ISSN: 2454 - 4248
28 – 31

Laser and Laser Beam Machining: A review

D.T. Dhande
Department of Applied Science and Humanities
MGICOET Shegaon,
Maharashtra, India
E-mail id - dhanshridhande@gmail.com

S.T. Dhande
Department of Mechanical Engineering
MGICOET Shegaon,
Maharashtra, India
E-mail id - stdhande@gmail.com

Abstract- Laser is one of the most important technologies used in many applications for manufacturing products like in medical instrument, aerospace and manufacturing industry. Laser is based on thermal energy and non contact type technology which solves the problems of wearing to material during operations. Laser formation is based on the thermal energy, vaporization and degradation of material. Laser machining is one of the applications which used in cutting of various kind of material.

In last few years researchers have done work on the improvement on laser beam and also find out the effect on operation in application. In the present paper few important studies are reviewed. From the literature it can be conclude that the in the machining of material in laser improved. Effect of laser machining parameter has its contribution in the improvement of life of products. Performance of the Laser machining as compared to the traditional machining is better. Also this studies shows that performance of laser machining can be improved by proper selection of laser machining parameter.

Keywords-*Laser, Laser maching , Aapplication in indusrty*

*****

I. INTRODUCTION

Laser (light amplification stimulated by emission of radiation) beam is used in many more application like machining of material , processing of material, heat treatment , alloying, cladding , sheet metal product. In this processes thermal energy is used to convert raw material to final product. Laser are now also used in regenerative machining, rapid prototype processes like stereo-lithogrophy, sintering processes. Laser beam can be generated easily by focusing the laser beam on the optical lance as their wavelength range from half micron to around the 70 micron. Focused laser as indicated can have power density in excess of 1 MW/mm^2. Laser is incident on material and energy absorbed by the working material. Because of high temperature material get heated at spot area. This was result in the melting and vaporization.

II. LASER

A. Basic of laser

In laser formation light emits through processe of optical amplification based on stimulated emission of electromagnetic radiation. It is one type of phenomenal concept in which beam of coherent monochromatic light by stimulated emission of photons from by excitation of atoms from higher energy level to low energy level. Laser always emits the light which is coherent. This property allows the light to tight spot on the given material. Spatial coherence will provide the laser beam with stay narrow over great distance collimation [1]. Laser is also with the high temporal coherence, which emit the light with narrow spectrum. This type of laser emit single color of light

Albert Einstein in 1917 defines the basic working principle through industrial experimental which was carried out in 1960s.

Then the first laser was built by 1960 by Theodore H. Maiman at Hughes research laboratories, based on theoretical work of Charles Hard Townes.

B. Working mechanism of laser

In the atomic arrangement the negatively charge electron rotates around the positively charged nucleus in give orbital path. The radius of the orbit is depends on parameter like number of electrons, presence of electrons, atoms in orbit, electronics structure, electromagnetic field etc. every electron in orbit have specific energy with unique level. When all electronic occupy their lowest potential energy the zero temperature of atom is considered at ground level [2].

The electrons from ground state get excited to higher orbit energy by absorbing energy form external sources. This external source is electronic vibration at elevated temperature, through chemical reaction or by absorbing energy of the photon. The mechanism of absorption of energy photon by electron shows in the figure 1. The electron moves from a lower energy level to a higher energy level.

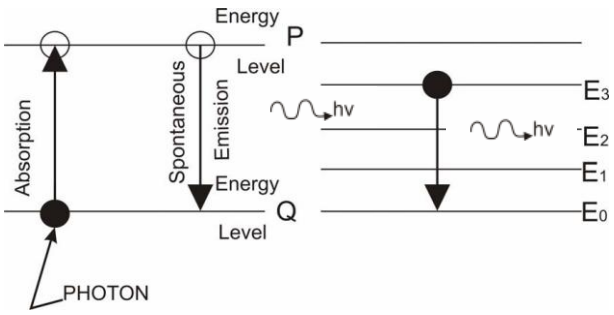

Figure 1 Energy bands in materials [2]

