ADDITIVE MANUFACTURING : Theory & Practice

Future of Additive Manufacturing: Standards & Standardization

Review Article

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Abstract: Standards have to satisfy the needs of the different groups represented, such as industrial, trade, and consumer groups of all of the countries involved. Most experts agree that the lack of additive manufacturing (AM) standards is a key point to take into account in the barriers to broad adoption of AM. Although over the past two decades several entities and groups of experts have demanded the development of specific standards for additive manufacturing, the most important steps forward have been taken in the last few years, mainly through the actions of international organizations such as International Organization for Standardization (ISO) and American Society for Testing and Materials (ASTM), with the support of technical groups and projects focused on the standardization of AM. This work, which is successfully providing new standards for AM, is expected to be reinforced by a global agreement between ASTM and ISO with the aim of collaboration on common AM standards. This paper presents a summary and review of actions carried out so far by different organizations and projects, based on the work of several road maps and workshops, with the aim of developing new standards in this particular field.

Keywords: Additive Manufacturing • Future Manufacturing • Sustanable Manufacturing

1. Introduction

Standards have to satisfy the needs of the different groups represented, such as industrial, trade, and consumer groups from all of the countries involved. This is an ongoing issue for the field of additive manufacturing (AM) where, as will be seen, most experts agree that the lack of standards is an important barrier to the broader adoption of AM. This paper therefore reviews progress in this field up to the present time. The AM concept is based on solid freeform manufacturing technologies for the direct automated production of bespoke parts and products in small to medium size batches without resorting to specific molds and tools. According to American Society for Testing and Materials (ASTM) 2792-12, AM is defined as processes of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing fabrication methodologies. AM is a multidisciplinary field requiring close interaction between design, material, technology, and information and

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communication technologies (ICT). Implementation of AM concepts will enable a transition from mass production to the customized, need-oriented, and eco-efficient manufacturing requirements of the future. At present, AM involves procedures for the addition of material layer by layer starting from digital information (3D solid computer-aided design (CAD)). AM technology cuts across a large number of industries and applications and that is part of what makes its potential so compelling. Aerospace, automotive, medical, and consumer products will drive AM into the future[1].

The ASTM F42 committee has1112 categorized AM processes into seven areas (between brackets are shown an example of each area):

- Vat photopolymerization (e.g., stereolithography, SLA)
- Material jetting (e.g., Polyjet)
- Binder jetting (e.g., some 3D printers by powder and binder).
- Material extrusion (e.g., fused deposition modeling, FDM).
- Powder bed fusion (e.g., selective laser sintering, SLS)
- Sheet lamination (e.g., Sheet Forming)
- Directed energy deposition (e.g., laser cladding)

All the AM technologies have a common base in terms of the general procedure. The process starts from the 3D model which is translated into stereolithography (STL) file format (or additive manufacturing file format (AMF)) and by means of software for slicing the solid body layer by layer, and a sequence of movements is sent to the AM equipment where the part is finally made. Depending on the AM technology, a post-processing could be required AM technology is considered high value and advanced manufacturing; nevertheless, some authors have reported barriers to the broad adoption of AM in industry, and among these, the following may be highlighted[1] :

- Material types and properties
- Process understanding and performance
- Part accuracy
- Surface finish of contoured surfaces
- Fabrication speed
- Build volumes/part size
- Need for qualification and certification
- Lack of AM standards

