A brief overview of Additive Manufacturing

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Abstract. In this paper, a brief overview is presented, resulting from a recent literature review of some representative books or papers regarding various research on additive manufacturing. Some basic terms are presented, in the context of founding the existence of several terminologies for some specific expressions of this subject, as well as different definitions for them materials used at that process, areas of using, problems appeared during process of manufacturing, heat treatments used, advantages and disadvantages. This research is carried out to identify a solution for controlling the parameters during the additive processing (AM) process, parameters with which to improve the quality of the parts obtained by AM

1. Introduction

A new industrial revolution is the implementation of additive manufacturing (AM), designed to replace totally or partially technologies for manufacturing processing and subassembly in all industrial fields. Industrial analysts are considering PAs new rights or technologies mentioned to currently influence and change industrial technologies. PA is often referred to as printing (3D printing), which may be similar to laser printing (figure 1). PA builds solid objects by superimposing material layers; each layer is drawn by the computer [1,2].

For manufacturing of parts with AM process is necessary to use a powder as:

- Carbon steel
- Aluminum
- Stainless steel
- Titanium
- Another material

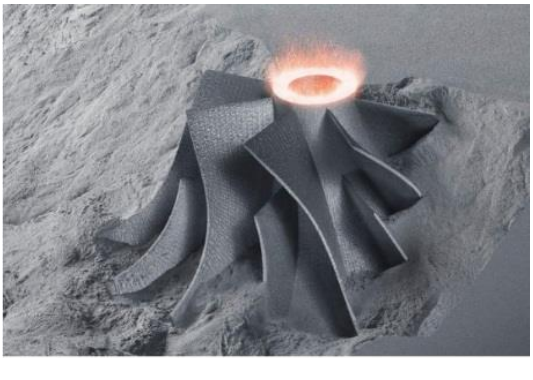


Figure 1 Laser fusion of metals [2]

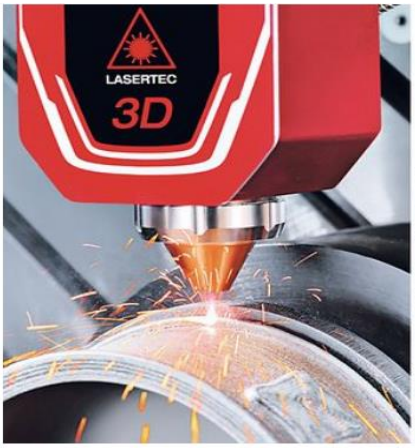
At manufacture of parts from metalic materials, the parts is built by metalic powder and laser light (figure 2), and the direction of deposition is diferent with de milling operation (figure 3). The parts are built layer by layer using a laser, according to a 3D model. Thus, additive processes have a different approach than milling, turning and deformation processes, used predominantly in industrial production.

Figure 2 Laser metal fusion (LMF)[3]

Figure 3 Laser metal deposition (LMD)[4]

Research has shown that hybrid design systems have potential and efficient use for high-functional molds in production, almost smooth nest shape manufacturing, repairs and coating (LMD). There are a number of companies that have built hybrid machines that incorporate selective laser melting (SLM) technology and milling function as a solution for finishing the part obtained through SLM [5].

Laser additive processing equipment makes it possible to manufacture parts of very high shape and complexity, only in terms of roughness and dimensional accuracy; the parts manufacturing by laser fusion or loaded by laser welding do not correspond, thus being necessary subsequent finishing operations (figure 4).



a) LMD deposition

b) Milling part after LMD deposition

Figure 4 LMD Proces and milling (on -LASERTEC 65 3D hybrid) [5]

For a very good accuracy and dimension, it is necessary that the part is milling on the same machine (mixed machines) as shown in figure 4 a), where the part was obtained by laser melting deposition (LMD) or by LMF or on another machine. The tools which are used at this manufacturing process is, a laser melting head, the head through which the metal / non-metal powder is also evacuated, and for the finishing of the resulting part, we use cylinder-frontal mills, spherical, profiled cutters, drills (figure 4b).

