or are dedicated to products development for AM and their production by Powder Bed, those are already quite well geographically distributed and established. AM with powder bed is done typically with a fleet of commercial machines (and pre-set recipes), each one dedicated to a specific material. Also Intellectual Properties issues are to be faced once the target is the “improved copy” of a part. Because of the typical applications and of the constraints listed above, Enel did not pursued the internalization of the specific technology. Nevertheless, it is considered important to have some experience about Powder Bed in order to deeply know the technology, the peculiarities of products (e.g. typical microstructures, properties dependence on production parameters, typical defects and the like), the qualification of processes (more than the qualification of single parts) and to be able to properly specify the services if/when required. The experience shall be done through qualified producers on risk-free selected parts. The goal Enel should pursue is to create an internal excellence center with all the competences needed for vendor qualification and technical requirements specification.

The strategic value of Direct Energy Deposition is the possibility of re-using/repairing and improving parts (especially envisaged for valuable parts driving the availability and reliability of plants) and of creating parts no longer available on the market. Moreover, it is a step towards the digitalization of assets, circularity and sustainability. Within Enel, different approaches were adopted and will be detailed hereinafter.

In consideration of the fact that many leading industrial players are using and developing this new powerful technique, Enel recognizes as strategic activities both the follow-up of the AM technological progress and the creation of an internal expertise in this new sector.

The Infralab laboratory opened in Haifa by Global Infrastructure & Networks and Shikun & Binui is already equipped with different models of 3D printers, used by start-ups for the creation of prototypes and mechanical parts of their systems.