Journal of Advances and Scholarly Researches in Allied Education
Vol. XIV, Issue No. 3, (Special Issue) February-2018, ISSN 2230-7540

A Review Study on Optimizing Materials for the Selective Laser Sintering Method

K. S. Srikanth*

Assistant Professor, Department of Mechanical & Chemical Engineering, Galgotias University, Greater Noida, Uttar Pradesh, India

Abstract – Additive manufacturing technology has a quickly expanding ability to replace some of the current traditional processes in research and production. Additional production means that construction components are produced by layer by layer, which directly from a computerized design (CAD) model provide three-dimensional physical models. In a short period, with higher accuracy, the additive production process will manufacture completely dense metal components. The selective SLS technique uses a powder bed fusion in which a laser or electron beam is fused selectively to each powder bed sheet. It is the most promising industrial additive technology for the small to medium volume manufacturing, basic and complex metal components. This review highlights SLS technology's changes, existing state and obstacles. The paper focused on the SLS technology processed metal content. It also speaks in terms of advantages/disadvantages, components, machinery and implementations regarding SLS technique.

Keywords – Laser Sintering, Sintering Process, Additive Manufacturing Technology, SLS

- X -

INTRODUCTION

Selective laser sintering (SLS) is a quick production method using pulver material directly from CAD drawing for the manufacture of various components. Materials such as titanium, stainless steel, and tool steel are broadly used for the manufacture of components for various standard manufacturing thermoplastics such as polyamides, ABS, polycarbonate and nylons and metal parts. Plastic and metallic laser sintering is a very difficult task, primarily because of its slight power, size inaccuracy and low surface ruggedness. Density and durability are two major parameters for manufactured components that influence the efficiency and rely very heavily on the laser synchronization stage. For polymeric products, the direct association between the stiffness and the density of the components exists along with other mechanical characteristics. The durability of the polymer components, linked to compaction state and component density, is discussed. Hardness. Hardness Therefore, additional caution is required when choosing the various laser sintering parameters. Only the operator's expertise, the guidance and previous research activities will enable that. The level of parameters varies with the substance used for laser sintering. This is the biggest challenge that needs to be addressed, and often reduces the variety and uses of such lasers.

Several studies were conducted in previous years utilizing various input synchronization parameters to achieve accurate output (accuracy, mechanical properties, and surface roughness of parts). Yet good quality components of large engineering as well as other applications may still be manufactured. Our literature review shows that few studies have analyzed density using polymers as a working material. The effect of various laser-sintered parameter on nylon powder was researched by Gibson and Shi. The density rises at higher laser power levels but decreases as scan spacing and scan speed are increased. Williams and Deckard also investigated the impact on polycarbonate sections of laser-sintered parameters and found that time and spot sizes of time delay had a major effect on the strength and density of the components generated. Ho et al. investigated polycarbonate rendered specimens' physical mass, traction and morphology. It is observed that with the rise of energy level, the physical density and tensile properties increase. The impact of the bed temperature on component density was investigated by Childs and Tontowi. This thesis proposes to attain optimum partial density through a linear equation between bed temperature and energy density. Shi et al. examined the impact of various properties on the consistency of SLS components for the polymeric materials such as particle size, crystallization intensity, molded viscosity and molecular weight. It is also shown that sections of higher density can be produced by retaining the particle size of 75–100 μm. Bugeda et al. have created an SLS-made part density prediction model. In addition, Vijayaraghavan et al. have proposed a FEA-EA simulation model of SLS-made components for measuring densities.

SELECTIVE LASER SINTERING (SLS) PROCESS

Selective laser sintering is an additive process in which the substance is in the shape of a powder. First, the powder content is stretched over the bed (Fig.1) to form the same thickness film. The scanner then scans the laser over the powder layer for the sintering process according to the given CAD pattern. The piston is reduced by a volume equal to the thickness of the deposited sheet. The powder distribution mechanism is increasing by the same number, and a new layer is now passing through this phase. Time and again the same technique is replicated. This produces the workpiece by SLS process.