2. Materials used at Additive Manufacturing AM and areas of use

Additive processing (PA) builds solid objects by superimposing layers of materials, and as the raw material used by PA is the powder that can be made of thermopolymer, or metal, which can be aluminum, stainless steel, titanium or other materials. The layers can contain even more types of materials [7].

With additive manufacturing systems could be produced in the future, better aircraft engines with lower fuel consumption. To do this, engineers need to improve today's industrial 3D printers so that these machines can process extremely heat-resistant and obviously high-strength alloys [8].

In the medical field for to find an alternative solution to edentulism problems, a procedure for the development and manufacture of a personalized dental appliance, less expensive and adequate are the implants, avoiding an initial surgery and allowing immediate intervention [9]. This procedure, in addition to direct 3D digital modeling of the custom implant [9], uses a combination of the two advanced additive manufacturing technologies, SLM and SL [10,11].

This combination allows the photopolymerization of a polymer in the gaps of a 3D housing of the metal core previously produced by SLM. These biocompatible metal housings, which have the necessary mechanical strength, have been optimized based on the models, favoring the regeneration and growth of rigid and soft tissues. The basic structure is then placed on the SL platform and the additive process begins with the first polymerization of the resin layer until the complete manufacture of the tooth crown, the crown that will be built based on the 3D CAD model (figure 5)

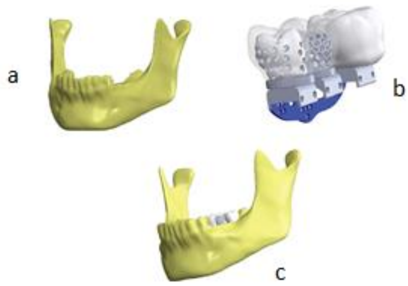


Figure. 5 3D CAD Model: a) the jaw of the patient with edentulism problems; b) generation according to a Voronoi model and a topological and geometric optimization plan for establishing the dental points; c) resulting from the assembly between the jaw and the personalized bio-inspired dental implant. [10]

After the 3D modeling, the additive deposition will be performed and a dental crown will be presented, shown in figure 6, resulting in the dental bridge (figure 7).

Figure 6 Production by SLM of dental cores and dental bridge [11]

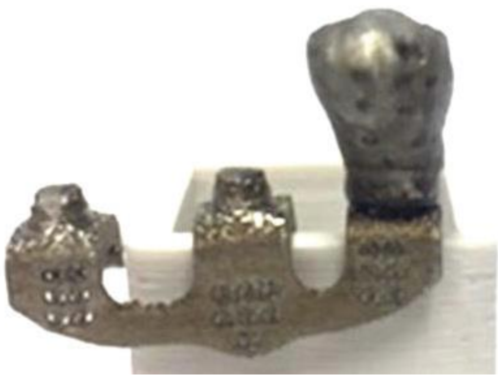


Figure 7 Multimaterial and personalized physical model of the dental bridge [11]

There are also other areas such as the automotive industry where it is suitable for manufacturing prototype parts (figure 8) for new cars, parts that after optimization will be mass-produced or if it is a very small or unique series cars, they can be obtained entirely by 3D printing, parts made of different types of metals or alloys [12,13,14].

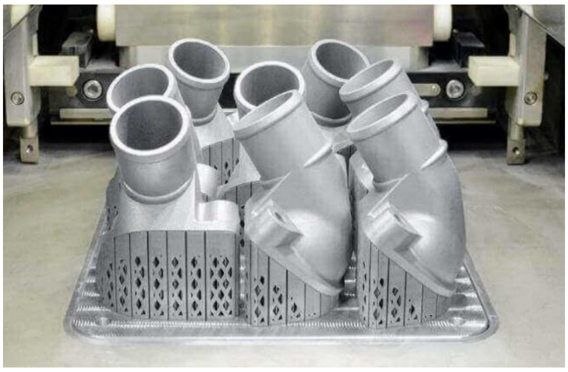


Figure 8 Mercedes Benz thermostat cover with technological addition [13]

3. Problems encountered at laser fusion of metals

Among the various materials processed by selective laser melting, steel is one of the most used materials for manufacturers due to its wide range of properties and applications [15].