When the electron reaches to higher energy level it shows the unstable energy band. Because of instability it comes back to its ground state within and releasing a photon. This phenomenon is called spontaneous emission as shown in the Figure 1 and 2. The spontaneously emitted photon would have the same frequency as that of the "exciting" photon. Atom then comes back to metastable state which is excited state of

ISSN: 2454 - 4248
28 – 31

an atom [3]. Atom stay for a shorter lifetime than the stable ground state. Atoms in the metastable state remain excited for a considerable time in the order of 10^{-6} to 10^{-3}

[4] From above details change of energy state puts the electrons in a meta-stable energy band. Instead of coming back to its ground state immediately it stays at the elevated energy state for micro to milliseconds. Population of inversion occurs which is more important to form laser action, in which more number of electrons pumped to higher energy level as compared to the ground energy level atoms..

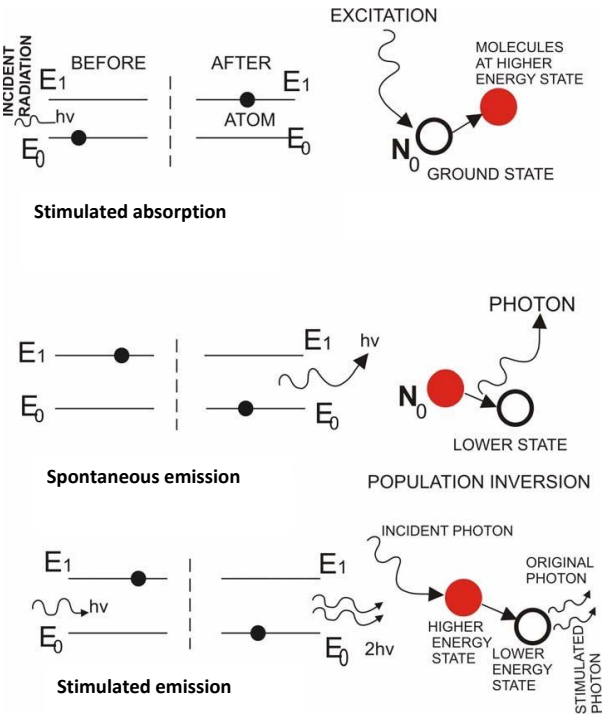

Figure 2. Spontaneous and stimulated emission [1]

Such electrons at higher energy meta-stable state, can return to the ground state in the form of an avalanche provided stimulated by a photon of suitable frequency or energy. This is called stimulated emission. Fig. 2 shows one such higher state electron in meta-stable orbit. If it is stimulated by a photon of suitable energy then the electron will come down to the lower energy state and in turn one original photon, another emitted photon by stimulation having some temporal and spatial phase would be available. In this way coherent laser beam can be produced.

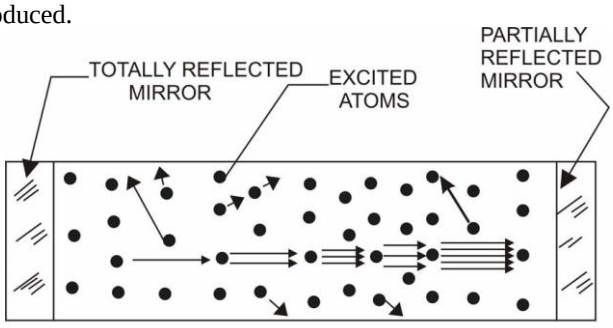

Figure 3. Lasing action [4]

Figure 3 schematically shows working of a laser. There is a gas in a cylindrical glass vessel. This gas is called the lasing medium. [8] One end of the glass is blocked with a 100% reflective mirror and the other end is having a partially reflective mirror. Population inversion can be carried out by exciting the gas atoms or molecules by pumping it with flash lamps. Then stimulated emission would initiate lasing action. Stimulated emission of photons could be in all directions. Most of the stimulated photons, not along the longitudinal direction would be lost and generate waste heat. The photons in the longitudinal direction would form coherent, highly directional, intense laser beam.

