Preparing Your Process and Facility for Metal Additive Manufacturing

7 Steps to Success with Metal AM

This white paper explores the safety and building considerations when bringing metal additive manufacturing into your production facility.

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Executive Summary

Metal additive manufacturing (AM) is experiencing rising acceptance and strong growth across a wide range of industries. Metal AM enables the production of complex metal parts with superior mechanical properties without the need for costly tooling and eliminates the design-for-manufacturability constraints of conventional subtractive manufacturing processes. This also increases design freedom to a level that often makes it possible to consolidate multiple parts into one while reducing overall size and weight. The ability to produce parts in days rather than weeks or months enables engineers to more rapidly iterate to an optimized design, making it possible to bring superior products to market in less time.

Yet as more companies move to capitalize on these technological benefits, questions arise how to set up facilities to ensure user safety and maintain high productivity. Here we will review the safety and environmental considerations, facilities requirements, supporting and post-processing equipment, and cross-contamination avoidance methods needed to successfully implement selective laser melting (SLM), one of the most relevant metal additive technologies. Exactly how to best prepare your facility will depend on its unique characteristics, your applications, workload, resource availability, local codes and ordnances and what services, if any, will be better served outsourced. As a comprehensive partner in metal AM, SLM Solutions has a team of applications and systems engineers available to consult on the best options for individual facilities and needs.

1. Safety Considerations

The powders used in the SLM process are fine and can contain particles as small as 10 microns. These powders can be hazardous to one's health. Operators should wear personal protective equipment (PPE) when the doors to the machine are open or powder is otherwise being handled. This equipment should normally include a National Institute for Occupational Safety and Health (NIOSH) full face respirator or powered air purifying respirator (PAPR), powder-impermeable protective gloves, electrostatic discharge (ESD) steel toed shoes and arm protection including disposable arm protectors and lab coat.

Precautions should be taken to avoid spreading metal powder throughout the facility. Access to the production environment should be limited, either by locks or signage, especially when metal powder is being handled. Tack mats at exits help prevent residual powder from being transported to other areas on footwear.

Secure entry with signage and tack mats inside the lab door prevent powder contamination outside of the machine area

Alloys used in additive manufacturing vary in their environmental impact so the specific characteristics of the materials used in the facility should be considered. If reactive materials such as aluminum or titanium are in use, powder handling concerns are amplified by the potential danger of fire or explosion. It is important to ensure that no ignition source is present so there must be no open flames or hot surfaces in the area where powder is handled. The greatest concern is usually static electricity and this risk can be alleviated by use of special flooring, mats and shoes to prevent electrostatic discharge.

Laser melting of metal powder should always be conducted under an inert gas atmosphere, in most cases Argon. This creates the risk of asphyxiation if large quantities of gas are released into a closed room. To safeguard against this risk, the room where the additive manufacturing machine is used should contain a low Oxygen alarm and sufficient air conditioning and ventilation capacity to clear the largest conceivable Argon leak.

2. Environmental Considerations

Metal additive manufacturing generates powder and liquid wastes, so proper disposal of these materials is a serious matter. Once the build is completed, stray powder should be removed from the machine. Normally, the first step is to brush or vacuum as much powder as possible from the build chamber into the overflow bin for reuse. A lint-free cloth can be used to wipe up the remaining powder. Then, a wet separator vacuum is used to remove any leftover metal powder from the machine. The wet separator vacuum includes a water column that passivates the metal powder, rendering it nonflammable and simplifying the disposal process. Stray powder should also be removed using the same methods from the PPE, post-processing equipment and anywhere else it has the potential to land. Additional sources of dry waste include wipes and any other disposable materials that have been exposed to powder. Walk-off tack mats should be positioned on the floor near exits from rooms where powder is handled to pick up loose powder from the bottom of shoes to avoid tracking it into the rest of the facility.

Passivating filters come out of the additive manufacturing system loaded with potentially flammable soot. The filter flooding station is used to flood these filters to render them nonreactive. Both the filter flooding station and the wet separator produce soot-laden waste water so a container must be provided to store this water until proper disposal.

Most companies will contract with an industrial waste company to pick up and dispose of both liquid and solid waste. Focusing on minimizing waste generation can reduce disposal costs. For example, brushing as much powder as possible into the overflow bin of the additive manufacturing machine after the build is completed will reduce the waste stream.

3. Facilities Requirements

Key facilities support required for additive manufacturing includes temperature and humidity control, reliable electrical power, compressed air, inert gas, a clean environment and controlled access. Most SLM metal additive manufacturing machines use 400-volt 3-phase power and are supplied with a transformer that steps up or down power normally found in US shops to 400 volts. A stable power supply is important because a loss of power during a build might not only cause downtime but may also cause a complete loss of the build. In some cases it is worth investing in an uninterruptible power supply (UPS) and backup power source. The machine also needs a supply of clean, dry compressed air. Argon or Nitrogen gas can be provided by purchasing reusable tanks of the gas from a local supplier.