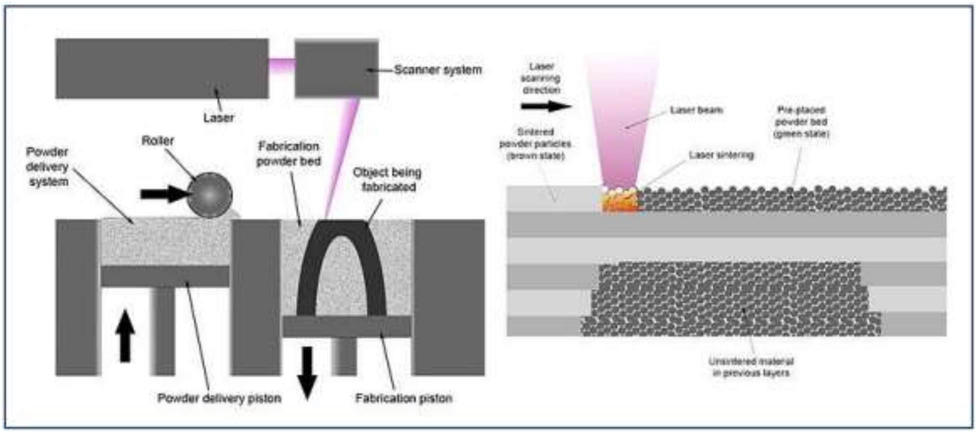

Figure 1: Selective laser sintering process

MATERIALS USED IN LASER SINTERING OPERATION

SLS Polymer Materials

Thermoplastics such as Nylon / Polyamide (PA), Polystyrene, Elastomers and Composites are used in a substance manufactured by SLS technique.

Next to polycarbonate, new grades of nylon powders (i.e. Duraform PA12, Fine Polyamide, PA2200) now produce resolution and surface resilience, rendering PA also suitable for cast silicone and epoxy molds. Additional widely usable polymer-based fabrics consist of investment casting acrylic styrene and a rubber-like elastomer. Windform XT recently entered the commercial market focused on a carbon-filled PA and produced black pieces with a smooth finish and a sparkling look.

For SLS therapy only a few formulations are provided to date and nearly all are dependent on polyamide 12. (PA12). Table I provides a short summary on the current most popular varieties of PA12 on the SLS market.

Table 1: SLS process parameters divided into environmental parameters, substance, lasers and scanners.

Material	Laser	Scan	Environment
Composition	Mode	Scan speed	Preheating
Powder density	Wave length	Hatching space	Pressure
Morphology	Power	Layer thickness	Gas type
Diameter of grains	Frequency	Scan strategy	O_2 level
Distribution	Pulse width	Scan sectors	
Thermal properties	Offset	Pulse distance	
Flow properties	Spot size	Scaling factors	

(a) (b) (c) (d)

Figure 2: Examples of application a) Sieve in Stainless Steel GP1, (b) core instrument in Miraging Steel MS1, (c) knee implant in Chrome MP1, (d). Titanium Ti64 Humeral plate.

TABLE 2. PA12 powders most often used in SLS technology

Trade name	Supplier
DuraForm_ PA	3D-Systems
PA 2200/2201	EOS
Orgasol Invent Smooth	Arkema
DuraForm_ HST	3D-Systems
Duraform_ GF	3D-Systems
PA3200 GF	EOS
Alumide	EOS
CarboMide	EOS

SLS (DMLS): Metal Materials

DMLS is an additive production method on which aerospace and the medical industry depend heavy on it. Direct laser sintering is an additive process. DMLS is viewed by the SLS strategy as an offshoot. All metals that can be constructed layer after layer using this 3D-printing technique include titanium, Inconel, stainless steel, chrome and aluminum. DMLS components are expected to demonstrate more powerful mechanical properties than cast components in the immediate future, according to DMLS computer manufacturers. Researchers also stated that the cast component would still have less strength when comparing a piece taken from a solid piece of metal to a cast portion. However, DMLS pieces typically only have 5–10% less strength than cut metal, such that DMLS is reliably stronger than cast. The following parts also highly illuminated some of the metal products used by DMLS processing technology. Reference for information concerning physical and mechanical properties may be used by interested readers.

