

LBM on variant geometrical features for orthopaedic implants and aerospace alloys: A Review

S.Namdev¹, A. Pandey¹, A K. Pandey²

¹Manipal University Jaipur, Manipal University Jaipur

²Bundelkhand Institute of Engineering & Technology Jhansi

Email- satish.namdev@jaipur.manipal.edu

Abstract. Laser beam machining (LBM) is an advance machining process, it is highly precise machining for any type of material with typical geometries. Various machining processes like cutting, drilling, grooving can be performed by LBM for material removal. CO₂ and Nd: YAG lasers are generally used for industrial purposes. This paper provides views about various geometrical feature of the laser beam machining implemented for orthopaedic implants metals and aerospace alloys. Modeling and simulation of Laser beam machining is very important for optimization purpose. This paper also gives an overview of current status of research in modelling and simulation of laser beam machining of smart alloys.

Keywords. LBM, Nd:YAG, modeling, optimization and review

1. Introduction

LBM is one of the non-traditional manufacturing process which is used for shaping almost whole range of engineering materials. The laser beams are widely used for cutting, drilling, marking, welding, sintering and heat treatment [1]. Laser Beam has three unique characteristics, so it is useful in processing of materials. Characteristics of Laser beams are better focusing, highly directional and have highly power density. Among various type of lasers used for machining in industries, CO₂ and Nd: YAG lasers are mostly used in industries for machining [2-4].

1.1. Need of Industry

Some text. Now a days we are using advanced material those are having great characteristics as high strength, high durable, high thermal resistance, long lasting, light weighted etc. these characteristics can be found in steel, titanium alloy, fiber reinforced composite materials, ceramics. These types of materials are difficult to machine from conventional process. Un-conventional machining process are used to fabrication of advanced or smart materials [5-6].

Laser beam machining (LBM) is an unconventional machining process, in this process a laser beam is focused towards the material for operation. Laser beam have two great characteristics, these are monochromatic and parallel so it can be directly focused to a micron size diameter and can produce high energy (like 100MW) for micro size area. It is best for making a precise micro size hole. Also, it can be used for other micro machining on all types of materials. LBM process is have one more characteristics that make it differ from other UMPs i.e. By LBM can be perform machining on any conducting, semi conducting and non-conducting materials [7-9].



1.2. Physics of LBM

Laser (light amplification by stimulated emission of radiation) is a consistent and boosted beam of electromagnetic radiation. Unique quality characteristics like high power density, better focusing of laser beam make it useful in processing of materials. Heating, melting, vaporizations are three different stage of material removal mechanism by LBM [10-13]. When laser beam of high energy density is focused on work surface, thermal energy is absorbed by surface, heat transforms work volume into a molten, vaporized or chemically changed state and molted material can be easily removed by high pressure assist gas jet flow. The schematic of LBM has been shown in Fig. 1.

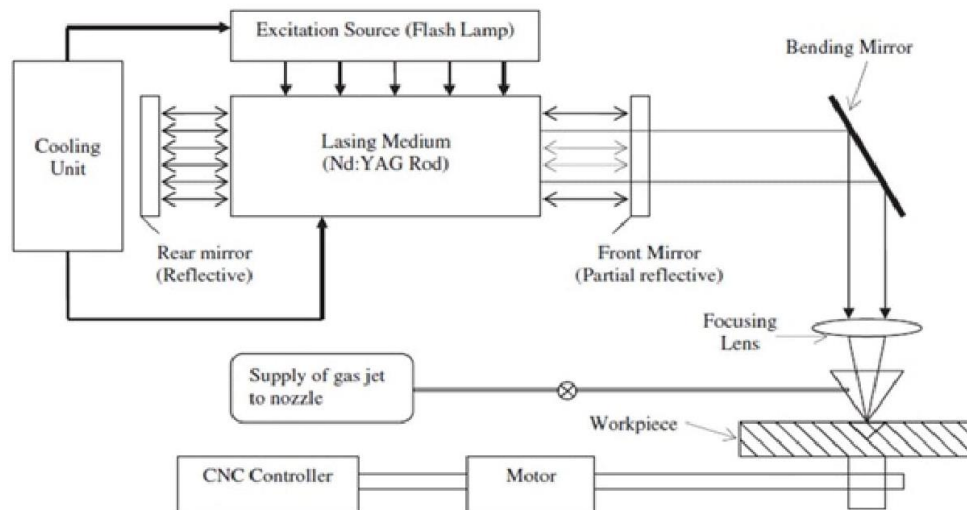


Fig-1 Laser Beam Machining Process [42]

2. LBM operation

LBM is a flexible machining process. That's why it can be used for many types of machining process. LBM can also work on non-conducting materials. Its special quality makes it differ from other AMPs [14-15]. When combined laser beam with computer controlled multi-axis work piece positioning system or a like robot, then heat treating processes, cutting, drilling, welding and grooving on a single machine can be performed on a single machine. The major configurations of LBM are: drilling, cutting, grooving, turning and milling, and micromachining of various work piece materials [16-17].