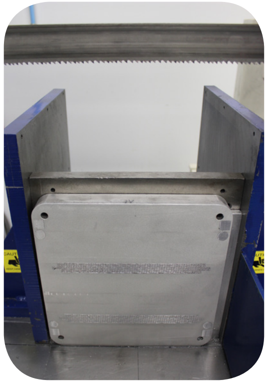
SLM systems do not require a cleanroom, but do need a relatively clean working environment to prevent contaminating the laser optics. An office environment is not suitable because powder will be present and those in the proximity would need to wear PPE when the machine is open. For this reason, the room where the system is used should be able to be locked when the machine doors are open. The temperature in the room should be controlled within the range of 20°C to 25°C. Relative humidity should be within 40% to 60% as too high humidity prevents powder from flowing well while too low humidity increases the risk of generating sparks.

A separate room is also desirable for post-processing equipment such as a bandsaw, machining center, etc. This, of course, assumes that post-processing is done in-house as opposed to the alternative of outsourcing this function. Further, an area to carry out dirty parts of the process, such as changing filters, cleaning the wet separators and flooding filters, is needed.

4. Supporting Equipment

Metal additive manufacturing requires additional equipment to support the printing process including an external chiller and powder sieve. The chiller, which is needed to cool the laser and optics, is often placed in a separate room from the additive manufacturing system because it produces noise, heat and humidity. The chilled water is piped to the selective laser melting machine and there are requirements for the minimum size and maximum rise of these pipes. The powder sieve is used to process the unmelted powder after each build, separating the small particles that can then be reused in subsequent builds from larger particles and contaminants which are typically disposed.

5. Post Processing Equipment



A bandsaw removes parts from build plates

Post-processing equipment is necessary to remove parts from build plates, resurface those plates for reuse, perform heat treatment and inspect parts. A bandsaw or electrical discharge machine (EDM) is used to remove parts from the build plate. Build plates can be finished with a small machining center, milling machine or grinder. Another option is to outsource the task to a local machine shop, but this option requires a larger plate inventory.

A heat treating oven may be needed to remove residual stresses and improve the mechanical properties of the part. The oven will also need electrical service and a supply of inert gas. A shot peener is useful for smoothing and putting compressive stress into part surfaces. Tumblers can also be used for smoothing and a grit blaster can generate a matte finish. Another useful tool is a downdraft table, which is a workbench with a downward flow of air that ensures any residual powder or debris is captured. The inspection equipment required depends on the type of parts being produced. A microscope is valuable for examining surface quality. Many companies use a coordinate measuring machine (CMM) or laser scanner to inspect part geometry. Companies with very strict customer requirements, such as those producing parts for the aerospace industry, may have a full metallurgical lab including technologies such as x-ray or computed tomography (CT) scanning. Sophisticated inspection capabilities can also be outsourced.

Workshop area including furnace, downdraft table and peener

The workshop area where parts are removed from plates and post-processed can require a significant amount of space on its own. The workshop at the SLM Solutions' facility in Wixom, Michigan is about one-half the size of the additive manufacturing room. The workshop contains a bandsaw, machining center, heat treating oven and two shot peeners that support four additive manufacturing machines. A company running high volume production and doing a considerable amount of post-processing work might require even more workshop capacity for the same number of additive manufacturing machines.

6. Information Technology Needs

The information technology (IT) requirements depend on the number of machines being run, the level of sophistication of the resource planning and the need for security. A fairly powerful personal computer or professional workstation is recommended to prepare files for additive manufacturing. Ideally, the computer should be connected to a network so that engineers can transfer files to it.

The machine itself should also be networked so that users can transfer build files from the workstation to the SLM machine. Users might also provide controlled network access to SLM Solutions for troubleshooting when needed.

7. Avoiding Cross- Contamination

In producing critical components such as for the aerospace or medical industries, it's important not to mix powders of different materials. Cross-contamination with even a small amount of a foreign powder may cause the end part to fail inspection. The ideal approach for a shop running multiple materials is to store and handle the different powders in separate rooms, for example, nickel-based alloys in one room and titanium based alloys in another. In a low production environment, cross-contamination can be avoided by careful workflow practices, such as clearly labeling machines, powders, sieves, etc. to indicate which material should be used in each process. Nevertheless, if materials are switched often, or if there are several machines in the same area running different materials, it is difficult to prevent cross contamination with labeling alone.

Conclusion

Metal additive manufacturing is experiencing significant growth and acceptance across a wide range of industries due to its ability to accelerate innovation by compressing the time required to build and test new designs. Metal AM also provides engineers with unprecedented design freedom and reduces the need for costly tooling. This article introduced some of the major considerations involved in setting up your facility for safe and productive manufacturing of high quality metal parts. It is not possible in an article of this length to address every potential implementation consideration, so please contact SLM Solutions to address in more detail the specific issues involved in implementing metal additive manufacturing at your facility.

About SLM Solutions

SLM Solutions is a leading provider of metal-based 3D additive technology and machinery for prototypes and manufacturing production. SLM Machines support an optimal approach for safe, flexible and cost efficient metal part production across the aerospace, automotive, academia, energy and medical industries. Systems include the SLM 125, SLM 280 and SLM 500. With multi-laser options, bi-directional recoating, open-software controls and closed-loop powder handling, Selective Laser Melting systems achieve best-in-class safety and increased build speeds for complex and completely dense metal parts.

Headquartered in Lübeck, Germany, SLM Solutions Group is a publicly traded company (TecDax AM3D.DE) with its North American offices located in Metro-Detroit. SLM Solutions NA, Inc. offers full support for local customers featuring a development lab, application engineering team, PhD. metallurgist and service engineers located around the county.

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