Working parameters during deposition have an influence on the fatigue resistance of steel parts obtained by SLM [16,17], and from here results in the apparition of cracks. Current studies show the importance and the effects of deposition, directions of deposition, heat treatment, surface quality, and the energy density of the beam during deposition by SLM (figure 9) [18].

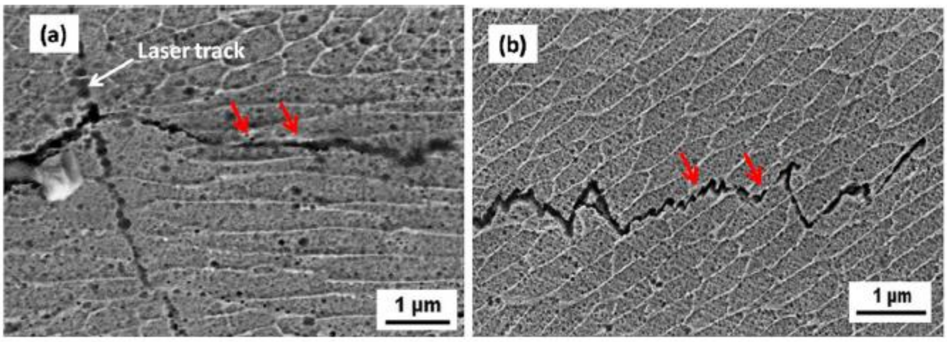


Figure 9 Crack propagation after mechanical test part (a) horizontal (b) vertical steel 316L [18].

Therefore, the appearance of cracks is due to the fact that the working parameters of the machine are not adjusted correctly (melting temperature, deposition speed, the distance between layers), parameters that are adjusted according to the type of powder material, to avoid overheating (figure 10) [19].

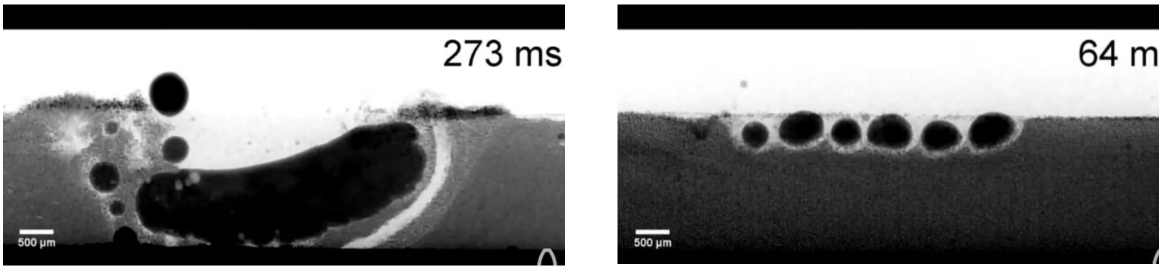


Figure 10 Appear of the inclusions at 3D printing [19]

Have also been made to improve the printing process, so that no further operations are required as specific heat treatments (isostatic pressure) [20, 21].

4. The influence of heat treatment applied to different types of metals

In general, there are four types of post-treatments recommended for LPBF from IN625: annealing of normalization of internal stresses, normalization of recrystallization, treatment with a solution, and hot isostatic pressing [22,23].

Carrying out the heat treatment on samples of nickel superalloys (IN625), heating them to 700 C, 1000 C, and 1150 C and keeping them one hour before air cooling, it was found that the microstructure of the IN625 parts at the annealing state at 700 ° C was the same as that of a state of material obtained by casting.

