ARTICLE IN PRESS

Materials Today: Proceedings xxx (xxxx) xxx

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

DMLS – An insight for unproblematic production

Avinash Malladi, K. Karunakaran *

Department of Mechanical Engineering, School of Engineering, Vels Institute of Science Technology and Advanced Studies (Deemed to be University), Vels University, Chennai, TN, India

ARTICLE INFO

Article history:
Received 21 June 2020
Accepted 21 July 2020
Available online xxxx

Keywords:
Trial products
Manufacturing
DMLS
Three dimensional printing
Powder-based AM

ABSTRACT

Three dimensional printing is a kind of production of things stratum by stratum deposition of material. It helps to cross many limitations to manufacture the product with desired features which are difficult to machine in subtractive manufacturing methods. At earlier stage of progress of three dimensional printing, objective of coming out with basic creation of some trial products, reduces the manufacturing time in reckoning. Current trend is with powder-based AM, where a part is manufactured with DMLS (Direct Metal Laser Sintering process) which helps to produce an end-use part. Every manufacturing process will be having some defects during the unorganized parameters. In this regard, this paper discusses about the complete procedure of DMLS and defects and the causing parameters to facilitate the trouble free and defect free manufacturing of parts. This papers also addresses the research scopes.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Newer Trends and Innovation in Mechanical Engineering: Materials Science.

1. Introduction

Here introduce the paper, and put a nomenclature if necessary, in a box with the same font size as the rest of the paper. The paragraphs continue from here and are only separated by headings, subheadings, images and formulae. The section headings are arranged by numbers, bold and 10pt. Here follows further instructions for authors. DMLS is the foremost profit-making additive manufacturing technique to manufacture metallic product in solo process. The conventional properties of on the product be able to accomplish by use of high-power laser beamand 20 μm sized powder of metal in DMLS. In which no binders employed. In comparison with SLS the DMLS process has an additional advantage of using the thinner layers and also enables the smaller powder diameter. Ref. [1] reported that commercial Inconel 718 is found less corrosive resistance when compared to DMLS Inconel 718 when tested with 1.0 M H_2SO_4 solution at room temperature. Ref. [2] investigated the two different grade of ASTM B348 standard with grade of 23 and ASTM F-136 standard with grade of grade 5, of Ti6Al4V alloys manufactures at different DMLS manufacturing facility of identical organization and found that DMLS Ti6Al4V alloys satisfies O_2 and N_2 contents for medical application within the range. Ref. [3–5] experimentally proved that DMLS AlSi10Mg parts met closest tolerance with CAD drawing in down-facing surfaces as well as self-supporting faces. Ref. [6–8] altered the Ti-6Al-4 V alloy properties by including TiB_2 powders and fabricated through DMLS and reported that wear and hardness properties altered significantly. Ref. [9] altered stainless steel properties and fabricated a sample of TiN -SS316 metal matrix composites which exhibited good metallurgical bond, wear and hardness properties altered significantly. Ref. [10] estimated residual stress formation by simulation of DMLS Ti-6Al-4 V alloy and reported that residual stress level is very low than conventional processed part. Ref. [11–13] compared recycled powders with the virgin powder in the process of DMLS AlSi10Mg and reported that slightly the recycled powder made part has insignificant differences with identical samples which manufactured with use of virgin powder. Ref. [14] delivered some important research outcomes with metal deposition (MD) simulation that diffusion rate found quicker in case of unequal size particles that equal particle size similarly in case of alloy (multi-component) system. Ref. [15] recommended that AFB (Abrasive Fluidized Bed) technique improved the surface finish in machining flat DMLS AlSi10Mg part. Ref. [16–18] studied the temperature distribution in DMLS by means of discrete element model (DEM) on particle-based. The temperature of powder bed is proportionate to laser power, did not effected with small laser hatch spacing and laser scan speed. Higher laser hatch spacing leads to heterogeneity in microstructure and uneven temperature

* Corresponding author.
E-mail address: ksivasakthi1966@gmail.com (K. Karunakaran).

https://doi.org/10.1016/j.matpr.2020.07.492
2214-7853/
Selection and peer-review under responsibility of the scientific committee of the International Conference on Newer Trends and Innovation in Mechanical Engineering: Materials Science.