1) 316L steel

2) Laserform A6

3) LaserForm™ ST-100 Powder

4) LaserForm ST-200

5) 17-4 Stainless Steel

6) 15-5 Stainless Steel

7) Cobalt Chrome

8) Maraging Steel MS1

9) M2 high-speed steel

10) Inco 718 and 625

11) Aluminium Alloy AlSi10MG

12) Titanium Ti6AI4V / ELI

1) 316L steel

316L steel, inter alia for implantation, belongs to a category of rubber-stainless steel known as surgical [20]. This steel has been used to the manufacture of bone-breaker screws, cell plates, full prothesis packs, drilling drills for prosthetic purpose, as well as to all types of medical devices [21]. Stylish stainless steel is used for the production of jeweler and for 316L watches as a form used in such applications where it is possible to re-surface and is not used to oxidize or render black. 316L is then used to ensure a maximum resistance to corrosion when welding is required. 316L is the variant 316 of the lower carbon which is free from sensitization and is most mostly used for scolding parts. Applications include: Chemical, garment, medicinal, etc.

2) Laser Form A6

The steel of LaserForm A6 is the SLS tool. Laserform A6 is powdered steel polymer (binding). The binder is sintered during the component construction phase. For a maximum of 24 hours, the resulting portion is uncovered and the binder is burned and bronze is infiltrated in the part.

This results in the metal prototype obtained of 80% stainless steel and 20% bronze. LaserForm A6 may be processed using some of the techniques such as machining, EDM, polishing, grading, texture, etc. LoserForm A6 is a magnetic medium that can be attached via magnetic chucks. SLS with LaserForm A6 offers advantages in the fields of fast tool/prototyping, in which steel with LaserForm A6 is mold-making applied. Close to 20%-40% shorter moulding cycles can be accomplished by adding productivity and power to inserts made from LaserForm A6. SLS device components or instruments may have polished surface toughness as high as HRc = 20, or HRc = 39 thermal heat for additional wearing power. For even higher surface toughness the surface may be covered. LaserForm artifacts can be quickly finished and polished with traditional processes with almost twice the thermal conductivity of other tool steels.

3) Laser Form ST-100

ST-100 laser shape, C35-like properties Steel is a product material designed specifically for SLS, which is ideal for making practical prototypes and resilient metal inserts from CAD files directly without any expensive casting, CNC programming or intensive machining. Tool inserts manufactured from Laser Form ST-100 are so durable that, depending on the content molded, they can mold more than 100,000 plastic pieces. The strong thermal conductivity of laser type ST-100 results in cycle times of manufacture and high comparability. The application can be used in robust tooling designs, bridge tools, limited runs of metal parts and prototypes Even laser shape inserts ST-100 are ideal for aluminum, magnesium, and zinc casting. It can also be used to design prototypes that feature and have complex geometries.

4) Accura LaserForm ST-200

Chemical properties are very similar to P20 steel in Accrua LaserForm ST-200. This stainless-steel composite is a specialty made of stainless steel designed for SLS systems in order to manufacture rugged and completely dense metal components, injection molding and die molding inserts. LoserForm ST-200 is the best substrate for prototyping and manufacturing applications. LaserForm ST-200 material inserts have good thermal conductivity, so they can be used in metal tools and a decrease in cycle time of about 20-40 percent relative to conventional tools is achievable. The content is used for high temperature uses, brief cycles of metal components and prototypes and inserts for metal tools for complicated geometries and features.

5) Stainless Steel 17-4

The 17-4 is a reallowed fine powdered stainless steel. The material has a very good resistance to corrosion and mechanical properties, especially excellent ductility, and can be used extensively in various engineering applications. The laser-sintering parts manufactured from EOS Stainless Steel 17-4 can be soldered, machined, micro-shots, polished and, if necessary, even painted. Powder can be reused unexposed. For several component building applications as for example practical metal samples, small-scale goods, individualized products or spare parts, Stainless Steel 17-4 is ideal.

6) Stainless Steel 15-5

In the DMLS phase, inox steel 15-5 (stainless steel PH1) is a prototype material; even in the fine powder shape a prealloyed inox. Stainless PH1, particularly in the hardened precipitation condition, is characterized by its high corrosion resistance and mechanical properties. This type of steel is commonly used in various applications in aircraft, medicines and other engineering that need high durability, strength and resistance to corrosion.

