APPLICATION NOTE

ADDRESSING THE CHALLENGES FOR 3D PRINTING SPEED AND COST IN LASER ADDITIVE MANUFACTURING

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INTRODUCTION

3D printing technologies hold promise for revolutionary advances in design, prototyping, and manufacturing in environments as diverse as building construction, automobile manufacturing, medical device and prosthetics fabrication, and consumer goods [1]. 3D printing technologies employ various methods to fabricate complex artifacts using layer-by-layer construction. Laser-based Additive Manufacturing (LAM) is one fabrication methodology within the category of 3D printing technologies. LAM encompasses a suite of fabrication methods, including Selective Laser Sintering, SLS; Selective Laser Melting, SLM; and Laser Metal Deposition, LMD [1] [2]. These methods employ a high-powered laser as an energy source for sintering, melting, or deposition of additive material in the fabrication of artifacts. Typically, LAM fabrication produces artifacts by building up the material structure on a point-by-point, line-by-line, and layer-by-layer basis. The adoption of 3D printing technologies and, in particular, LAM methods for both small- and large-scale manufacturing can potentially provide unique advantages over conventional fabrication methods in terms of process simplicity, environmental sustainability, access to complex structures not easily fabricated by conventional means, and local, low-volume, on-demand production of critical component parts and products. Rapid prototyping with 3D printing is much quicker and more cost effective than with conventional machining approaches.

While the potential advantages of 3D printing are widely acknowledged, the fabrication of artifacts using these methods is generally limited to smaller, niche products or components in larger assemblies, owing to certain critical limitations in the technology. 3D printed artifacts are limited in terms of the available selection of materials. Not all plastics and metals can be used in this technology. Laser additive manufacturing of metal parts, in particular, are limited by the high energies necessary when using a CW laser to melt certain metals. As it moves a laser spot across the metal powder bed, a 3D laser printer focuses laser energy between 200W and 1000W on a single spot of diameter 80 – 100 microns to fuse the metal powder in that spot to the layer below. Fused lines and areas of metal are produced by scanning the laser spot over the metal powder bed in a pre-defined pattern. Most 3D printing platforms can't produce small parts with fine features at high accuracy, resolution, and precision. At the other end of scale problems, LAM fabrication, for example, is typically limited to structures with build volumes of less than a cube having approximately 40 cm sides. Finished parts manufactured using 3D printing techniques can exhibit deficiencies in surface finish and other quality measures that must be resolved post-production. 3D printing is time-consuming compared to more conventional production methods. Where a mass-production technology may require minutes or less to produce a single artifact, 3D printing can require up to a couple of hours to fabricate the same item, depending on the balance between size, structural complexity, and any requirements for surface finish. Finally, the cost of fabrication for 3D printed parts remains a concern. Laser additive manufacturing methods can cost between \$1–2 /cm3 for artifact construction. Given these factors, 3D printing methods have mainly found application in the production of small, high-value products in areas such as medical, energy, and aerospace where the rapid prototyping capability and ease of on-demand manufacturing of complex structures obviates the relatively slow rate of production and high cost.

Increasing Speed and Reducing Cost in LAM

Seurat Technologies has introduced a novel methodology for LAM of metals that provides solutions for some of the key limitations in 3D printing. Labelled “Area Printing” this new methodology was originally developed by researchers at Lawrence Livermore National Laboratory (LLNL) [3] [4] [5]. Area Printing offers reduced cost and significantly increased speed of manufacturing for 3D printed metal artifacts, as compared with point-by-point and line-by-line LAM methods. Using a technique analogous to that of the Pointillist artists of the late 19th Century (hence, the company name, Seurat), Area Printing uses a powerful laser to produce a pulsed IR beam that contains over 2.3 million pixels that micro-weld the defined geometrical area of thin metal powder layer to the layer below. Prohibitive energy requirements, such as would be encountered if CW lasers were used in this method, are avoided through the use of a pulsed IR laser that delivers a single, very short, very intense pulse of IR energy in a shaped beam. The energy in this single laser pulse is sufficient to print an entire area of metal at once, as compared with the single, focused spot achievable using CW laser-based methods.

