How Laser AM Can Help Mitigate Insecurities with Supply Chain Issues and Carbon Footprint

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ABSTRACT

In recent times, much of the world has suffered from supply chain difficulties that have affected shipments and deliveries of food, medicine and equipment. In manufacturing, supply chain issues have resulted in delays due to a lack of materials and parts, as well as from a lack of skilled labor. It is reassuring however, to know that Additive Manufacturing (AM) and Laser AM in particular, create the potential to overcome some of these difficulties. 3D printing by Laser Powder Bed Fusion and/or Laser DED are ideal processes for manufacturing near or at the point of end use. A significant lead time advantage can be achieved through the adoption of these processes and even reduce the carbon footprint associated with production, which also decreases waste and makes financial sense.

Keywords: Times Roman, image area, acronyms, references

1. INTRODUCTION

During the COVID crisis, particularly from 2020-2021, global supply chains were extremely constrained. The entire world suffered from the effects of these supply chain difficulties which included delayed shipments, deliveries of food, medicine and equipment. Fortunately, 3D printing and Additive Manufacturing showcased itself as a solution to these problems. The first visible demonstrations of this technology's benefits in the medical sector included producing parts for ventilators, face shields and face masks, especially when these items were in short supply. Members of the public including students, 3D printing hobbyists, and people from manufacturing in other industry sectors stepped up and used 3D printing, cutting, welding, texturing polymer parts, and other technologies to produce parts in fast and innovative ways using out-of-the-box thinking. Another innovative example was 3D printing of plastic "no-touch door handles," as seen in Figure 1, which helped to reduce the number of touchable surfaces and spread of germs. To prevent duplication of effort however, the FDA and VA issued guidelines as to what 3D printed parts were allowed to be used in critical care cases.

Figure 1. No-touch door polymer handle developed by Materialise and produced by Additive Manufacturing [1].

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Laser 3D Manufacturing X, edited by Bo Gu, Hongqiang Chen,
Proc. of SPIE Vol. 12412, 1241202 · © 2023 SPIE
0277-786X · doi: 10.1117/12.2662407

1.1 SUPPLY CHAIN ISSUES

Three years after the height of the pandemic, supply chain issues are still affecting many facets of life here in the United States. A number of crises have caused worldwide shipping delays. For example, in 2021, when a vessel was stuck in the Suez Canal, thousands of unloaded shipping containers remained stranded in the port of Los Angeles, resulting in shortages of many items normally produced in China and other Asian countries, most famously it led to a shortage of the tapioca pearls, or boba, used for making boba tea [2], as well as shortages of other materials needed to produce consumer products and parts such as silicon chips and computer control systems. And of course, everyone remembers the general lack of food items on shelves in stores, Figure 2. In the face of increased anxieties resulting from recurring shortages, the question becomes, how do we get goods and products to customers and end users, and how do we overcome the lack of manpower, skills and general labor shortage?

Figure 2. Bare shelves in 2020 due to coronavirus panic shopping [3].

1.2 CARBON EMISSIONS DURING THE PANDEMIC

One silver lining that appeared during the pandemic period: less carbon dioxide was released into the environment. When lockdowns occurred in many cities and urban areas, freeway driving dropped, and aviation travel slowed. Studies show that carbon dioxide emissions around the December 2020 timeframe were below 2019 levels [4]. One particularly startling example was that in the absence of traffic smog, people were able to see the snow on the San Gabriel mountains from downtown Los Angeles in the spring of 2020 [5]. Decreasing the amount of human transportation by conventional methods resulted in dramatic falls in global carbon emissions. Certainly, we could continue to lower carbon emissions by using more fuel-efficient vehicles and lower carbon-based fuels, as well as by changing the way we travel and transport goods. But what if Additive Manufacturing and 3D printing could take advantage of the problems in *all* these areas; material and manpower shortages, transportation issues, and working to reduce carbon emissions, to provide a solution that mitigates some of these problems? How would we accomplish this?