Please cite this article as: A. Malladi and K. Karunakaran, DMLS – An insight for unproblematic production, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.07.492

distribution. Hence DMLS has many merits; this paper analyzed the specific features and challenges in the DMLS process in defect free and trouble free manufacturing.

2. The DMLS process cycle

In the overall production process the DMLS is one unique type of Additive Manufacturing process and various technologies which are under this roof enables the customized and most complex shapes in a short time in metal materials (refer Fig. 1a).

3. DMLS process flow

The DMLS process flow depicted in the Fig. 1b. It starts with CAD Design and end with application on part. The process starts once a 3D CAD files starts modelling or converting the scanned detail into the 3D model. This model is converted into standard. stl format. This format files are forwarded to the DMLS machine used software's for getting the model sliced, which means making the model for understanding of laser movement into XY directions. The sliced model represents the nodes of X&Y with respect to laser movement for scanning and sintering process. When laser scans the bed and start focusing on the nodes of this X&Y the powder gets sintered from last layer of the part and slowly gets added one over the other and finally the part is mad. The powder is recoated one over the other as laser starts making one layer of its scanned pattern. This process doesn't require any support structure as the loose powder available in the chamber will acts like a supports.

4. Types of DMLS process

The DMLS process is classified based on the technique by which metal feed like powder bed (PB) technique and powder deposition (PD) technique. Each layer differs by these techniques. Whereas in PD technique, powder of metal which placed in hopper, which will be melting and placed as skeletal layer on the platform at which product is built. But in PB technique, the very fine metal powder distributor piston lifts the supply of fine metal powder and then recoated arms gives out a layer on the platform at which product is built.

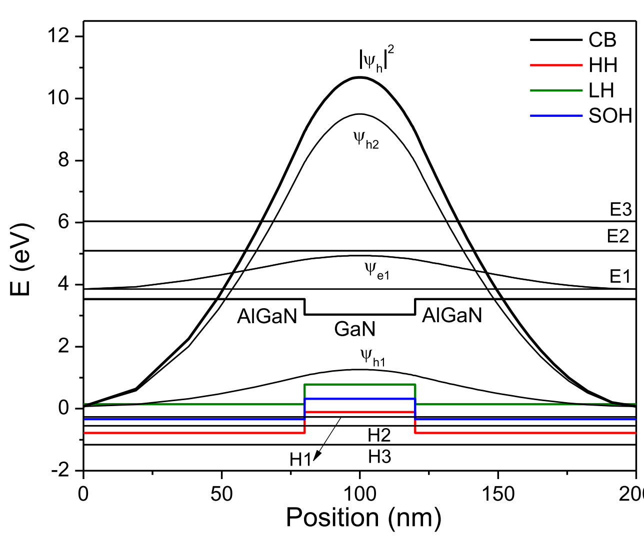

Fig. 1. (a) Out line of DMLS process (courtesy: materialise); (b) flow process of DMLS; (c) classification of DMLS process techniques.

The two different methods of DMLS process (refer Fig. 1c) are: (a) Powder Deposition & (b) Powder Bed. In the both methods, the each layer will differs. Whereas in the powder deposition the metal powder which is placed in a hopper will be melting and gets placed as slim stratum onto the platform at parts built. The other method that is in powder bed process the powder dispenser piston increase the supply of powder and then a recoated arm dole out a stratum onto the platform at parts built.

5. Defects in parts build in DMLS process

Based on these methods there have been identified defects and they are majorly categorized in four types and they are explained in the below tree diagram (Fig. 2):

6. Unique recompense of DMLS

The following Table 1 illustrates the unique recompense of DMLS.

7. Process parameters in DMLS

The study says that the factors (process parameters) role is most significant in building up the model in DMLS process. Most of the parameters involved in DMLS process are of two categories (i) Controlled, these are the parameters which can be controlled by the user as per the requirement & (ii) Pre Defined, and these are the parameters which are already defined as per the standard usage of the machine. The four major domains in which the parameters are identified which perform a key role in influencing the DMLS Process (refer Fig. 3).

8. Scope and influencing parameters of DMLS process

The scope and influencing parameters of DMLS process are detailed in the following Table 2.

