Metals-Based Additive Manufacturing: Metrology Needs and Standardization Efforts

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INTRODUCTION

In recent years additive manufacturing (AM) has received significant visibility, both in the popular media as well as in scientific journals. In fact, the number of publications on additive manufacturing (including 3D-printing) jumped from approximately 1,600 in 2011 to over 16,000 in 2012 [1]. Additionally, impressive *niche* successes, such as a metal jaw replacement made completely via additive manufacturing [2], contributes to the fervor that makes up the future vision for additive manufacturing. This vision for additive manufacturing is simultaneously imaginative, outrageous, and inspiring. And while it is difficult to accurately predict the full future impact of additive manufacturing, it is easy to imagine how it *could* potentially impact every major industry – aerospace, defense, medicine, transportation, food, fashion – and have an even bigger impact on U.S. manufacturing than the robot revolution. [3].

While this vision is impressive, there remain significant technical challenges that first must be overcome if this vision is to be fully realized. This paper will summarize the key metrology-based technical challenges that are preventing metals-based additive manufacturing processes from being more pervasive, and describe current standardization efforts that are underway to address these challenges.

ROADMAPPING EFFORTS

Collaborative roadmapping efforts have helped capture and define the most importanttechnical hurdles that are preventing the vision of additive manufacturing from being realized today. These efforts include a roadmap development sponsored by the National Science Foundation in 2009 [4] as well as a more recent effort that focused on metals-based additive manufacturing [5]. Both of these activities included broad participation from industry, academia, and government, and the list of challenges resulting from these activities had a high degree of overlap. Most of these challenges will require a significant metrology effort, if they are to be successfully solved. The following summarizes the key technical needs developed in these roadmapping efforts as they apply to metals-based additive manufacturing processes:

Material Properties

The material properties of parts made via additive manufacturing are not well understood and there is a lack of high-quality, pedigreed data necessary for using AM parts in high-stress applications such as turbine blades or jet engine components. There is also a lack of understanding on the relationship between powder properties and part properties. In addition, currently there are very few commercial powders available for use in metals-based AM systems.

Process Understanding

Although many metals-based processes involve heating, melting, and cooling of metal – which is understood at a fundamental level – the difficulties in measuring these processes *in-situ*.result in a lack of process understanding, and difficulties in optimizing the processes. Many of these processes also have large day-to-day variability.

Qualification and Certification

There are currently no standardized methods for qualifying and certifying AM input materials, processes and parts. Current empirical methods for qualifying parts are unwieldy and impractical for AM, due to the large number of test samples required and the large number of process parameters.

Part Accuracy and Surface Finish

The accuracy and surface finish of AM metal parts is generally poorer than that of traditional material removal processes.

Fabrication Speed, Build Volumes and Part Size

AM processes are generally slow, and the build volumes and part sizes are limited.

Lack of AM Standards

Currently there are very few additive manufacturing-specific standards that have been developed in a consensus method through a standards development organization (SDO).

Data Formats

Currently there are only two general data formats in use, one (STL) that is widely used but has some limitations, and another (AMF) that overcomes some of the STL limitations but is not widely used due to the limited number of systems that are compatible with it.

STANDARDIZATION EFFORTS

AM standards are essential if AM technologies are to achieve wider use. Standards provide technical correct and consistent methods, which if followed properly, give the confidence that everyone in the industry is doing things the same, correct way.

Despite there being few AM-specific standards in existence today, the current state of affairs for AM standards development is very favorable. There already exists two relatively new SDOs for AM, the ASTM-I F42 Committee on Additive Manufacturing Technologies, and its sister committee, ISO TC261. Fortunately we are also still in a very early phase of AM technology development, which allows for strategic planning of which standards are needed, and when they should be developed. Such strategic planning is already taking place between ASTM-I F42 and ISO TC261. In fact, F42 and TC261 have a unique agreement that allows them to co-develop and co-brand standards. This favorable standards development situation will also minimize the need for future standards harmonization efforts, which are often slow and laborious.

Additionally, in many cases, existing standards (e.g., for measuring powder and part properties) can be used as the basis for AM-specific standards, either as currently written or with some minor adjustments. This already existing base of standards will greatly accelerate the development of AM-specific standards.

SUMMARY

There are significant technical hurdles, many of which require metrology-based solutions, which are hindering the full vision of AM from being realized today. These challenges will require collaborative, inter-disciplinary efforts to solve. One hurdle is the lack of AM-specific standards. However, the current SDO infrastructure in place to develop these standards is well-suited to do so.

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