The AMGTA (Additive Manufacturing Green Trade Association) whose mission is to increase awareness and educate 3D printing entities and users to become more mindful of their carbon footprint, stated that "On-demand or near-demand manufacturing reduces insecurities, costs and environmental impacts of producing, warehousing and eventual obsolescence of every combination of size, style, color and model of parts and finished goods. The associated risks and costs of shipping all those parts is correspondingly reduced, especially expedited shipping, which carries the most cost, risk and environmental impact." [6]. So indeed, as we begin to hear terms like "medical 3D printing at the point of care," essentially 3D printing a part at the place where a medical device will be used, it makes sense that there may no longer be a need to have a part manufactured overseas or even on the other side of the country, then shipped to the medical practitioner – the end user. In one step, we can reduce lead time, transportation costs, and carbon emissions – just by printing the part where it is actually needed.

1.3 Smart Manufacturing

Some other "food for thought" is that AM and intelligent processes will help address the labor shortage. Call this "Smart Manufacturing," if you will. Automation of many manual processes can now take place in "Smart Factories" using more digital tools, robotics, and machine learning/AI all add value and improve efficiencies, as well as drive down the carbon footprint, Figure 3 [7]. Other ethical considerations concerning labor and working conditions for people in the supply chain may also be addressed.

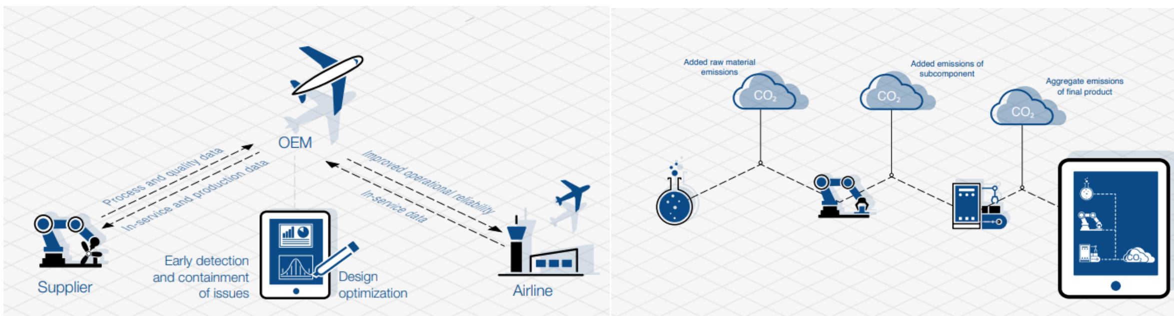

Figure 3. How transforming the manufacturing and supply systems might work [7].

2. CENTRAL BENEFITS OF LASER AM and 3D PRINTING

2.1 MULTIPLE BENEFITS OF LASER AM

The use of 3D printing, and laser AM in particular can achieve many goals but specifically, geometric complexity, part count reduction, weight reduction, cost reduction, speed and sustainability. These last 3 items are of specific interest to this Hot Topic, Figure 4.

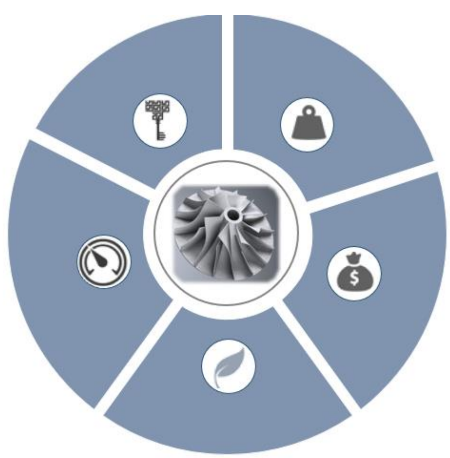

Figure 4. Schematic view of the benefits of 3D printing with speed, sustainability and cost shown.

