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Introduction to Sintering Process in Additive Layer Manufacturing Processes

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***Abstract*: Sinter hardening is a cost-effective process to manufacture P/M parts exhibiting high strength and apparent hardness at lower cost than conventional heat treatment. This process is particularly attractive for parts that are difficult to quench due to their size and shape. Indeed, during the sinter hardening process, the transformation to martensite takes place during the cooling phase of the sintering cycle, thus reducing thermal stresses as compared to oil quenching. Many powder grades have been developed for sinter hardening applications. Depending on their alloy formulation, these grades offer a wide range of compressibility and response to hardening. The objective of this paper is to discuss the various techniques used in Sintering Process in order to achieve additive layer manufactured product.**

***Keywords*: Sintering, Selective Laser Sintering (SLS), Powder Materials, 3D printing**

1. Introduction

Additive layer manufacturing (ALM) or Additive Manufacturing (AM) is a modern fabrication process that can use a wide range of materials to create products ranging from medical implants to parts of an aircraft wing. Three dimensional parts are built up in two-dimensional layers as little as 0.05 mm thick; this way of building parts offers great flexibility and opportunities for creating new products at low cost, whilst reducing the carbon footprint associated with manufacturing. Additive Layer Manufacturing or ALM is in general the opposite of subtractive manufacturing, where material is removed to reach the desired shape. In ALM 3D parts are built up in successive layers of material under computer control. At the beginning 3D printing was used mainly for rapid prototyping. But manufacturers didn't take long to realize the endless capabilities of this new fabrication process. Using Additive Layer Manufacturing especially in advanced applications as aerospace and cars not only makes the production of existing components more efficient, but also allows the creation of brand-new ones, that weren't possible before. Some of the most used materials are 3d printed Inconel 718 and titanium Ti6Al4V. (Streitfeld, n.d.)

Additive Layer Manufacturing (ALM)" or simply "additive manufacturing (AM)", are terms that encompass many others such as 3D Printing, Rapid Prototyping, Rapid Manufacturing, Direct Digital Manufacturing or Layered Manufacturing. More generally, it qualifies any process that does not operate by subtractive manufacturing (where the material is removed to attain the desired shape.) Instead, additive manufacturing is the process of joining materials to build objects from 3D model data, usually layer after layer. While it is commonly referred as "3D-printing", "additive manufacturing" or "additive layer manufacturing" are the proper terms to use within the industrial scope. Indeed, all the ALM processes are "additive" but not all of them look like "printing". Industrial applications also refer to the technology as such.

2. Layer manufacturing process

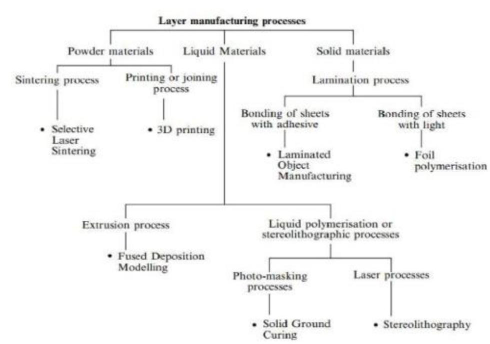

Fig. 1. Flow chart

The above flow chart depicts the different types of Additive Layer Manufacturing Process.

A. *Powder materials*

Powder bed fusion additive manufacturing designates the processes in which thermal energy (from a laser or an electron beam) selectively fuses regions of a powder bed.

1) *Sintering process*

Sintering is a heat treatment applied to a powder compact in order to impart strength and integrity. The temperature used for sintering is below the melting point of the major constituent of the Powder Metallurgy material. After compaction, neighboring powder particles are held together by cold welds, which give the compact enough "green strength" to be handled. At sintering temperature, diffusion processes cause necks to form and grow at these contact points.

There are two necessary precursors before this "solid state sintering" mechanism can take place:

- Removal of the pressing lubricant by evaporation and burning of the vapours.
- Reduction of the surface oxides from the powder particles in the compact.

These steps and the sintering process itself are generally achieved in a single, continuous furnace by judicious choice and zoning of the furnace atmosphere and by using an appropriate temperature profile throughout the furnace.

