

A Review on Machine Process Parameters of Laser Engineered Net Shaping

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Abstract

Manufacturing sectors are shifting their interest toward additive manufacturing technologies, where components are fabricated directly from CAD models layer by layer. Laser engineered net shaping most known to produce a near net shape of functionally graded materials. In this paper, process parameters that affect mechanical properties, surface topology and physical properties are reviewed. Powder feed rate, hatch distance and layer thickness more related to porosity of the parts that being produced. Mechanical properties get affected by laser power scan speed. Density and hardness sensitive to focal distance of the optimal convergence of the maximal laser intensity and the localized spatial concentration of the powder beam. To get homogeneous microstructure shorter focal distance is preferable. However, working distance has no such impact on density.

A Review on Machine Process Parameters of Laser Engineered Net Shaping

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Abstract

Manufacturing sectors are shifting their interest toward additive manufacturing technologies, where components are fabricated directly from CAD models layer by layer. Laser engineered net shaping most known to produce a near net shape of functionally graded materials. In this paper, process parameters that affect mechanical properties, surface topology and physical properties are reviewed. Powder feed rate, hatch distance and layer thickness more related to porosity of the parts that are being produced. Mechanical properties are get affected by laser power scan speed. Hardness is sensitive to focal distance of the optimal convergence of the maximal laser intensity and the localized spatial concentration of the powder beam. To get homogeneous microstructure shorter focal distance is preferable. However, working distance has no such impact on density.

Keywords: Additive manufacturing, laser power, scanning speed, focal distance.

Introduction

A three-dimensional object is primarily created utilizing the highly developed fabrication technique known as additive manufacturing (AM), which builds an object layer by layer. Charles Hull's invention of stereo lithography, later known as AM technology, received the first acknowledged patent. In addition, he is credited with creating the STL model format for standardized interface, which bears the same name as this manufacturing method. Because AM has so many advantages over traditional manufacturing processes like casting and machining, it is becoming more and more popular. There can be significant savings in raw material use and waste when designs are created additively rather than subtractively. The use of additive manufacturing engineers increased utilization of design freedom, manufacturing time and cost part inspection

reduced and counts radically reduced. Furthermore, components produced on demand, reduce responsive time and storage needs.

Over the last four decades, scientific and industrial research has enabled significant advances in additive manufacturing, allowing the production of a variety of products made of polymers, metals, ceramics, and composites with unviable or even impossible geometries by other processes. The LENS machine is a "real" direct-metal Rapid Prototyping technique, producing items made of full strength metals. Based on the Cooperative Research and Development Agreement, Sandia National Laboratories and various other organizations produce it (CRADA). Direct Energy Deposition (DED), Direct Light Fabrication, Direct Laser Deposition, Direct Laser Fabrication, Laser Rapid Forming, and Laser Solid Forming are some of its synonyms. The geometric data in a Computer-Aided Design (CAD) solid model is used by LENS 3D printers to autonomously control the LENS process as it builds a component layer by layer. Powdered metals are fused together by the systems into completely dense three-dimensional structures using high-power lasers. In order to prevent impurities from picking up during deposition, the LENS process is contained in a chamber that is purged with argon so that the oxygen level stays below 10 parts per million. The Optomec patented powder-feed mechanism, which can flow small volumes of powder very accurately, feeds the process with the metal powder. Once finished, the component is removed and can be machined, heat-treated, or polished in any other way.

LENS is a highly focused metal deposition technology that creates an extremely small weld bead, exposing the component to far less heat than traditional techniques. Stainless steel alloys, nickel-based alloys, tool steel alloys, titanium alloys, and other speciality materials have all been used to produce parts, in addition to composites and functionally graded material deposition. The LENS components are fully dense and exhibit no compositional degradation, according to microscopy studies. Outstanding as-fabricated mechanical qualities are revealed through mechanical testing.

Laser engineered net shaping has the following benefits:

Excellent material qualities: Fully dense metal components can be created using the LENS technique. Produced metal parts may also include embedded features and improved material characteristics. The microstructure created is likewise generally of good quality.