C. Mediums used in the formation of laser

In the formation of laser [5],the set up is required lasing medium like semiconductor, dye, solid state and gases state. But in the laser cutting solid state and gases state are more preferable. Solid state medium consists of ruby rod of chromium, aluminum alloy, Nd-YAG glasses etc and gases medium includes carbon dioxide, Helium-Neon, Argon etc.

D. Applictions of laser

Due to characteristics of laser like Coherence, Directionality, [6] High intensity, Monochromatic, it can be in various field like free-space optical communication and storage, industrial, military and defense, metrological and geophysical, laser imaging and holography, medical, laser spectroscopy, fundamental research , reading barcodes, and in recording and playing compact discs, laser lighting displays for entertainment etc. In this paper we discuss about the industrial application of laser which include laser machining process.

II. LASER BEAM MAHINING

Laser beam machining is one of the most widely used nonconventional machining processes. This is a form of machining, in which a laser is directed towards the work piece for machining. This process uses thermal energy to remove material from metallic or nonmetallic surfaces. The high frequency of monochromatic light will fall on the surface then heating, melting and vaporizing of the material take place due to impinge of photons. It is non-contact type advance machining process and used for machining of various whole range of materials. Laser machining processes is suitable for complex profile cutting geometry, for brittle materials with low conductivity, for small holes in material sheet. In industry CO_2 and Nd:YAG based machine are used [1-3] many times.

A. Laser Cutting

Laser cutting is a non-contact process in which a laser is used to cut materials, which results in high quality, dimensionally accurate cuts. This process works by directing the laser beam through a nozzle to the work piece. In this process combination of heat and pressure creates the cutting action. The material is first melts, then burns, and vaporizes, or is blown away by a jet of gas, leaving an edge with a high-quality surface finish [3].

B. Principle of laser beam cutting

In laser machining processes material is removed in various stages. In first stage the generated high energy density laser beam is focused on the work piece material. The thermal energy produced by laser absorbed by the

ISSN: 2454 - 4248
28 – 31

material because of this the surface is completely melt [1-3]. In the second stage the vaporization of molten metal is started and material is removed by the high pressure assist gas jet. During this the chemical bond are completely break and material completely degrade

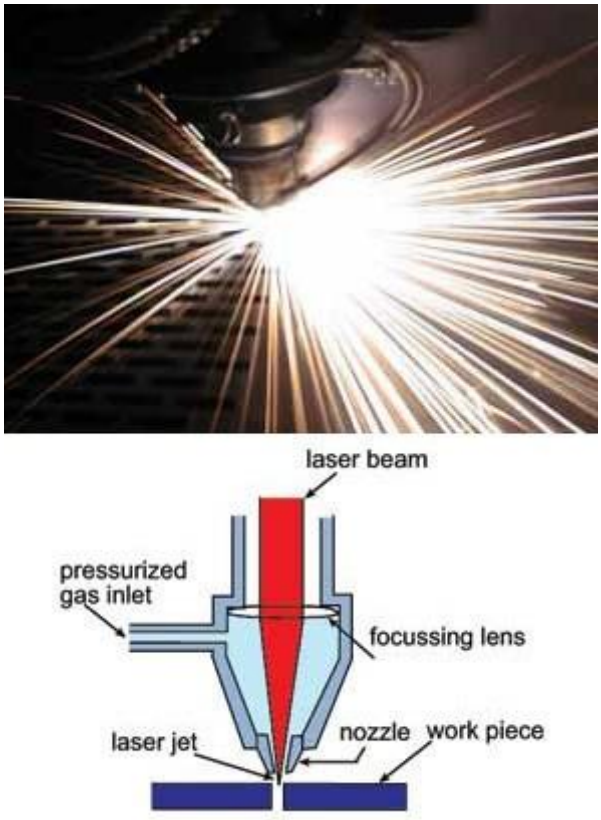

Figure 4. Laser machining [4]

In the following Figure 5 shows the different method of laser cutting are shown.