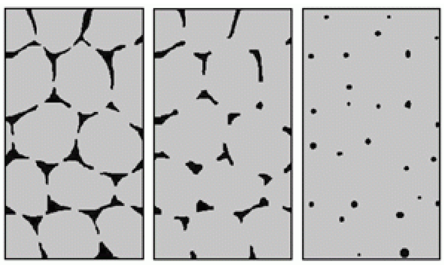

Fig. 2. The three stages of solid-state sintering: left: initial stage, centre: intermediate stage, right: final stage (Courtesy EPMA)

2) Selective laser sintering

Selective laser sintering (SLS) is an additive manufacturing (AM) technique that uses a laser as the power source to sinter powdered material (typically nylon/polyimide), aiming the laser automatically at points in space defined by a 3D Model, binding the material together to create a solid structure. It is similar to direct metal laser sintering (DMLS); the two are instantiations of the same concept but differ in technical details. Selective laser melting (SLM) uses a comparable concept, but in SLM the material is fully melted rather than sintered, allowing different properties (crystal structure, porosity and so on). SLS (as well as the other mentioned AM techniques) is a relatively new technology that so far has mainly been used for rapid prototyping and for low-volume structure of component parts. Production roles are expanding as the commercialization of AM technology improves.

An additive manufacturing layer technology, SLS involves the use of a high-power laser (for example, a carbon dioxide laser) to fuse small particles of plastic, metal, ceramic, or glass powders into a mass that has a desired three-dimensional shape. The laser selectively fuses powdered material by scanning cross-sections generated from a 3-D digital description of the part (for example from a CAD file or scan data) on the surface of a powder bed. After each cross-section is scanned, the powder bed is lowered by one-layer thickness, a new layer of material is applied on top, and the process is repeated until the part is completed. Because finished part density depends on peak laser power, rather than laser duration, a SLS machine typically uses a pulsed laser. The SLS machine preheats the bulk powder material in the powder bed somewhat below its melting point, to make it easier for the laser to raise the temperature of the selected regions the rest of the way to the melting point.

In contrast with some other additive manufacturing processes, such as stereolithography (SLA) and fused deposition modelling (FDM), which most often require special support structures to fabricate overhanging designs, SLS does not need a separate feeder for support material because the part being constructed is always surrounded by unsintered powder, this allows for the construction of previously impossible geometries. Also, since the machine's chamber is always filled with powder material the fabrication of multiple parts has a far lower impact on the overall difficulty and price of the design because through a technique known as 'Nesting' multiple parts can be positioned to fit within the boundaries of the machine. One design aspect which should be observed however is that with SLS it is 'impossible' to fabricate a hollow but fully enclosed element. This is because the unsintered powder within the element can't be drained. Since patents have started to expire, affordable home printers have become possible, but the heating process is still an obstacle, with a power consumption of up to 5 kW and temperatures having to be controlled within 2 °C for the three stages of preheating, melting and storing before removal.

3. Observations

A. Advantages

A distinct advantage of the SLS process is that because it is fully self-supporting, it allows for parts to be built within other parts in a process called nesting – with highly complex geometry that simply could not be constructed any other way.

- Parts possess high strength and stiffness
- Good chemical resistance
- Various finishing possibilities (e.g., metallization, stove enamelling, vibratory grinding, tub colouring, bonding, powder, coating, flocking)
- Bio compatible according to EN ISO 10993-1 and USP/level VI/121 °C
- Complex parts with interior components, channels, can be built without trapping the material inside and altering the surface from support removal.
- Fastest additive manufacturing process for printing functional, durable, prototypes or end user parts.
- Vast variety of materials and characteristics of Strength, durability, and functionality, SLS offers Nylon based materials as a solution depending on the application.
- Due to the excellent mechanical properties the material is often used to substitute typical injection moulding plastics.

B. Disadvantages

SLS printed parts have a porous surface. This can be sealed by applying a coating such as cyanoacrylate.

4. Conclusion

This paper presented an overview on sintering process in additive layer manufacturing process.

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