2.2 LASER AM DEFINITIONS

The two main types of laser AM are laser metal fusion (LMF) also called laser powder bed fusion, and laser metal deposition (LMD) also called laser directed energy deposition (DED), Figure 5. Each one has its advantages and disadvantages. In both cases, the heat source is a laser, typically in the IR wavelength range (1030-1063nm). LMF is a precise method for generative fabrication of complex parts out of a powder bed, however, build rates can be slow. LMD is a productive method for repairing, coating and generating components using blown powder. Build rates can be fast, but the surface finish usually is not as good as LMF. Users should choose carefully which process is best suited for their part and production rates.

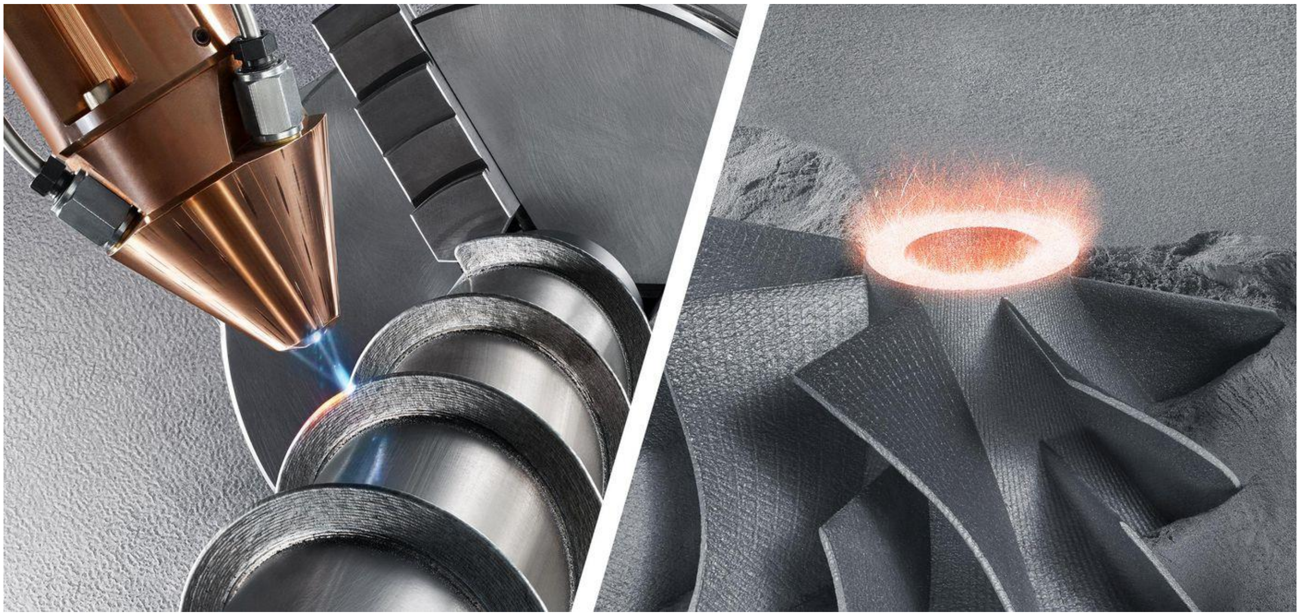

Figure 5. Schematic view of the benefits of 3D printing with speed, sustainability and cost shown.

2.3 AEROSPACE AND SPACE APPLICATIONS

With so many metallic parts on aircraft and space launch vehicles, the opportunities for new designs and new parts to be made using laser AM are vast and change on an almost daily basis. Since commercial aviation suffered a massive dip during the pandemic, AM processes helped to solve the problem of lead time in non-critical parts by allowing the manufacturers to look at more prototypes and see where weight and cost savings could be made.

In aerospace, LMD is very suitable for repair of parts susceptible to wear such as blade, vanes and shrouds on aircraft engines, whereas LMF is very suitable for complex structural parts, such as fuel nozzles and even light-weighting of other components like brackets, seat-belt buckles, and hangars.