Method	Concept	Relative Energy
1. Vaporisation		40
2. Melt and blow		20
3. Melt, burn and blow		10
4. Thermal stress cracking	Tension	1
5. Scribing		1
6. "Cold cutting"	hν High energy photons	100

Figure 5. Methods of laser cutting []

C. Applicationg of laser cutting in industry

Laser beam machine are use in various operations in industry like Trepan and percussion laser beam drilling, one dimensional drilling, Laser cutting and grooving operation in die making processes, laser milling process, Micromachining of different work piece materials Laser cutting of monolithic materials like metals and alloys. It also established in various industries including aerospace, medical instruments and automotive. Laser machining is used for various materials like ceramic, steels, composite material. Composite materials are advance and introduced for many industrial application and productions [8].

III. LITERATURE

Surendra Kumarand [1] studied the material characteristics in laser trepan drilling of Zirconia Toughened Alumina ceramic. This material (ZTA) is used in aerospace, military and biomedical application. Ceramic based material is difficult to cut by traditional machining processes to overcome this problem this study was carried out by using Laser machine processing. After laser machine processed as a result he found that that lower pulse width or trepanning speed, and higher air pressure reduce the recast layer thickness and microcrack width.

According to B S Wardhana [2] Laser cutting is a cutting technology that enables fast processing in high precision. This technology utilizes high temperatures generated by engine to perform the cutting process. Selection of cutting parameters becomes the main factor to determine the cutting surface quality. They studied the effect of laser cutting parameter on surface of steel material. Cutting parameters in the form of cutting speed and gas pressure are varied between 60 mm/minute - 100 mm/minute and 17 bar - 21 bar to examine the effect on surface character. Roughness, hardness and microstructure were studied after machining of steel material and he found the effect of laser machining parameter on it. They found the improvement in the surface quality, surface hardness.

Antonio R. [3] Represented a technical study on laser grooving as breakthrough and vital solution in wafer saw process. This work addressed various defects such as chippings, metal dangling and peel off, cracks, and other wafer-related defects induced during wafer saw process. In this study he compared to the conventional and universal mechanical sawing using blades, with laser grooving technology and found the the better result in laser grooving operation.

Kwang-woon [4] worked on the ultra-high-speed laser in which cutting on two kinds of CFRP with long or short carbon fibers using high brightness cw disk laser. The mail objectives of work were to obtain better cutting quality on CFRP sheets. They evaluated the effect of laser cutting parameters on CFRP cut qualities such as HAZ, kerf width, and kerf depth. He found that the HAZ at the cutting surfaces became narrower and smaller with higher the cutting speed also there is increase in the laser power till up to 5 kW which reduce the processing time for full cutting.

Ghoreshi [5] use the response surface methodology to investigate the effect of laser machining parameter on taper hole and circularity of steel sheet material having thickness of 2.5 mm. they compared the result with mild steel .The variables of laser machining are hole diameter, taper position of hole , power, pulse frequency, number of plus , gas assist and plan position. He found that pulse frequency had effect on whole geometry in steel and there is no effect on mild steel hole.

Kuar [6] has also worked on the preparation of mathematic modeling for heat affected zone and taper drilling of zirconai, ceramic sheet of 1mm thickness using q-switch model. They found that minimization of heat affected zone found at

ISSN: 2454 - 4248
28 – 31

optimum lamp current, pulse frequency, assisted air pressure and pulse width 17 amp, 2.0 kHz, 2.0 kg/cm^2 respectively .

Elyas Haddadia [7] studied laser cutting process using low power CO2 laser on extruded polystyrene sheets with thickness of 3 mm based on full factorial Design of experiments. He get result that, increasing the laser power and cutting velocity can help to reduce the heat affected zone, on the other hand using covering gas has a greater effect on controlling and limiting the HAZ width. The results also showed that in order to increase the ratio, application of higher cutting velocity with lower laser powers is beneficial, but in this case, taking advantages of higher cutting velocity is more effective than the laser power. Cutting velocity is the major controlled variable influencing cutting angle and ratio of top kerf width on bottom kerf width.