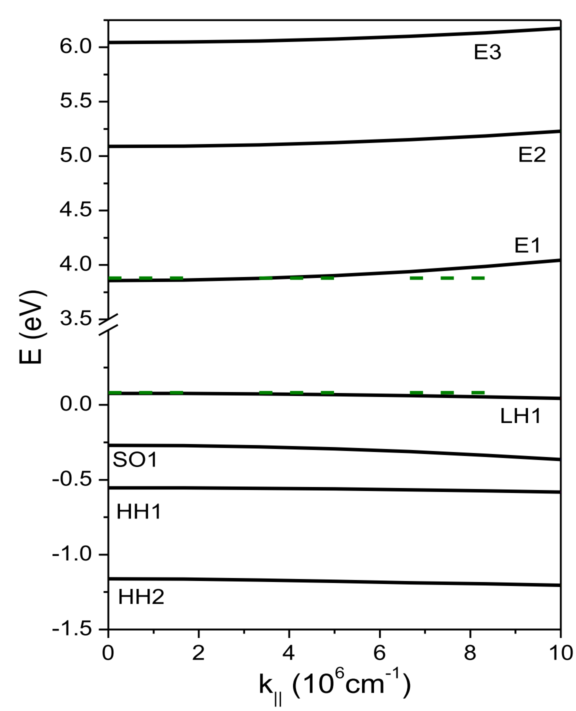

Fig. 2. Defects in parts build in DMLS process.

Table 1
Unique recompense of DMLS.

Dimensional accuracy	Material properties & flexibilities	Surface finish	Support structure
As DMLS process facilitates the cure of parts in short span of time, the residual and environmental stresses formation is avoided.As this process is controlled temperature and its dependent, the excess fusing of material is avoided hence by this process, one can get exact part with perfect dimensions.	The advantage with DMLS is as there are no binders used the final finished part is also having the similar properties of the material even after undergoing sintering process.As the material is used as powder, the advantage for the customized parts can be easily done. But the properties and studies to be extended with respect to the reactive metals with respect to the combination of various materials	As sintering process is fusing material without complete melting, but the material forms a bond at the base levels and provides the powdery surface at the final finish of the part.The poor surface finish needs to be machined or any other process to accomplish the desired output.	The support structures are not mandatory for this process, but it depends or varies from part to part.