Complex components: The LENS system excels in functional metal components with intricate details.

Less post-processing is needed: Cycle time is shortened by decreasing post-processing.

The limitation of LENS technique are:

Limited resources: Currently, the method is exclusively utilized to create metal components.

Size of a large physical unit : To house the unit, a sizable space is needed.

Heavy electricity usage : The watts needed by the laser system is very high.

There are a number of applications for LENS technology.

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1. Parts that are completely dense and have no compositional degradation
2. Create mold and die inserts.
3. Manufacturing time and cost savings in the production of functional metal parts.
4. Equivalent to or superior to those of mechanical qualities used in conventional processing
5. Manufacturing titanium components for the automotive sector
6. Make titanium components for biological implants.
7. Develop functional gradient structures

8. Environmental compatibility is achieved through the controlled containment of expensive and hazardous materials during processing under inert conditions. Fig. 1 Parts produced by LENS (a). Blade (b). H13 Tooling (c). WES Housing

LENS Process

An STL file is used to feed a three-dimensional CAD model into the laser equipment (slicing of the designed model into layers). The laser system decodes the sliced image. Both CO₂ and Nd:YAG (Neodymium Yttrium-Aluminum Garnet) laser sources can be used with the laser system. A delivery head of the laser system is coupled to powder feeding systems, and an inert gas acts as the material powders' carrier gas as it travels from the feeding system to the work area. A lens that focuses the laser beam to a focal point to produce a molten pool is part of the delivery head. When the powder is deposited co-axially with the laser beam into the molten pool, it melts and fuses, forming a layer along the direction of deposition. Fig. 1 depicts this process. An extremely thin cross section of the geometry is deposited after the substrate is shifted beneath the laser beam. A layer is first deposited, and then another is added by moving the powder delivery nozzle and focusing lens assembly in the Z-direction. Until the component is finished, this procedure was repeated. A unique powder delivery nozzle and powder feeder have been created in order to guarantee uniform deposition and enhance overall part quality.