Dong Sun [8] perform many experiment to verify feasibility and characteristics of water jet–guided laser cutting of CFRP laminate. And he conclude that the experiments using multi-pass scanning strategy without parallel passes, the kerf had a sawtooth shape on the side wall. This phenomenon occurred because the shape of the kerf influenced the flow of water, which further affected the propagation of laser. In the experiments using multi-pass scanning strategy with parallel passes, different scanning strategies also had remarkable effect on the surface quality. In the first strategy, layer-by-layer removal of materials facilitated the processing of thicker CFRP, because the water jet is relatively intact. In the second strategy, the side surface quality was better, but the CFRP need to be cut off first. 3. The last pass plays an important role in trimming the finishing surface and the machined surface quality can be improved by adjusting the parameters [9]. A relatively optimal result was obtained under the experimental conditions.

S. Marimuthu [10] investigate the laser cutting of 2 mm thick aluminum metal matrix reinforced with aluminum oxide fiber (Al MMC). They were examined the quality of cuts and effect of cutting parameter. They found that MMC are not vaporized but are removed along with the molten, low melting point matrix materials.

CONCLUSIONS

The work presented here is an overview of few studies on laser and its industrial application

From above discussion it can be concluded that:

1. Laser beam have its scope in aerospace, medical defense and manufacturing industry.
2. As the focus was on laser machining processes there is lot of scope in the metal cutting industry to improve the performance of laser cutting machine as well as product quality.
3. Laser machining is suitable for complex geometry product as well as micro holes.
4. In most of cases it is found that performance of laser machining is depend on the laser parameter like laser power, wavelength, modes of operations
5. It also depends on the material shape size and its thickness and geometry.
6. In laser machining heat affected zone is also important.

REFERENCES

[1] Surendra Kumar, Saini Avanish Kumar Dubey “Study of material characteristics in laser trepan drilling of ZTAJournal of Manufacturing ProcessesVolume 44, August 2019, pp 349-358.

[2] B S Wardhana, K Anam, R M Ogana and A Kurniawan “Laser Cutting Parameters Effect on 316L Stainless Steel Surface Materials Science and Engineering” 2019, pp429 International Research Journal of Advanced Engineering and Science ISSN (Online): 2455-9024 279

[3] Antonio R. Sumagpang Jr. and Frederick Ray I. Gomez, “Wafer saw defects mitigation through laser grooving technology”2019 pp123

[4] Kwang-woon, J. Yousuke, K., & Seiji, K. “ Ultra High speed laser cutting of CFRP using a scanner head” 2013,pp 9–14

[5] M. Ghoreshi D.K.Y.Low ,”Comparative analysis of hole taper and circularity in laser percussion drilling” International journal o f machine tool and manufacturing 42 (2002) 985-995

[6] A.S. Kuar, B. Bhattacharyya, Modeling and analysisi of pulsed Nd: YAG Laser machining of zirconica , International journal tool and manufactuing 42 2002 pp985

[7] Elyas Haddadia , Mahmoud Moradib, Ayub Karimzad Ghavidela , Ali Karimzad Ghavidela , Meiabadid Saleh “Experimental and parametric evaluation of cut quality characteristics in CO2 laser cutting of polystyrene ” International Journal for Light and Electron Optics 184 2019, pp103–114

[8] Dong Sun, & Fuzhu Han, & Weisheng Ying “The experimental investigation of water jet–guided laser cutting of CFRP” The International Journal of Advanced Manufacturing Technology. 13 December 2018

[9] Avanish Kumar Dubey,Vinod Yadava “Laser beam machining-A review” International Journal of Machine Tools & Manufacture 48 2008, pp 609–628

[10] S.Marimuthu, J.Dunleavey, Y.LiuM.Antar, B.Smith “Laser cutting of aluminium-alumina metal matrix composite” Optics & Laser Technology Volume 117,September 2019, pp 251-259