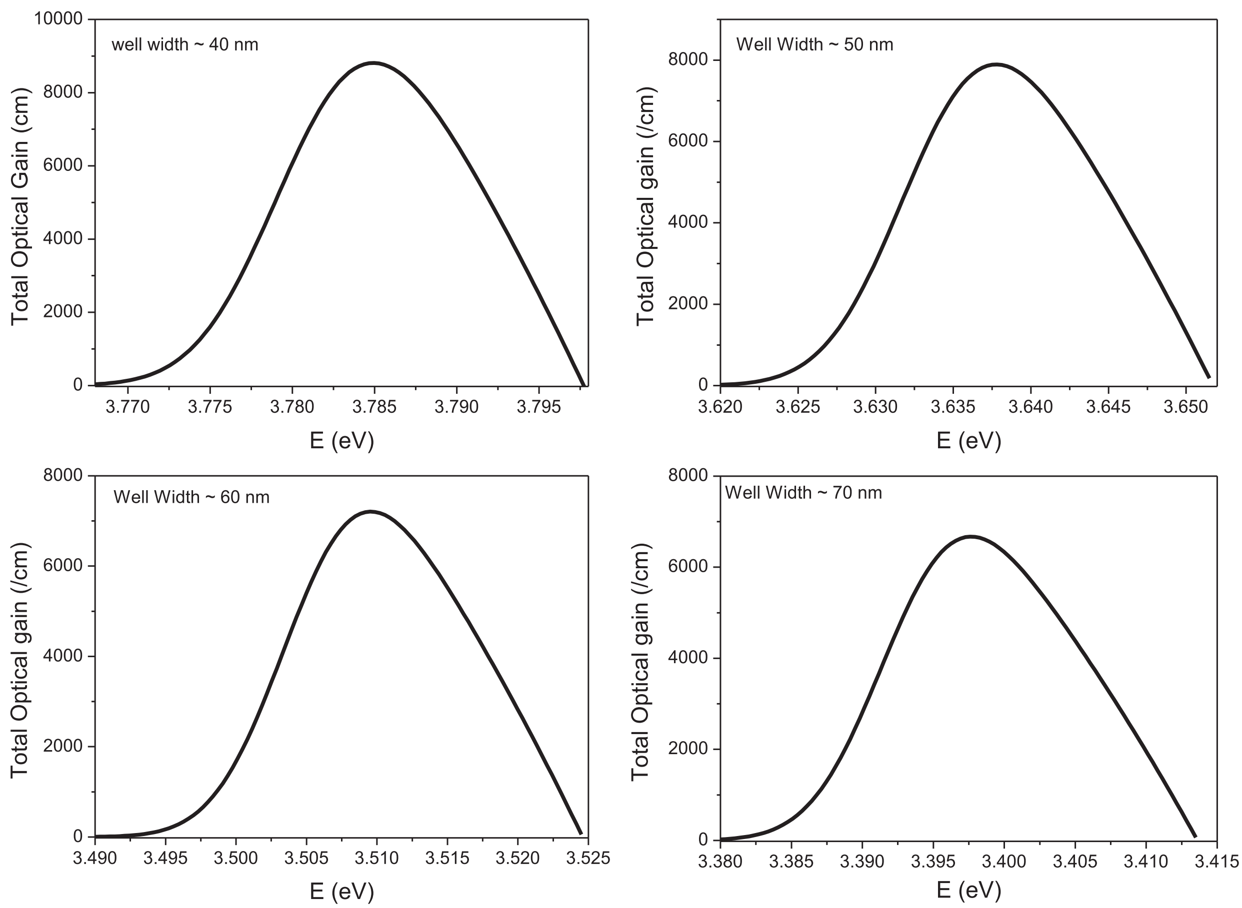

Fig. 3. Major influencing process parameters of DMLS.

Table 2
Scope and influencing parameters of DMLS process.

S. No.	Process parameter	List of details of parameters
1	Laser based parameters	■ width of the Pulse - Laser pulse's length during the pulsed mode ■ Pulsed Mode or Continuous wave mode ■ Pulses with respect to time that is frequency. ■ The Circular or elliptical Spot type and its size ■ Mean/Total power output of a laser ■ Wavelength of the laser ■ ax out power- greatest power measured in a laser pulse
2	Parameters which related to Scan	■ Space between laser passes termed as 'scan spacing' ■ Pattern of scanning like spirals, zig-zags and hatches etc. called 'Scan strategy Pattern' ■ The velocity of laser in crossways on build surface that is 'scan velocity'
3	Powder's Material and its Properties	■ Thermal expansion coefficient ■ Density of the material ■ Surface roughness ■ Enthalpy

(*continued on next page*)

Table 2 (*continued*)

S. No.	Process parameter	List of details of parameters
		■ Material's thermal conductivity ■ Boiling point ■ Material absorptivity ■ viscosity of melt ■ Particle morphology like circularity, aspect ratio, and elongation ■ Specific Heat capacity of the material ■ Diffusivity ■ Melting point ■ Particle size and its distribution ■ Latent heat of fusion ■ Solubility ■ Surface free energy. ■ Vapor pressure
4	Recoat	■ Deposition system parameters o Type of recoater (Soft or hard) o Dosing o Pressure o Speed of providing layer with respect to pattern of scan
5	Powder bed	■ Heat capacity of the powder ■ temperature of Powder bed ■ packing density of the powder ■ Emissivity of the powder ■ Absorptivity of the powder ■ Layer thickness ■ Thermal conductivity of the powder
6	Condition of Part Making	■ Flow velocity of shield gas to control the condensate removal and convective cooling ■ Viscosity of shield gas to balance convective heat transfer and to control free surface activity ■ Surface free energy of shield gas to control the melt pool shape ■ Thermal conductivity of shield gas to balance heat transfer ■ Shield Gas employed either He, Ar or N2 ■ Convective heat transfer coefficient of shield gas for controlling convective heat transfer of cooling ■ molecular weight of Shield gas employed to balance heat and control diffusivity in the part ■ Pressure of shield gas to control the oxygen content and vaporization of metal ■ Ambient temperature helps to control the preheat requirements control the residual stress and heat balance purpose ■ Level of Oxygen to control changes in wettability, metal oxide formation and welding energy required ■ Heat capacity of shield gas to balance heat transfer

9. Conclusion

The advancement in manufacturing process helps to cross the limitations on the conventional processes of manufacturing. DMLS process is a part of additive manufacturing, the systematic process analyzed and presented. The complete features of DMLS processes discussed. The listed out advanced features, limitations, challenges and research scopes of DMLS process helps to manufacture the trouble free parts and understanding process challenges and limitations well. In particularly, the identified defects with respect to the process parameters may be addressed with suitable studies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors sincerely acknowledge to the Department of Mechanical Engineering, School of Engineering for offered necessary research facility and guidance for publishing this research work and sincerely acknowledge to the management of Vels Institute of Science, Technology and Advanced Studies, Vels University, Chennai, Tamil Nadu, India for offering continuous support and encouragement to do lot of research work.