2.1. Drilling

Laser beam drilling process has been accepted worldwide economical process for drilling for micro size hole in structures. Basically two types of drilling can be performed by laser beam, these are trepan drilling and percussion drilling [18-19]. These are shown in fig.2. In Trepan drilling a hole is generated around the circumference by laser beam, whereas in percussion drilling is like as a punches in which removing material directly from the work piece without any relative motion between work piece and laser beam.

2.2. Cutting/Groove/Slit

Laser beam machining is used on conducting as well as non-conducting materials. This amazing characteristics make it very useful for cutting and grooving operations on metallic and non-metallic materials (ceramic and plastic) [20-21]. Punching, marking and cutting can be performed on materials have. Laser beam cutting mechanism can be understood easily by fig.3. It is superb to any cutting method either advanced or non-conventional because of it can be used on any materials, no contact between tool and work piece so no wear or change of tool, no material wastage, maximum utilizations of materials with high accuracy and edge quality.

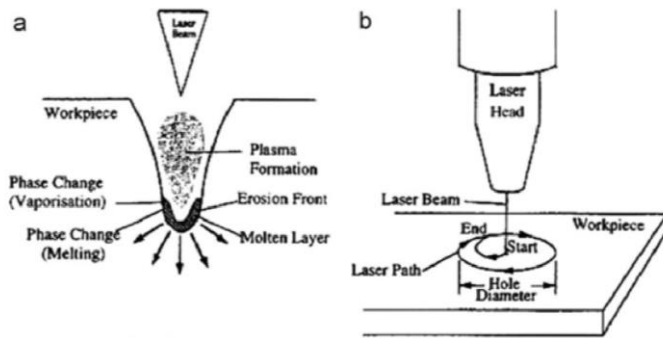


Fig 2- (a) Percussion drilling (b) Trepan drilling [42]

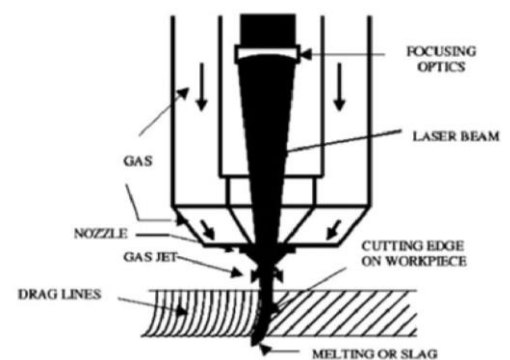


Fig 3- Laser Beam cutting [42]

2.3. Laser beam turning and milling

Laser beam turning and milling is shown in fig 4, are three dimensional operations and need simultaneous two laser beams to get desired profile in the work piece. To get desired profile, beams can be focused at certain angles by fibre optics [22-23]. Generally laser milling machining is used to manufacturing of complex types of geometry.

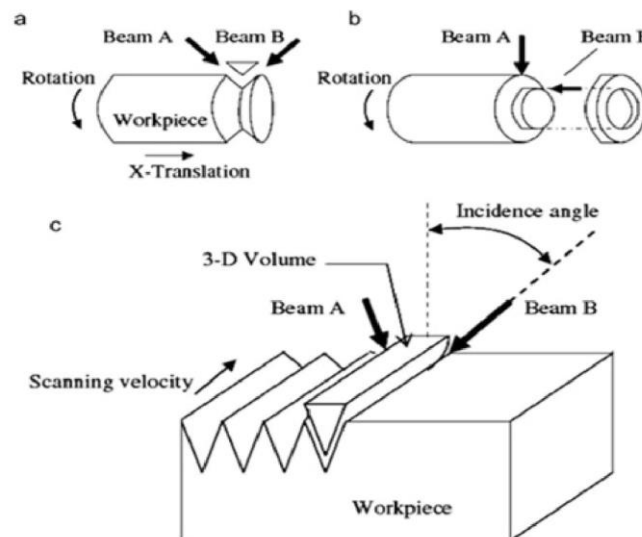


Fig 4 – Laser turning (a) helix removal (b) ring removal (c) laser milling [42]

3. Literature Review

On the basis of literature review authors have investigated many changes in surface morphology with using various process parameters on various geometrical features. Some of them are below.