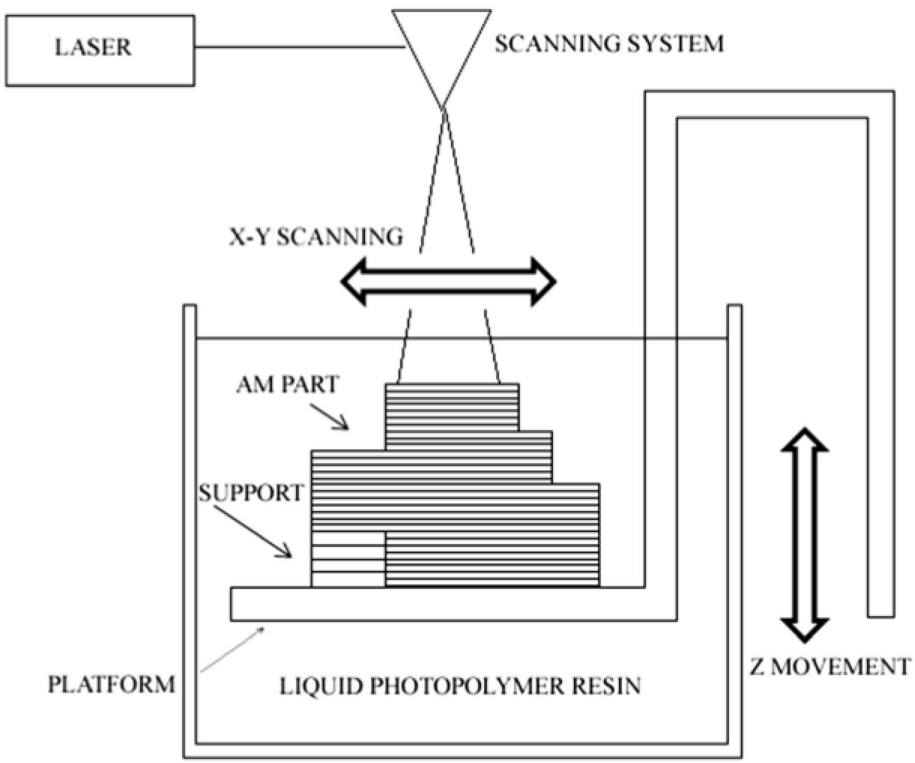

Figure 1. **Example of AM process: stereolithography, SLA[1]**

- Data formats

Most experts agree that the lack of AM standards is a key issue that must be taken into account when barriers to the broad adoption of AM are considered. In relation to this, two questions must be asked: are the existing standards suitable for AM? And, do these existing standards respond to the specific characteristics of AM? The response to both questions is generally negative, and in some ways, this circumstance obstructs the application of systems of qualification and certification, particularly in those fields where the certification is mandatory, such as medical, aeronautical, automotive, etc[1].

2. Need for standards in Additive Manufacturing

The standards currently applied with regard to other manufacturing processes (machining, welding, casting, polymer processing, etc.) or materials (metals, plastics, ceramics) are not always suitable for AM technologies. AM, which involves different technologies, has particular characteristics in particular materials and operational parameters, which have great influence on the final quality and properties of the part. Despite the absence of AM standards, convention- al standards commonly used in other manufacturing processes have been applied in the industry. For example, Figs. 3 and 4 show a summary of results in terms of number of tests carried out

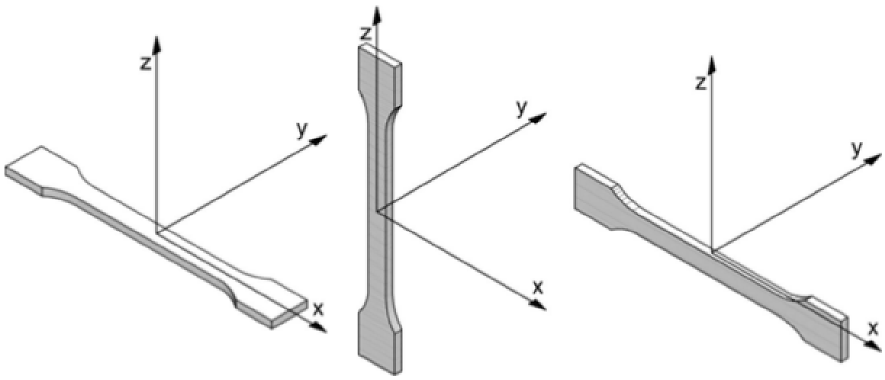

Figure 2. **Samples made under different directions within the build chamber[1]**

by the manufacturers of materials and AM equipment and provided to customers in material data sheets. It must be noted that not all the tests necessarily correspond to an official standard (International Organization for Standardization (ISO), ASTM, Deutsches Institut fr Normung (DIN), etc.); companies sometimes use their own tests and, in some cases, the standard is not even mentioned in the information provided. On the other hand, several tests use the same standard. All these circumstances produce a difference between the number of tests and the number of standards, as seen in Figs. 3 and 4. The summary shown in both figures represents the total number of 46 different parameters coming from the corresponding tests (not available for all the manufacturers) and included in the data sheets of materials. [1] These tests were grouped as follows:

- General properties (density, moisture absorption, ash con- tent, etc.): up to five tested parameters
- Mechanical properties (tensile strength, tensile modulus, flexural modulus, izo impact, etc.): up to 28 tested parameters
- Thermal properties (heat deflection temperature, coefficient of thermal expansion, specific heat capacity, etc.): up to eight tested parameters
- Electrical properties (volume resistivity, surface resistivity, dissipation factor, etc.): up to five tested parameters.

Figure 3 relates to five AM technologies and companies for rigid plastics, whereas Fig. 4 relates to three AM technologies for metals (company and technology names have been omit- ted to avoid references to commercial trademarks). The need for new standards for AM has been recognized by the industry, research centers, and academia for several years. A number of surveys have been carried out, such as the road map for AM standardization [19], a survey concerning the need for AM standards in the industry, and AM community (106 stakeholders) that resulted in the following conclusions[1]