References

[1] B. Anush Raj, J.T. Winowlin Jappes, M. Adam Khan, V. Dillibabu, N.C. Brintha, Optik 202 (2020) 163735, https://doi.org/10.1016/j.ijleo. 2019.163735.
[2] N. Kazantseva, P. Krakhmalev, I. Yadroitsev, A. Fefelov, T. Kurennykh, Mater. Lett. 20915 (2017) 311–314.
[3] E. Atzeni, A. Salmi, J. Manuf. Proc. 20–3 (2015) 500–506.
[4] A.S. Patil, V.D. Hiwarkar, P.K. Verma, R.K. Khatirkar, J. Alloys Comp. 77710 (2019).
[5] Vijay Mandal, Manowar Hussain, Vikas Kumar, Alok Kumar Das, N. K Singh, Mater. Today: Proc., 4- 92017 (2017) 9982–9986.
[6] A.K.S. Chauhan, M. Shukla, Mater. Today: Proc. 18–72019 (2018) 5189–5195.
[7] A. Hadadzadeh, C. Baxter, Babak Shalchi Amirkhiz, Mohsen Mohammadi, Additive Manuf. 23 (2018) 108–120.
[8] Jyotirmoy Nandy, Natraj Yedla, Pradeep Gupta, Hrushikesh Sarangi, Seshadev Sahoo, Mater. Chem. Phys., 2361(2019), https:// doi.org/10.1016/ j.matchemphys.2019.121803.
[9] E. Atzeni, M. Barletta, F. Calignano, L. Iuliano, V. Tagliaferri, Additive Manuf. 10 (2016) 15–23.
[10] W.-H. Lee, Y.i. Zhang, J. Zhang, Powder Technol. 31515 (2017) 300–308.
[11] A. Godwin, Antony, V. Vijayan, S. Saravanan, S. Baskar, M. Loganathan, Analysis of wear behaviour of aluminium composite with silicon carbide and titanium reinforcement, Int. J. Mech. Eng. Technol. 9 (2018) 681–691.
[12] V. Vijayan, S. Saravanan, A. Godwin Antony, M. Loganathan, S. Baskar, Heat transfer enhancement in mini compact heat exchanger by using alumina nanofluid, Int. J. Mech. Eng. Technol. 10 (01) (2019) 564–570.
[13] S. Saravanan, A. Godwin, Antony, V. Vijayan, M. Loganathan, S. Baskar, Synthesis of SiO2 nano particles by using sol-gel route, Int. J. Mech. Eng. Technol. 1 (2019) 785–790.
[14] S. Dinesh, A. Godwin, Antony, K. Rajaguru, V. Vijayan, Experimental investigation and optimization of material removal rate and surface roughness in centerless grinding of magnesium alloy using grey relational analysis, Mechanics and Mechanical Eng. 21 (2017) 17–28.
[15] S. Dinesh, K. Rajaguru, V. Vijayan, A. Godwin Antony, Investigation and prediction of material removal rate and surface roughness in CNC turning of EN24 alloy steel, Mechanics and Mechanical Engineering, 20(2016), pp. 451-466.

[16] S. Baskar, V. Vijayan, S. Saravanan, A.V. Balan, A. Godwin, Antony, Effect of Al2O3, aluminium alloy and fly ash for making engine component, Int. J. Mech. Eng. Technol. (IJMET) 9 (12) (2018) 91–96.

[17] S. Baskar, V.Vijayan, I.J. Isaac, Premkumar, D. Arunkumar, D. Thamaran, Design and material characteristics of hybrid electric vehicle, Mater. Today: Proc. (2020), https://doi.org/10.1016/j.matpr.2020.05.352.

[18] B. Suresh, Kumar, V. Vijayan, N. Baskar, Burr dimension analysis on various materials for convenantionally and CNC drilled holes, Mechanics and Mechanical Eng. 20 (2016) 347–354.