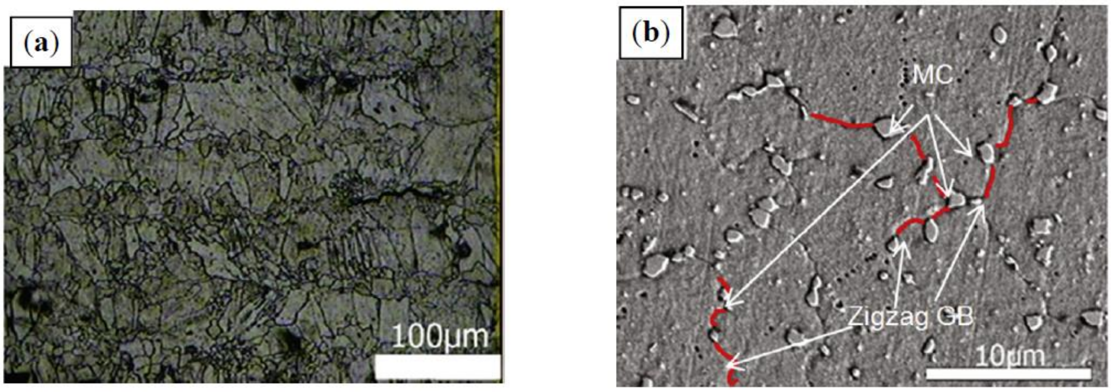


Figure 11 LPBF plane microstructure of LPBF of IN625 samples after annealing at 1150 C. (a) Metallographic optical image, (b) Boundary structure and carbide distribution [24]

Comparison of different types of recycling temperatures can be concluded that recovering the high temperature allows recrystallization (figure 11a) of a sample built IN625, High Z contrast deviations are dissolved and MC carbides precipitate and granule delimitation becomes stable due to carbide fixation MC (figure 11 b) [24].

5. Conclusion

The purpose of this article is to present a brief overview, resulting from a recent literature review on the additive manufacturing process, and in future identify a solution for controlling the parameters during the additive processing (AM) process, parameters with to improve the quality of the parts

References

[1] Ebert-Uphoff, Imme & Gosselin, Clément & Rosen, David & Laliberte, Thierry "Rapid Prototyping for Robotics." Rapid Prototyping for Robotics. 10.5772/4639 (2005).

[2] Linkan Bian, Nima Shamsaei, and John M. "Laser-Based Additive Manufacturing of Metal Parts" Usher-by Taylor & Francis Group, book title Modeling, Optimization, and Control of Mechanical Properties 2018

[3] W Meiners,K Wissenbach &R Poprawe "Laser additive manufacturing of metallic components: materials, processes and mechanisms" Institute of Materials, Minerals and Mining and ASM International Published by Maney for the Institute and ASM International DOI 10.1179/1743280411Y.0000000014 2012

[4] Yamazaki Mazak Corporation, Oguchi, Aichi. "Development of A Hybrid Multi-tasking Machine Tool: Integration of Additive Manufacturing Technology with CNC Machining" 480-0197, Conference on Electro Physical and Chemical Machining (ISEM XVIII) Japan Procedia CIRP 42 (2016) 81 – 86 18th CIRP