In the space industry, revenue is not as reliant on consumer spending, so during the pandemic, development was able to occur at a more stable rate, especially at private space companies. For space launch vehicles, satellites and payloads there are opportunities for LMF again, in structural components like brackets and communication devices like RF antennae. Rocket engines with complex geometries that are difficult to manufacture by traditional methods, especially injectors, thrust chambers, turbo-machinery and even satellite thrusters, have had the total number of parts simplified by LMF, whereas LMD has been shown to produce large nozzles using freeform DED processes. A wide variety of materials can be printed -- including highly reflective materials like copper for coils, heat exchangers and rocket engines, or very expensive materials like C103, which has complex processing routes for traditional methods. Using unique laser technology such as a green wavelength of 515nm to process metallics in the visible spectrum of light enables much higher process efficiencies for highly reflective materials like copper, gold, silver, aluminum and platinum. RPM

Innovations have been able to utilize a green laser optic combined with their LMD system to produce full size copper alloy nozzles. Laser AM is a welcome alternative technology for these materials.

Figure 6. GR Cop 42 copper alloy rocket nozzle demonstrator processed by LMD using a green wavelength.

2.4 DENTAL APPLICATIONS

During the pandemic, supply chain shortages affected local medical practitioners including the dental industry. Many traditional workers producing metallic dental implants, plates, screws and fixation devices took the opportunity to retire out of the industry. Laser AM was able to offer a solution to many of the resulting supply chain issues.

In the case of RPD (removable partial denture), a dental prosthesis designed to place missing teeth, AM processes have a huge benefit. Traditionally, the process involves taking an impression of the patient's mouth. A technician marks the area for attachment then uses wax to manually sculpt a frame. A mold is created around the wax frame, liquid metal is poured into the mold (essentially a casting), then when solidified, the sprues are cleaned off and polished before shipping back to the dental practitioner. The technician time is between 1-3 days for highly skilled manual labor. With the AM process, an impression is taken of the patient's mouth, then a technician scans the area, uses software to design the frame, makes a print via LMF, then heat treats it, cleans off supports, and polishes it. The entire AM process time takes less than one day, resulting in huge time savings. There is also a cost reduction from about $65 in traditional part costs to $10-20 for AM (without labor included). There is better dimensional tolerance, resulting in a perfect fit and excellent surface finish with minimal post processing.

2.5 SUCCESS STORIES

The dental AM success story is a particularly interesting situation in which the product not only decreased in price and lead time, but moreover, it decreases the patient's pain and suffering, which is almost incalculable. LMF machines designed for the dental industry have become more reliable, easier to use, and with a smaller footprint so they can fit into most dentists' offices, and dental practitioners have become more enthusiastic to learn and use the technology [8]. And of course, bringing the AM process into the office also reduces the carbon footprint associated with shipping parts from a lab. Another important factor is that more insurance policies and Medicaid cover the costs of these parts. Moreover, the

FDA has already approved many basic designs for printing preforms for dental implants, which saves time and reduces duplication of effort [9].

3. CONCLUSION: LASER AM CAN HELP MITIGATE INSECURITIES

The pandemic resulted in huge difficulties in the global supply chain with shortages of materials, goods, transportation and labor. The flipside of the reduction in mobility is that carbon emissions also dropped. As we work towards building more robust supply chains and using intelligent manufacturing processes, while continuing to mitigate carbon emissions, laser AM and 3D printing can play a significant role. Parts can be made faster, better, stronger, more efficiently, and cheaper. We can use new designs, better materials, automation and digitize laborious processes. Smart Factories or “Factories of the Future” with more robotics, machine learning/AI processes will help us achieve these goals. In aerospace and space applications, we are pushing the limit of what is possible with better designs, materials and technologies -- whether it be for satellite antennae or rocket engine components. For dental applications, the ability to take production of dental implants into the hands of the practitioners themselves results not only in lowered costs, less shipping, better accuracy, and shortened lead time, but also in significantly reduced pain and suffering for patients. Laser AM and 3D printing creates the opportunity to decrease emissions from transportation and reduce the overall carbon footprint, essentially improving quality of life for us all.

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