Artificial neural network (ANN) approach to make a model to material removal process during Laser machining. By this model can be calculated crater depth and diameter w.r.t. pulse energy for brass, copper and stainless steel [24]. Author has been used Nd:YAG Pulsed laser cutting for Titanium alloy sheet to improve the surface quality of blade hole cutting of bladed ring parts of Jet engine and see the effect of various process parameters like pulse rate, pulse energy, cutting speed, and various gases (Argon, oxygen and nitrogen) pressure on HAZ layer. By the medium pulse energy, high pulse rate, high cutting speed with high pressure of argon gas can be acquire thin layer, but in the presence of oxygen and nitrogen gas pressure micro cracks developed and reduced surface quality of titanium alloy sheet [25].

Researcher has used Pulsed Nd:YAG laser for micro drilling of ZrO₂ and shown HAZ thickness and taper both are increase with lamp current, pulse width. HAZ thickness increase and taper

decrease with increasing pulse frequency. Author developed a mathematical model and optimal analysis for precision micromachining operation on engineering ceramics [26]. Author has developed L-27 orthogonal array for experiments and generate a mathematical model NN-GA for kerf taper and surface roughness for laser cutting of titanium alloy of grade V [27].

Grey fuzzy methodology is utilized for optimization of laser cutting of Duralumin sheet. He decreased kerf width and in kerf taper used optimum values of process parameters like gas pressure, pulse width, pulse frequency and cutting speed [28]. Author has studied and discussed about the effect of Focal length and laser power on various quality characteristics of laser cut on brass sheet. Focal length affect surface roughness and cutting speed [29].

Laser cutting on titanium alloy with using fuzzy expert system to predict kerf width and its deviation, he found that pulse width and pulse frequency are important factor for kerf width. Kerf width increase with increase in pulse frequency [30]. Author has done his research work on curve cut profile on nickel based super alloy sheet by Nd:YAG laser with DoE orthogonal array L-27, got more kerf taper angle, less kerf width and less kerf deviation in curve cut profile while comparison with straight cut profile [31].

Some experimental study based in ANN and GA was conducted to get good quality micro groove on laser turning. By this approach he minimized upper width, lower width and depth during the micro groove. [32]. Researchers conducted NSGA approach, for this work experiment carried out CO₂ laser machine to cut 3 mm thick plate of material stainless steel AISI 321 .it is a posteriori approach known as NSGA (non-dominated sorting genetic algorithm) for multi objective optimization aspects of LBM Process parameters are considered. Author has focused posterior approach is better to priori approach in this paper [33].

Author has done theoretical study of Ra for mild and Response Surface Methodology to find the relation among laser machining parameter (cutting speed, frequency and duty cycle) with responses. He used L-27 OA [34]. Author has investigated various characteristics efficiency, absorption and cut for fusion and oxygen cutting for direct diode laser source for laser cutting of metal sheets. He got Beam parameter product(BPP) of 22mm mrad with output power 2KW give better performance when cutting SS or Al with inert gas [35].

ANOVA software utilized to see the effect of focal length and laser power during laser cutting on 1 mm thin brass sheet. He found focal length should be proper because improper focal length affect surface roughness and cutting speed [36]. Researchers has used CO₂ laser to cutting two different alloy steel sheets (1.4828 and 1.4571) and using N₂ as assist gas [37].

CO₂ and fiber laser to cut AISI 304 stainless steel. He found that surface roughness occurs between 4 and 6mm in case of fiber optics and between 8 and 10 for CO₂ laser under the defined experimental condition also difference in kerf shapes and kerf cross section areas [38]. High power CW and pulsed CO₂ laser for cutting fiber reinforced thermoplastic sheet of 2.1 mm thickness [39].

Methodology has been adopted to make model of LBPD of thin Al sheet. Input process parameters like pulse width, pulse frequency and peak power are increased then reduce tapering and increase MRR. Increase Pulse width and pulse frequency increase HAZ but increase in peak-power can be reduced HAZ [40]. 2-dimensional model in FEM based ANSYS Software for thermal distribution on Inconel-718 sheet for micro hole size 3 μ m using process parameters for Nd: YAG Laser like pulse widths, pulse frequency, radius of laser beam and peak power and found if increasing pulse width [41].

4. Conclusion

Laser beam cutting is thermal energy based process. It is non-contact advanced machining process used for cutting operation on almost all conducting and non-conducting materials. CO₂ and Nd:YAG lasers are commonly used for this advanced machining process. In recent years, researchers are working on improving performance of LBM by analyzing different factors those are affected quality characteristics. Most of researchers have used various modeling and optimization techniques applied for laser cutting

on various categories of materials. In this paper, critical study of different modeling and optimization techniques applied to improve performance of laser cutting has been presented. This paper also provides a review of the various methods used for modeling and optimization of the laser beam cutting process as well as key researches done in this field so far.