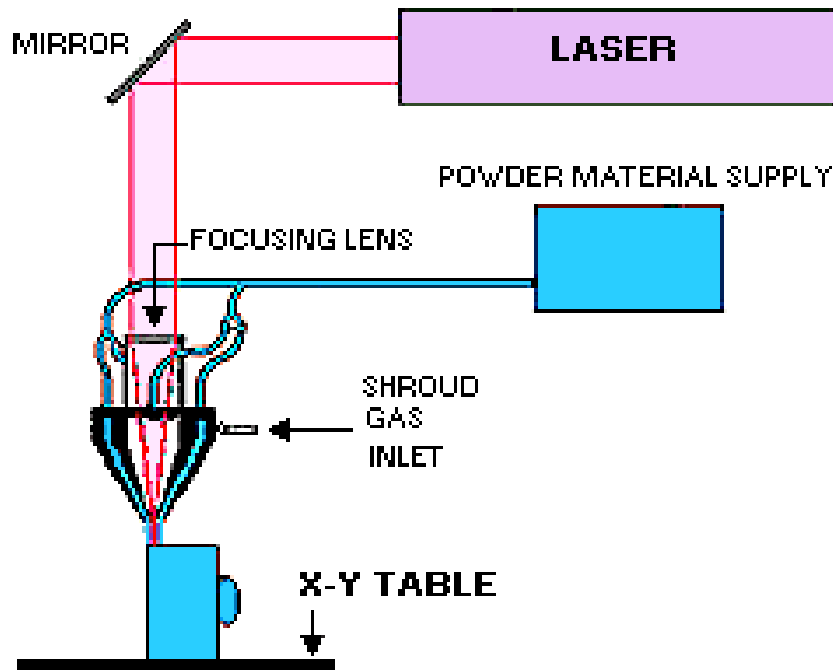


Fig. 2 LENS set up process

Process Parameters of LENS

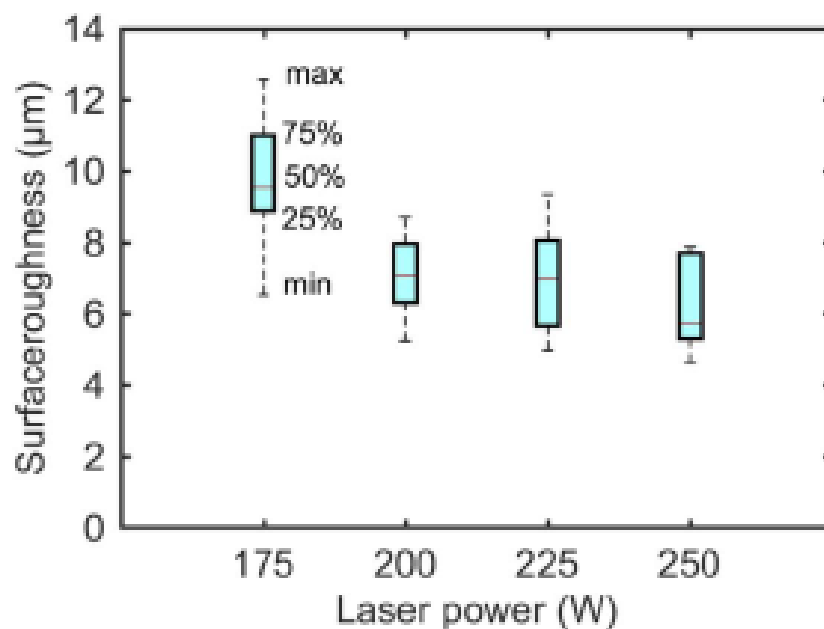
Controlling features such as surface finish, microstructure, and mechanical property is possible by selecting appropriate processing parameters for the LENS process. The process parameters are laser power, scan speed, deposition pattern, layer thickness, powder feed rate, hatch distance and focal distance are the main parameters reviewed in this paper. Each variable has a significant impact on the deposited material.

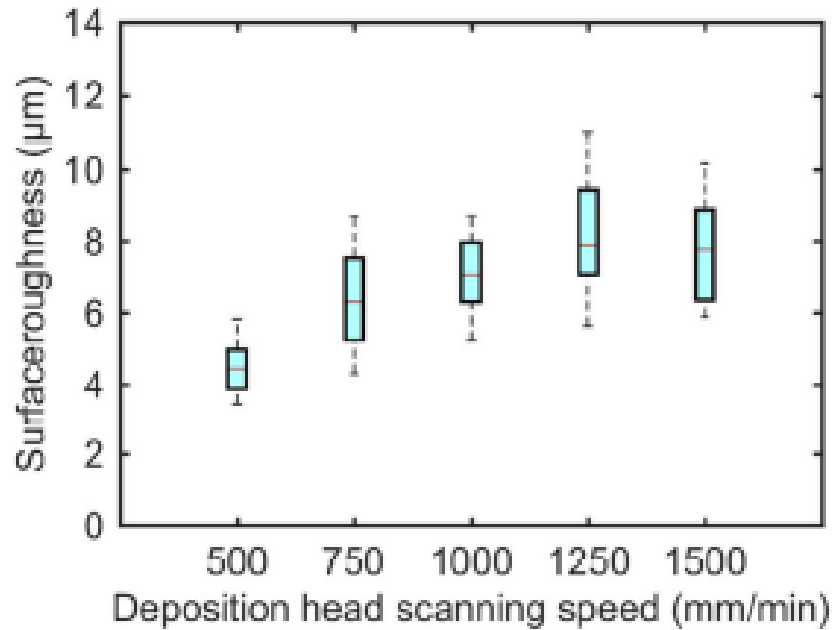
3.1 Laser power

A high power laser is used to melt metal powder supplied coaxially to the focus of the laser beam through a