To print a geometrically defined area of metal, the pulsed IR beam is first shaped to create a homogeneous square IR field (top field image to the left of the beam in Figure 1), then patterned to produce the desired field geometry. Patterning of the homogeneous square field is achieved by overlaying the pulsed IR beam with aligned and patterned low-intensity blue laser light, produced using a conventional laser projector (the second field image down, on the left in Figure 1). An Optically Addressable Light Valve (OALV) is then used to polarize the IR laser

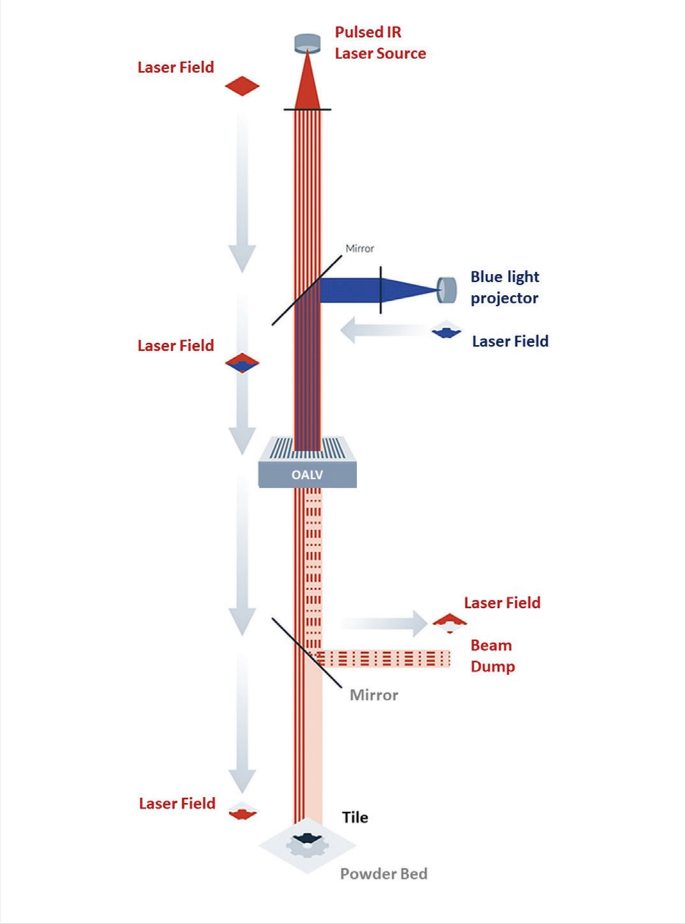

Figure 1- Seurat’s Area Printing Technology

beam horizontally where the blue and IR pixels overlap and vertically where the IR and blue light do not overlap. A detailed discussion of how the OALV produces these different states of polarization is provided in References [3], [4], and [5]. The vertically and horizontally polarized sections of the pulsed IR field are then split, allowing only the horizontally polarized section of the beam to impinge on the metal powder bed, fusing the defined area in the top layer of metal powder. Using Seurat’s Area Printing technology, laser pulse energy between 10 and 60 Joules per tile can be delivered to a patterned section within a tile 5 to 15 mm square. The 2.3 million pixels within the square field of the tile produce very high resolution that exceeds that achievable in other laser-powder bed fusion printers and the IR pulse frequency of

20 – 40 Hz provides a significant advance in processing speed for the 3D printing process. Additionally, the blue light projector permits control over the laser power of each individual pixel, offering graded material property capabilities that are unachievable by any other laser additive manufacturing method. Figure 2 provides a comparison of Seurat Area Printing with other LAM techniques for stainless steel additive manufacturing. Area Printing achieves or surpasses both the high build rates of wire arc deposition and the accuracy and resolution of the powder bed fusion techniques.