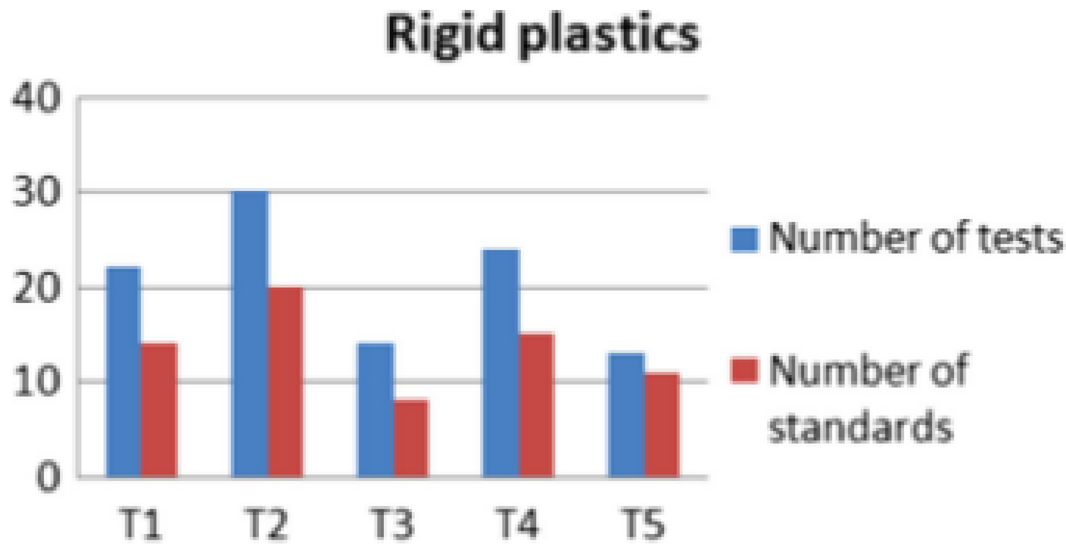

Figure 3. Tests and standards for materials of five AM technologies for rigid plastics[1]

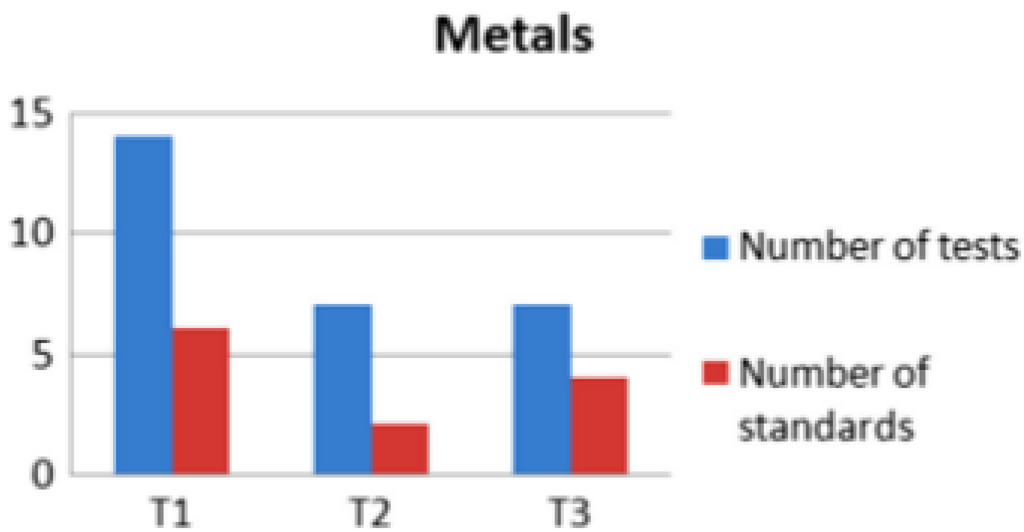

Figure 4. Tests and standards for materials of three AM technologies for metals [1]

3. Conclusions

Since the first workshops held in the 1990s by NIST up to the latest situation of joint standard development by ISOASTM for AM, the industry has taken some significant steps forward, providing several standards to the AM community. These new AM standards are expected to facilitate the growth of the AM activity and increase profits in the industry as well as assuring quality and facilitating certification of products in some sectors where this requirement is mandatory (medical, aerospace, automotive). Several road maps and many other initiatives. such as the SASAM project are strongly involved in this common objective, converging to a consensus regarding the structure for developing AM standards. This consensual structure will provide, in accordance with the priorities requested by stakeholders, a solid basis to provide useful standards in line with the spectacular development of AM technologies experienced over the lastand expected over the nextdecade. The first challenge of this standardization process is to address the real requirements and needs of the industry and AM community avoiding the unnecessary standard rules,therefore, increasing costs of production. The second challenge is an efficient coordination with other committees for standardization, working in materials, and processes. This is an important issue since the existing committees for AM (either in ISO or ASTM) are formed by experts coming from different fields in terms of industrial sectors (aerospace, automotive, medical, etc.) and expertise in materials (plastics, metals, ceramics). The risk is a certain level of overlapping with other committees working in metals, plastics, aeronautical, etc., where the result is much more general, beyond the specific application of AM technologies. In this sense, organizations as ASTM and ISO have recognized the need of having specific standards for AM because there is an important gap that general standards focused on materials or any other process cannot solve.

The possibility of common standards from ISOASTM opens new opportunities for the global spread of AM among countries and companies.

References

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