7) Cobalt Chrome

Cobalt Chrome is a cobalt chromium super alloy powder made of molybdenum and has been specifically designed to meet the requirements of dental reconstruction and is specially optimized in the manner of processing EOSINT M270 systems, to be covered with ceramic dental content. Cobalt Chrome provides outstanding tolerance to degradation and is well used for medicinal and dental prototypes.

8) Maraging Steel MS1

Maraging Steel is one of the products appropriate for the production with DMLS. The composite is very strong and highly tough in combination. It is perfect for making parts and just inserts or key applications used in different tooling applications, reducing molding times by providing an enhanced conformal cooling application. Parts made of Maraging Steel can even be polished and hardened to 54 HRC easily.

9) M2

M2 is tungsten-molybdenum heavy high-speed steel. The carbides are short and spread evenly. It is resistant to wear. M2 has an outstanding resilience along with hardness and abrasion resistance when correctly hard and tempered, due to its very low carbon content. M2 is used to produce a range of instruments, such as boxes, tabs and reamers.

10) Aluminium AlSi10Mg:

It is possible to construct aluminum AlSi10Mg faster than other DMLS products. While its thermal properties, strength and stiffness are fine, it has become a preferred prototype for lower costs. EOS AlSi10Mg is a common casting alloy, which has excellent casting properties and is used with thin walls and complex geometry for casting components. With the alloy silicon / magnesium mix, the strength and toughness of aluminum AlSi10Mg are important. It is used for heavy load components. The machined, welded, wired and electrically machined micro-blower, polished and painted parts made of ESO Aluminum AlSi10Mg Machines.

11) DMLS Inconel 718 & 625:

DMLS Inconel 718 (IN718) is the most recent of the products appropriate for DMLS processing. In 718, users discovered that accelerated manufacturing could be used as a development process. Machining IN718 is difficult and unpleasant, while the DMLS method allows for the production of Inconel parts easily and affordably. This material is suitable for many high temperature applications in the power and process industries, such as gas turbine components, instrumentation parts, and so on. DMLS IN718 has outstanding cryogenic properties and has the ability for cryogenic applications. Precipitation hardening heat treatments will easily post-harden EOS nickel alloy IN718 sections to 40-47 HRC (370-450HB). If required, nickel alloy IN718 pieces can be machined, welded, spark-eroded micro shot-peened, coated, and polished in both as-built and age hardened states. Inconel 625 is ideal for use in high-temperature, high-strength applications. It has high tensile, crawl, and rupture power and has outstanding corrosion tolerance in a variety of corrosive conditions. Aero and land-based turbine engine parts, missile and space materials, chemical and process industry parts, oil well, coal, and natural gas industry parts are examples of typical applications.

12) DMLS Titanium Alloy (Ti6Al4V):

At the moment, the majority of titanium-based aerospace parts are machined from solid stock, sometimes removing 90 percent or more of the initial steel. Since titanium investment casting is complex, it takes time and often has a large scrap rate, resulting in an expensive process. This is totally removed with DMLS titanium, and by utilizing the DMLS method, material waste is minimized, as well as an indication of accelerated processing in comparison to conventional methods [30]. DMLS parts may be machined, spark eroded, welded, micro shot-peened, polished, and coated if required [31]. Direct manufacture of usable devices, development of corrosion resistant components, biomedical implants, and so on are examples of applications.

METALLIC MATERIALS USED IN SLS TECHNOLOGY

In general, any substance that melts when exposed to a laser beam may be used in SLS technology. Today, specific laser sintering allows for the use of a broad variety of materials in the form of powders, alloys, or mixtures. Glass, nickel-based superalloys, titanium and its alloys, refractory metals, nickel alloys with bronze, cermet's, cobalt-chromium-molybdenum alloys, and copper alloys are among the metallic products used in this technology.

Great attempts have been made to increase the supply of powders for use in laser sintering. The first issue was the very brief period of laser contact with the powder layer while scanning. Within milliseconds, loose powder must be transformed into a permanent framework. This occurs during the object's creation through sintering with the use of liquid-phase emergence. Metal particles are melted as the laser passes across the surface of the powder scattered over the platform, resulting in the creation of inter-particle necks. Another challenge is maintaining the product's geometry and proportions during sintering. Since models are created by sintering successive material layers, part contraction can result in inadequate joining of edges and layers. The first attempts to selectively sinter single-phase metals failed due to caking. Where a liquid phase forms as a consequence of a laser beam's influence, molten powder automatically forms spherical structures of almost equal diameters to the laser beam instead of bonding with the sintered powder underneath it. This can be prevented by altering the process parameters, such as growing the powder and decreasing the scanning rate.