References

- [1] Zhian Syn C., Mokhtar M., Feng C. and Yupiter H.P. 2011 *ESWA* 38.
- [2] Meijer J. 2004 *J Mater Process Technol* 149.
- [3] Powell J. and Kaplan A. 2004 *ICALO*.
- [4] Yilbas B. 2004 *J Mater Process Technol* 155–156.
- [5] Basem F., Yousef George K., Knopf Evgueni V., Bordatchev Suwas K. and Nikumb 2003 *Int J Adv Manuf Technol* 22.
- [6] Lamikiz A., Lacalle L., Sa'nchez J., Pozo D., Etayo J. and Lo'pez J. 2005 *Appl Surf Sci* 242.
- [7] Loisos G., and Moses A. 2005 *J Mater Process Technol* 161.
- [8] Chen T. and Darling R. 2005 *J Mater Process Technol* 169.
- [9] Dixin G., Jimin C. and Yuhong C. 2006 *IJCNN, Canada*.
- [10] Lamikiz A., Lacalle L., Sa'nchez J., Pozo D., Etayo J., and Lo'pez J. 2006 *I Mech E* 220 B.
- [11] Shanjin L. and Yang W. 2006 *Opt Laser Eng* 44.
- [12] Lia C., Tsaia M., and Yangb C. 2007 *Opt Laser Technol* 39.
- [13] Baskoro A., Herwandi, Ismail K., Siswanta A. and Kiswanto G. 2011 *IJMME-IJENS* Vol: 11
- [14] Kuljanic E., Sortino M. and Totis G. 2010 *IREC TMT*.
- [15] Gilbert T., Krstic V. and Zak G. 2007 *J Mater Process Tech* 189.
- [16] Kuar A., Doloi B. and Bhattacharya B. 2006 *I J Mach Tool* 46.
- [17] Pandey A. and Dubey A. 2012 *Opt Laser Eng* 50.
- [18] Bandyopadhyay S., Sundar J., Sundararajan G. and Joshi S. 2002 *J Mater Process Tech* 127.
- [19] Uebel M. and Bliedtner J. 2014 *Procedia Engineering* 69.
- [20] Zhang G., Zhang B., Deng Z. and Chen J. 2007 *Annals of CIRP* 56.
- [21] Dhupal D., Doloi B. and Bhattacharyya B. 2009 *Opt Laser Eng* 47 .
- [22] Nukman Y, Hassan M. A. and Harizam M .Z. 2013 *Appl. Math. Inf. Sci.* 7.
- [23] Sharma A. and Yadava V. 2012 *Opt Laser Technol* 44 .
- [24] Yousef B., Evgueni G., Bordatchev V. and Nikumb S. 2003 *Int J Adv Manuf Tech* 22.
- [25] Shanjin L. and Yang W. 2006 *Opt Laser Eng* 44.
- [26] Kuar A., Doloi B. and Bhattacharyya 2006 *Int J Mach Tool Manu* 46.
- [27] Pandey A. and Dubey A. 2013 *J Mech Sci Technol* 27.
- [28] Pandey A. and Dubey A. 2013 *Int J Adv Manuf Tech* 65.
- [29] Madia M. and Patel D. 2013 *IJIRSET* 2.
- [30] Pandey A. and Dubey A. 2013 *Mach Sci Technol* 17.
- [31] Sharma A., Yadava V. and Rao R. 2010 *Opt Laser Eng* 48.
- [32] Sharma A. and Yadava V. 2013 *Opt Laser Eng* 51.
- [33] Pawar P. and Rayate G. 2014 *IJAME* 4.
- [34] Panu S., Gautam G., Singh K. and Norkey G. 2014 *IJAME* 4.
- [35] Rodrigues G., Pencinovsky J., Cuypers M. and Duflou J. 2014 *Opt Laser Eng* 61.
- [36] Madia M. and Patel D. 2013 *IJIRSET* 2.
- [37] Cekic A., Begic-Hajdarevic D., Kulenovic M. and Omerspahic A. 2014 *J Pro Eng* 69.
- [38] Stelzera S., Mahrlea A., Wetziga A. and Beyera E. 2013 *J Ph Pro* 41.
- [39] Schneider F., Wolf N., and Petring D. 2013 *J Ph Pro* 41.
- [40] Mishra S., and Yadava V. 2013 *Opt Laser Technol* 48.
- [41] Soni A. and Patel R. 2013 *IJESIT* Volume 2, Issue 3.
- [42] Dubey A. and Yadava V. 2008 *Int J Mach Tool Manu* 48.