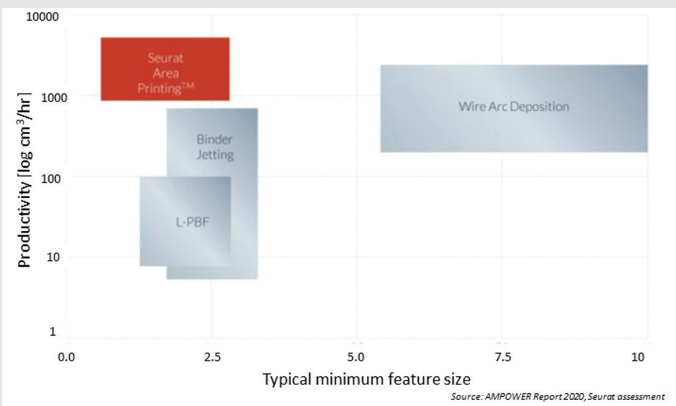

Figure 2- A comparison of productivity and feature size for different LAM techniques stainless steel).

Optical Components: Quality is Critical

Successful application of Seurat Area Printers is dependent on the stability, reliability, precision, and accuracy of the various components within the system. Seurat carefully canvassed the relevant equipment suppliers and selected MKS Instruments as the best suppliers for the inert atmosphere control and maintenance system and MKS Instruments Newport Division for many of the optical components in the optics transport system in the Area Printer.

MKS' pressure sensing and gas flow controls were chosen for use in Area Printing units by Seurat engineers because of a proven track record for cost-effectiveness, reliability, accuracy, and precision and for MKS' experience-in-depth with helping customers to integrate these components into their applications. MKS gas sensing components in Seurat Area Printers include Baratron capacitance manometer absolute and differential pressure sensors and MicroPirani pressure transducers. Gas flow control in Area Printers employs MKS Instruments' elastomer-sealed G-Series Mass Flow Controllers which are capable of precise gas flow control from 5 to 50,000 sccm (.005 to 50 SLM). Figure 3 shows the different MKS components used for gas sensing and flow control in Seurat's Area Printing units.

Figure 3. MKS Instruments gas pressure sensing and flow control components: (a) Baratron capacitance manometer; (b) Baratron differential pressure sensor; (c) MicroPirani pressure transducer; (d) MKS G-Series mass flow controller

MKS Instruments' Newport Division supplies critical optical components within Seurat Area Printers. Seurat engineers selected MKS components based on their stability, reliability, and precision. Vibrational and geometric stability is obviously critical to any optics application and starts with the support platforms used for the various optics components. MKS Instruments supplied state-of-the-art optical benches and custom vertical honeycomb breadboards with micro-locks to hold the equipment needed to position the laser and optical transport systems, designed specifically to Seurat's specifications. When mounted on these breadboards, MKS optics transport components exhibit the stability needed to achieve the high resolution inherent in the Area Printing method. MKS instruments supplies Seurat with actuators and actuator controllers for positioning the mirrors in the optics transport system with stable precision, accuracy, and repeatability. These actuators provide single or multi-axis control with advanced Backlash or Hysteresis compensation in a very small form factor. MKS supplies Seurat with special interferometer-verified Ultima mirror mounts support the large-scale mirrors. These mounts have axial three-point optical mounting and are specifically designed to minimize wavefront distortion.

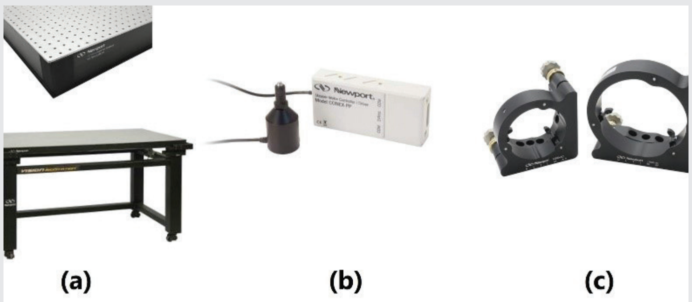

Figure 4. MKS Instruments Newport Division optical components employed in Seurat Area Printers. (a) optical breadboards; (b) mirror actuators; (c) low wavefront distortion mirrors.

Conclusion

Seurat's Area Printing technology provides new capabilities in productivity and resolution for laser-based additive manufacturing. This technology is critically dependent on the quality, stability, precision, and accuracy of the various components within an Area Printer. MKS Instruments and MKS Instruments Newport Division provide Seurat with the high-quality system components needed for optimal operation of their Area Printers at lower cost and with lower cost-of-ownership than competing systems.

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