A procedure based on biphasic metals was designed to remove the spheroidization tendencies of powder particles. The layer, as in the case of liquid phase sintering, comprises at least two ingredients of markedly different melting temperatures. The more fusible substance melts first during the laser's point motion on a powder sheet. The created liquid wets powder particles with a higher melting point, causing them to bind together. When using a metal mixture, particle bonding is affected by the viscosity of the liquid, assuming that the components are selected in such a way that inter-particle wetting occurs. Furthermore, the caking propensity is regulated by the viscosity of the solid-liquid phase combination, which rises as a result of particles retaining their solid state in the accumulated liquid phase. To stop spheroidization, it is critical to change the amount of solid step. Wetting is critical to the attachment of the ingredients present in the substrate which can take place during the very limited period of laser beam operation.

To achieve optimum commodity density in binary metal structures, the SLS method must have the following characteristics:

- for the solid phase:
  - appropriate size of powder particles,
  - high surface energy
  - good laser coupling
- for the liquid phase:

- high surface energy
- strong solid phase solubility coefficient
- no volatile components

APPLICATION OF SLS IN BIOMEDICAL ENGINEERING

From the beginning, the use of SLS in medicine progressed at an astonishing rate. This technology has found uses in medicine, orthopedics, dental reconstructions, tissue engineering processing of anatomical prostheses, and also educational or scientific purposes. Furthermore, it has achieved universal support and recognition, and it is playing an increasingly important function in the resolution of complicated cases. The use of SLS technology for the fabrication of bioengineering models allows for the production of medical products with the planned and necessary measurements and properties. Laser-sintered elements' long-term longevity means that their geometry can be maintained for a long time. As of now, it is possible to sinter one or more forms of powders with biocompatible properties that are suitable to the human body while retaining the required strength and density.

Despite the numerous techniques available for producing scaffolds for tissue engineering, when they are created through selective laser sintering, they have the required structural, porosity, and permeability parameters, as well as the appropriate repeatability factor. Furthermore, utilizing SLS to produce structures promoting bone tissue development has the advantage of preventing the occurrence of stresses and the occurrence of inflammatory states owing to the absence of harmful solvents in the procedure, as is the case for traditional processes.

As a means of obtaining dental crowns and bridges, SLS is an ideal alternative to conventional methods such as casting. For this reason, powdered Co-Cr alloy with particle diameters ranging from 3 to 14 microns is used. Another benefit is the elimination of tasks such as substance separation from and washing of molds. The whole procedure is based on the use of a 3D scanner and CAD software, which allow control of the virtual modeling operation. Editing the proportions and thickness of a crown or cement, as well as the appearance of a bridge width, is possible. This technical method may also standardize the above. Furthermore, the targeted laser sintering method guarantees high accuracy and workmanship efficiency. It is worth remembering that mistakes that are typical in conventional production methods are avoided. The development of a vast product sequence is not an impediment in the case of SLS. It enables the manufacture of high-quality and dense dental implants in quantities up to 20 times greater, demonstrating its superior performance. It is more predictable in terms of deformation than casting because of better geometry power.

Surgeons' use of implant designs made of composite materials has been a common trend in recent years. Titanium wire, for example, is used to graft maxillofacial bones. Despite its ease of deformation, this material necessitates the use of equipment for careful adjustment and forming of a model reflecting the geometry of the patient's bones. Such "training" enables not only the reduction of work done during operation, but also the discovery of previously unknown issues that may interrupt the work of a team of surgeons during surgery, as well as the optimization of the mesh, whose thickness and geometry may be adjusted depending on a surgeon's instructions.