[5] Ian Gibson , David Rosen , Brent Stucker" Additive Manufacturing Technologies 3D Printing, Rapid prototyping,and Direct Digital Manufacturing",book title Additive Manufacturing TechnologiesVerlag New York, Springer-2015
[6] ***https://en.dmgmori.com/products/machines/additive-manufacturing/powder-nozzle/lasertec-65-3d-hybrid*** accessed at 2020.03.04)
[7] ***https://www.ttonline.ro/revista/fabricatie-aditiva/prelucrarea-aditiva-pa-ii***Accessed at 2020.04.04
[8] ***https://www.ttonline.ro/revista/tehnologii/sistemele-de-fabricatie-aditiva-descopera-superaliaje*** Accessed at 2020.04.04
[9] O. Ciobanu and G. Ciobanu *"The use of 3D scanning and rapid prototyping in medical engineering*". Academica Brancusi (2013) 241-247.
[10] W. Gao, Y. Zhang, D. Ramanujan *"The status, challenges, and future of additive manufacturing in engineering "*, , Computer-Aided Design. 69 (2015) 65–89.
[11] P. Li, Z. Wang, N. Petrinic, C.R. Siviour, Materials Science & Engineering A 614*" Deformation behaviour of stainless steel micro lattice structures by selective laser melting"* (2014) 116–121.
[12] ***https://robbreport.com/motors/cars/father-and-son-3d-printing-lamborghini-2857428/*** accessed at 2020.04.06
[13] ***https://formlabs.com/blog/3d-printed-car-how-3d-printing-is-changing-the-automotive-industry/*** accessed at 2020.04.06
[14] ***https://www.sme.org/technologies/articles/2019/august/automotive-industry-warms-to-3d-printing/*** accessed at 2020.04.08
[15] Rui Li, Yong Seok Kim , Hoang Van Tho , Young Jin Yum , Won Jun Kim and Soon Yong Yang, *"Additive manufacturing (AM) of piercing punches by the PBF method of metal 3D printing using mold steel powder materials"* * Manuscript Received April 24, 2018; Revised September 14, 2018; Accepted October 20, 2018
[16] Shahriar Afkhami, Mohammad Dabiri, S. Habib Alav, Timo Björk,*" Fatigue characteristics of steels manufactured by selective laser melting*" Antti Salminen International Journal of Fatigue 122 (2019) 72–83
[17] Carelyn E. Campbell Sudha CheruvathurEric A. Lass" *Additive Manufacturing of 17-4 PH Stainless Steel: Post-processing Heat Treatment to Achieve Uniform Reproducible Microstructure JOM",* The Minerals, Metals & Materials Society (outside the U.S.) SUDHA CHERUVATHUR ERIC A. LASS and CARELYN E. CAMPBELL Vol. 68, No. 3, 2016 DOI: 10.1007/s11837-015-1754-4 _ 2015
[18] Suryawanshi J, Prashanth KG, Ramamurty U. Mater *". Mechanical behavior of selective laser melted 316L stainless steel"* Sci Eng, A 2017;696:113–21.
[19] **** https://www.oxmet-technologies.com/abd-xam*** accessed at 2020.04.08
[20] **** https://www.oxmet-technologies.com/abd-xam***
[21] Mater Kreitcberg, A.; Brailovski, V.; Turenne, *"S. E_ect of heat treatment and hot isostatic pressing on the microstructure and mechanical properties of Inconel 625 alloy processed by laser powder bed fusion"*. Sci. Eng. A **2017**, 689, 1–10.
[22] Fang, X.Y.; Li, H.Q.;Wang, M.; Li, C.; Guo, Y.B. "Characterization of texture and grain boundary character distributions of selective laser melted Inconel 625 alloy" Mater. Charact. 2018, 143, 182–190.
[23] Mater Kreitcberg, A.; Brailovski, V.; Turenne, *"S. E_ect of heat treatment and hot isostatic pressing on the microstructure and mechanical properties of Inconel 625 alloy processed by laser powder bed fusion"*. Sci. Eng. A **2017**, 689, 1–10.
[24] Zhihua Tian, Chaoqun Zhang , Dayong Wang, Wen Liu, Xiaoying Fang, DanielWellmann, Yongtao Zhao 2 and Yingtao Tian "*A Review on Laser Powder Bed Fusion of Inconel 625 Nickel-Based Alloy"* 17 November 2019; Accepted: 18 December 2019; Published: 20 December 2019