deposition head. The energy poured into the melt pool gradually rises along with the laser beam's intensity. The laser power is the rate at which energy is emitted from the laser beam. The laser is primarily used in the LENS process to liquefy metallic powder to form a melt-pool, which solidifies upon cooling to form the build voxel of a respective layer. Laser power is possibly the most important process parameter in LENS, with variations in this parameter having the greatest impact on the mechanical properties of a part. When a dense structure is required, for example, the laser power can be increased to avoid partial melting zones (porous structures), but this can also result in undesirable microstructural changes. In some cases, increasing laser power causes grain size to increase, lowering hardness and potentially affecting other mechanical properties. Not only does laser power affect mechanical properties; according to Mahamood and Akinlabi analysis, surface roughness decreased linearly with increasing laser power, improving surface finish.

3.2 Scan speed





Scanning speed is one of the critical process parameter in laser engineered net shaping. For 304 stainless steel, Chai R, et al. studied, smooth laser cladding surfaces with modest track widths/heights are produced at scan speeds ranging from 4 to 16 mm/s. If the scan speed is too slow, the material is exposed to the laser for a longer period of time, generating more heat and expanding the heat affected zone. The metal will not melt if the scan speed is too fast. Depending on the properties of the powder material being used, the scan speed should be chosen to be within or near the specified scan speed range. As shown in Fig. 3(b), scanning speed has also a negative effect on the surface roughness.

(b)

Fig. 3 a) Effect of laser power on surface roughness b) Effect of scanning speed on surface roughness

Deposition Pattern

Xinlin W. et al. were investigated the effect of scanning parameter (reciprocating and unidirectional deposition way) and z-increment on overhang structure and accuracy in 3-axis LENS process. In unidirectional deposition, the deposited overhang had uneven surfaces and voids on the left side (end side of the path). The surface of the overhang through the round-trip deposition path was flat and symmetrical compared to the unidirectional path. The z-increment had a significant effect on the angular accuracy of the deposited overhang. By optimizing the z-increment, the discrepancy between the designed overhang tilt angle and his experimental overhang tilt angle was greatly reduced. The optimal z increment value depends on various process parameters (laser power, scan speed, and powder feed rate).

Layer Thickness

Ronda N. et al. studied on M300 maraging steel parts the effect of layer thickness on the microstructure, metallurgical quality and mechanical properties. Microscopic observation of the structure of the samples unconcealed a fine cellular structure. It had been noted that a decrease within the layer thickness leads to a decrease within the cell size and at the same time lowers the porosity of the fabric. A rise within the layer thickness causes a little however noticeable deterioration of the fabric properties between the 0.5 and 0.75 metric linear unit layer thicknesses. While producing ceramic components, cracking is the main challenge. Crack range of made-up specimens decreases clearly with the rise of layer thickness, and crack direction step

by step changes from horizontal direction to transverse direction. Once the layer thickness is zero.8mm and on top of, close to crack-free structures are often obtained. Total energy consumption for every ceramic specimen decreases clearly with increasing of layer thickness, that is helpful to reduce the strain and therefore scale back the cracking behavior. Porosity increased as layer thickness increased.

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Figure 3. Microstructure of different Δz : (a) 0.2 mm; (b) 0.4 mm; (c) 0.6 mm; (d) 0.8 mm; (e) 1.0mm

Powder feed rate

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In LENS, powder feed rate is crucial as well. If the feed rate is reduced, there could not be enough powder to fill the space between two parallel lines, leading to porous zones. On the other hand, a thicker layer produced by a high feed rate may damage the integrity of the following build layers or result in part non-uniformities. The height of the deposited bead is mostly influenced by the powder flow rate. This is due to the fact that more material is capable of entering the melt pool and forming beads. The width of the bead can also be influenced by the powder flow rate, but this often only happens when the extra bead width is fused to the rest of the deposited material and not the substrate itself. It can be seen in Fig. 4 that for a constant laser power of 250W, lowering the powder flow rate results in a 0.8% decrease in sample porosity .