Many prostheses in use today are made up of standardized parts, which enable an implant to be tailored to the needs of a specific patient. However, the fact that a large proportion of people have deformed joints and bones despite surviving a disease must be taken into consideration. In such a case, it is difficult to choose a module from a regular collection that accurately represents the tissue geometry. When components are matched on an individual level, based on data collected directly through assessment of the patient using available imaging techniques, improved comfort and function may be achieved (computed tomography, magnetic resonance)

PROS AND CONS OF SLS PROCESS

Pros

SLS distinguishes itself by producing components from products such as Titanium and Nylon, which are often challenging to produce using conventional methods. The SLS procedure would not necessitate the use of any external support materials since the powder itself acts as a support material.

Cons

Post-processing of the produced component is a time-consuming method that necessitates the use of machining. The materials used in production are minimal. Still, SLS metal sections have a small use in the automotive sector. Aerospace-grade aluminum and other metals are currently being produced.

CONCLUSIONS

Based on the materials used in the procedure, the SLS process is a feasible time and cost saving approach for producing complicated prototype parts in the plastics and metals industries. The below are some of the advantages of using the system: The willingness to use a variety of materials, as well as the potential to increase the number of materials that can work in the project. DMLS appears to be at a crossroads between restricted use in prototyping applications and a far larger capacity in the areas of series production tooling, especially component production. According to certain studies, powder with a smaller particle distribution may be quickly melted and produces high density, superior mechanical power, and efficiency. However, laser sintering does not allow for the manufacture of near-net-shape artifacts with tight tolerances and a high-quality surface finish. Another challenge for these methods is the existence of micro structural flaws (e.g., voids, impurities, or inclusions) in the finished product. Such flaws can result in catastrophic failure. Given the above, it is clear that there are certain issues, shortcomings, or disadvantages associated with laser sintering and melting techniques, and that it would be preferable if improved methods and equipment were available capable of producing nearest-shape objects to close tolerances and/or having high quality surface finishes, and/or capable of reducing or eliminating cracks inclusions, and pores between deposit layers in a finished object

REFERENCES

1. E Yasa, J P. Kruth (2011). “Microstructural investigation of Selective Laser Melting 316L stainless steel parts exposed to laser re-melting”, Procedia Engineering 19, pp. 389-395.

2. M. Klimek (2012). “The use of SLS technology in making permanent dental restorations, Prosthetics”, 12, pp. 47-55.

3. Oliveira Setti, G, D., Oliveira, M.F., Maia, I.A., Silva, J.V.L.D., Savu, R. and Joanni, E. (2014). Correlation between mechanical and surface properties of SLS parts‖, Rapid Prototyping Journal, Vol. 20 No. 4, pp. 285-290.

4. Yuan, M., Diller, T.T., Bourell, D. and Beaman, J. (2013). Thermal conductivity of polyamide 12 powder for use in laser sintering‖, Rapid Prototyping Journal, Vol. 19 No. 6, pp. 437–445

5. Haworth, B., Hopkinson, N., Hitt, D. and Zhong, X. (2013). Shear viscosity measurements on PA-12 polymers for laser sintering‖, Rapid Prototyping Journal, Vol. 21 No. 3, pp. 28- 36.

6. Tiwari, S. K. and Pande, S. (2018). Material properties and selection for selective laser sintering process‖, International Journal of manufacturing Technology and Management, Vol.27 No. 4/5/6, pp.198-217.

7. Tiwari, S. K., Pande, S, Agrawal, Sanat and Bobade, S.M. (2015). Selection for selective laser sintering materials for different applications‖, Rapid Prototyping Journal, Vol. 21 No. 6, pp. 630-648.

8. Tiwari, S. K., Pande, and Bobade, S.M. (2016). Material Optimization during medical components development in selective laser sintering process using Value Engineering‖, International Journal of Research in Engineering and Technology, Vol.5 No. 11, pp. 186-194. Toloch

9. Goodridge, R.D., Tuck, C.J. and Hague, R.J.M. (2012). Laser sintering of polyamides and other polymers‖, Progress in Materials Science, Vol. 57 No. 2, pp. 229–267.

10. Tiwari, S. K. and Pande, S. (2012). Review of material properties and selection for selective laser sintering process‖, Proceeding of International Conference in Design and Manufacturing (InnDeM-2012), IIITDM, Jabalpur, India.

Corresponding Author

K. S. Srikanth*

Assistant Professor, Department of Mechanical & Chemical Engineering, Galgotias University, Greater Noida, Uttar Pradesh, India