STRATEGIC CHALLENGES FOR ADDITIVE FABRICATION

ADVICE NOTE ISSUED BY THE NATIONAL ACADEMY OF TECHNOLOGIES OF FRANCE (NATF), approved by vote at the June 10, 2015 plenary session

Additive manufacturing (also known as 3D printing) is defined by the French Standards Agency (AFNOR) as *"the set of processes that lead to fabrication of a physical object, layer by layer, starting from a digital model".* It is defined in opposition to subtractive manufacturing (removing matter by machine processes). 3-D printing raises lots of hopes today and is often described in the media and in numerous publications as the key to industrial relocalisation in the developed nations. This may seem surprising since the process has been known and used for 3 decades now. One reason for the enthusiastic appeal for 3-D printing was the fact that the FDM patent (*Fused deposition modelling*) expired in 2009, leading to an entrepreneurial upsurge in the area, to lower price tags for the 3-D printers, to an interest expressed by the public at large which can be seen in the intense programme of activities and wide-ranging service offers found in the Fab'Labs ("digital manufacturing workshops"). But many other factors are involved, notably the very rapid progress in printing technologies and the general impact of the digital revolution that fully justify the fact that additive fabrication be considered as a strategic priority.

In more general terms, the stakes for additive fabrication in industrial sectors are high. Its relevance at prototype stages goes without saying. Indeed, it can be used to considerably enhance product design. Moreover, the unit cost for the process is not related to the inherent complexity of the objects printed, once their design configuration has been specified and programmed. This implies that in certain cases, the absence of economy of scale can be offset and series production of these objects is soon profitable. It proves a useful way to repair objects and offer also new perspectives for art work and creativity in general, all the more so that to tools needed can now be installed in our homes. Finally, 3-D printing opens the way to inventing new economic models. It is when we consider the possible combinations of these factors, and include the very wide range of sectors, from aeronautics to jewellery, from foodstuffs to health sector, not forgetting architecture … that 3 D printing represents a breakthrough for the corporate world and for the economy as a whole. What we must do, however, is to identify the positive complementarities between additive manufacturing and more classic approaches and processes and not consider that the former will totally replace the latter.

Moreover, whereas plastic printing processes have been mainly under the spotlights to date, the future will certainly call for additive fabrication of metallic parts and components at the heart of an industrial reconfiguration which is showing new dynamics today. Additive fabrication is an important challenge for French industries today given the role it now plays in areas such as aeronautics and space industries.

Development of additive technologies are far from isolated. They could, in the future, be combined with other technological innovations such as those we see being developed in so-called flexible robotics to position fibre connections, not forgetting all the factors that will constitute future digital factories (*e.g.,* generalized use of sensors).

Under these circumstances and for the reasons set out above, the National Academy of Technologies of France (NATF) considers it to be of prime importance that the development of additive manufacturing be encouraged in France. In order to avoid seeing

dispersed efforts here, the Academy advocates the choice of a strategic axis and recommends to privilege material excellence for two reasons:

- Materials play a central role in 3-D printing activities and can be seen as a key factor to ensure progress, an area where French industry and associate R&D sectors could lead the field. To attain this objective, a determined national policy approach is absolutely necessary.
- Advanced skills in material sciences and engineering already exist in France and could lead to a significant international lead in the 3-D printing field, especially with additive metallic processes[1].

To illustrate this point, the manufacturing of components, notably those required to meet mechanical engineering needs, made from various materials such as advanced polymer composites, metals, ceramics, *etc.,* call for a special effort in R&D, largely reinforced in comparison with the situation today. Certain hurdles have to be crossed before additive manufacturing can be applied to a wider range of component parts and implement a wider range of print materials.

Better knowledge of the physics and physico-chemistry of the processes involved is needed to cross these hurdles. In particular, further investigations are needed in terms of phase changes, notably during the solidification of the material printed, at various temperature change rates (~10^6 °C/s), recycling powders and possible contamination factors, spread of mechanical properties and surface states that still limit the use of additive manufacturing processes to printing non-critical parts. Moreover, it will be necessary to optimize the composition of the alloys that 3-D printing could form. There is no proof or guarantee that the existing compositions used in "classic" manufacturing processes (moulding, solid state manufacturing, machining), are perfectly suited to the physical and thermal constraints of 3D printing and which are very specific to this process. In the case of metal alloys, the nature (powder, wire) and the quality and availability of the base materials are likewise important factors to be taken into consideration.

Final point- these new 3-D processes call into question numerous existing industrial processes. It is therefore also important that student engineers and technicians are appropriately trained in these new and promising design and assembly processes.

Some of France's HE establishments are already engaged in this respect (*e.g.,* the Ecole Nationale d'Arts & Métiers). Their efforts and commitment here are to be commended and supported and at the same time the national R&D system in regard to a material-intensive strategic axis should be strengthened.

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[1] *A contrario*, Germany today is playing (and will continue to do so) a key role for the 3-D printer units.