Fig.4 Powder flow rate vs porosity

3.5 Hatch distance

Hatch distance, which is a cross-sectional distance between two scan lines as illustrated in Fig. 5, determines the smallest feature size that may be created with additive manufacturing. Inconsistent builds will result from an excess of material forming on a layer if the hatch distance is too close to the melt pool. A layer will become devoid of material and develop localized porosities when the hatch distance is very large in comparison to the size of the melt pool. Bandyopadhyay et al. investigated this effect in order to create a controlled porous structure.

However, in biomedical, mechanical properties of permeable bio-materials can be changed and altered by controlling porosity, pore measure and shape, and pore mien to improve the common bone. A particular porous structure can diminish the solidness bungle and finish steady long-run fixation as a result of whole bone loosening. The strong facial plan of the permeable embed advances bone ingrowth into the pores. Bolster the natural obsession, and engage the stresses to be reassigned from the restorative embed to the bone, providing a life span to the embed firmness .

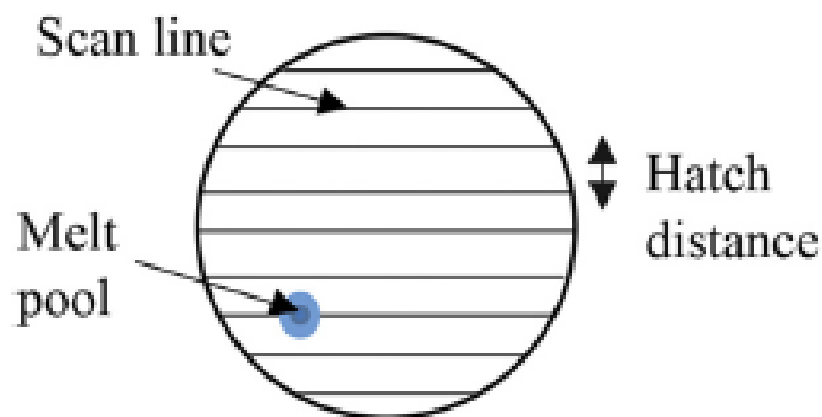


Fig. 5 Hatch distance

Focal Distance

Optimal convergence of the maximal laser intensity and the localized spatial concentration of the powder beam is referred to as the focal distance. Xiong Y. et al. looked at how the working distance and relative location of the laser beam's focal plane affected microstructure and characteristics. With varying working distances, microstructures with and without alternating sublayers can be created. When the Co binder in the top portion of a previous deposition layer is remelted, large WC particles may develop for the microstructure with alternating sub-layers produced across a longer working distance. Particle coarsening was insignificant for the homogeneous microstructure that was deposited across a shorter working distance. Working distance has no discernible impact on density. But using a shorter working distance produces more consistent microstructure and hardness values, which is crucial for using cermets .

The process parameters discussed above are machine parameters. Non-machine parameters, powder morphology and powder purity are also affect the properties of the parts that are being produced.

Conclusion

Higher laser power used to acquire dense structures by avoiding porous region. However, it my result small grain size which lower hardness and other mechanical properties. Furthermore, increasing laser power affect surface roughness of printed parts.

In LENS scanning speed is one of the decisive parameter. As scan speed getting lower, laser beam exposed to the material for long period of time, then it creates heat affected zone. In the other hand, if the scan speed is too fast metal will not properly melt.

Reducing powder feed rate results porous zone since enough powder not fill space between two parallel lines. On the other hand, a higher powder feed rate lead to damage the integrity of build layer that result part non-uniformity.

Unidirectional deposition pattern deposited overhand has uneven surface and create voids on end side of the path. In contrast, surface of overhang through the round trip deposition path is flat and symmetric.

To get homogeneous microstructure shorter focal distance is preferable. But, working distance has no such impact on density.

Hatch distance and layer thickness are parameters responsible for porosity if too large and creates built layer inconsistency if the two are too small independently.

Conflict of Interest

No conflict of interest

Acknowledgments

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