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Advance Manufacturing Processes Review Part V: Laser Beam Machining (LBM)

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***Abstract* -** *The technology includes more advanced machining. Laser beam is focused for vaporizing and melting the unwanted material from the parent or domain material. It is evident from the start many types of high-tech machines that have emerged and developed to inculcate the process more efficiently in the world. One of them is the Laser Beam Machining (LBM) which we described in this paper. Laser Beam Machining uses a monochromatic beam of high-power so that the tool can be used on any type of material. In day to day life, Laser Beam Machining is used as a tool to perforate or prick materials with high accuracy. Several techniques are developed to minimize the laser machining short comes to produce defect free machined parts. The main focus is related to the laser drilling, laser cutting, and laser-induced bending. The execution of this LBM needed professional expertise and operational costs are quite expensive. Optical properties such as low thermal conductivity, low diffusivity and low reflectivity are well suited for laser cutting process., the laser power, cutting speed, focal length, pulse frequency and pulse width are most important. However, the important performance measures in LBM are material removal rate (MRR), kerf width, heat affected zone (HAZ), surface roughness (SR), and surface hardness.*

Key words: *Laser Beam Machining, Laser Cutting, Laser Beam Machining, Process parameters, Monitoring, Process control, Optimization*

1.INTRODUCTION TO LASER BEAM MACHINING:

Laser is an abbreviation for Laser Amplification by Stimulated Emission of Radiation. it is a devise for producing a narrow beam of light, capable of travelling over vast distances without dispersion. It is also capable of being focused to give enormous power densities (10^8 watts per cm^2 for high-energy lasers). A laser converts electrical energy into a highly coherent light beam (9).

2.PRINCIPLE OF LASER MACHINING:

It works on the principle of conversion of electrical energy of flash lamp into heat energy to emit the laser beam by pumping the energy. Laser beam is then focused by a lens to give high energy in the concentrated form and helps to melt and vaporize the material of workpiece.

As laser interacts with the material, the energy of photon is absorbed by the work material leading to rapid rise in local temperature and result s in melting and vaporization of the work material (8).

3.LITERATURE SURVEY

1. Pedram Parandoush, Altab Hossain reviewed on modeling and simulation of laser beam machining and discussed laser beam machining (lbm) is a widely used thermal advance machining process capable of high accuracy machining of almost any material with complex geometries. co2 and nd:yag lasers are mostly used for industrial purposes. Drilling, cutting, grooving, turning and milling are the applications of LBM with different material removal mechanisms. Modeling and simulation of the LBM process is indispensable for optimization purposes. Modeling can be done by implementing analytical, numerical, experimental and artificial intelligence-based methods. This paper provides a review of the various methods used for modeling and simulation of the laser beam machining process as well as key researches done in this field so far [1].

2. Saif Ali Khan, Pranay Kumar Tiwari, Amol Shrivastava, Amit Sharma reviewed on laser beam micromachining and discussed laser essentially is a coherent, monochromatic beam of electromagnetic radiation that can propagate in a straight line with negligible divergence and occur in a wide range of wavelength (ranging from ultra-violet to infrared). Lasers are widely used in manufacturing, communication, measurement and medical. Energy density of the laser beam can be altered by varying the wavelength. This property has made the lasers proficient for removing extremely small amount of material and has led to the use of lasers to manufacture very small features in work piece materials. The production of miniature features (dimensions from 1 μm to 999 μm) in sheet materials using laser machining is termed as laser micromachining. In the present study, the fundamental understanding of

short and ultra-short laser ablation process has been explained. The critical analysis of various theoretical and experimental studies is used to describe the performance of laser beam micromachining (LBMM) on some of the advanced engineering materials [2].

3. Chithirai Pon Selvan M, Nethri Rammohan and Sachidananda HK reviewed a literature review on heat affected zones, cut quality and comparative study of laser beam machining and describes Laser beam machining is a form of non-traditional machining that can machine almost any known materials. It is thermal, non-contact process, which does not induce any mechanical stresses in the work-piece. This paper presents a review on the conclusions of the various research papers available on laser beam machining on the various properties that affect the quality of the process such as heat affected zone formed in the work-piece, laser cut quality and why laser beam machining is more advanced than the other machining processes[3].

4. Mr. Amitkumar D. Shinde and Prof. Pravin R. Kubade conduct investigation of effect of laser beam machining (lbm) process parameters on performance characteristics of stainless steel (ss 304) and described that this study investigates the influence of Laser Beam Machining (LBM) process parameters on surface roughness and kerf width while machining Stainless Steel (SS 304). Laser Beam Machining (LBM) is a non-conventional process in which material removal takes place through melting and vaporization of metal when the laser beam comes in contact with the metal surface. There are so many process parameters which affect the quality of machined surface cut by LBM. But, the laser power, cutting speed, assist gas pressure, nozzle distance, focal length, pulse frequency and pulse width are most important. However, the important performance measures in LBM are Surface Roughness (SR), Material Removal Rate (MRR), kerf width and Heat Affected Zone (HAZ). Experiments are carried out using L27 Orthogonal array by varying laser power, cutting speed and assist gas pressure for stainless steel SS 304 material. The results showed that the assist gas pressure and laser power are the most significant parameters affecting the surface roughness and kerf width respectively, whereas the influence of the cutting speed is much smaller [4].

5. Sandeep Kumar Singh and Ajay Kumar Maurya reviewed on laser beam machining process parameter optimization and stated the quality of laser cut is the most important factor in laser cutting process. All cutting parameters might have significant influence on the resulting quality of work. In general, cutting parameters are adjusted and tuned to provide the quality of cut desired. But this consumes exhaustive (enormous) amount of time and effort. Therefore, it is important to investigate the impact of cutting parameters on quality of cut. The aim of this study is to relate the CO_2 laser cutting parameters namely laser power, cutting speed laser scanning speed. Laser cutting is a fairly new technology that allows metals to be cut with extreme precision. The laser beam is typically 0.2 mm in diameter with a power of 1-10 kW. Depending on the application of the laser cutter a selection of different gases is used in conjunction with the cutting. When cutting with oxygen, material is burned and vaporized when heated by the laser beam to ignition temperature. The reaction between the oxygen and the metal creates additional energy in the form of heat, supporting the cutting process. For certain well-defined applications, e.g. cutting metal sheet using CO_2lasers, suppliers of laser cutting machines provide a comprehensive database for process parameters [5].

6. Amitkumar D. Shinde, Pravin R. Kubade reviewed on current research and development in laser beam machining (LBM) and discussed laser beam machining (LBM) is a non-conventional process in which material removal takes place through melting and vaporization of metal when the laser beam comes in contact with the metal surface. There are so many process parameters which affect the quality of machined surface cut by LBM. But, the laser power, cutting speed, assist gas pressure, nozzle distance, focal length, pulse frequency and pulse width are most important. However, the important performance measures in LBM are surface roughness (SR), material removal rate (MRR), kerf width, heat affected zone (HAZ) and surface hardness. This paper reviews the research work carried out from the inception to the development of LBM within past few years. It reports on the LBM research relating to performance measures improvement, monitoring and process control, process variables optimization. The paper also discusses the future trend of research work in the area of LBM [6].

7. R.S. Barge, R.R. Kadam, R.V. Ugade, S.B. Sagade, A.K. Chandgude, M.N. Karad reviewed effect and optimization of laser beam machining parameters using TAGUCHI and GRA method and discussed laser cutting is one of the widely used non-contact type and thermal based non-conventional machining process. Due to its increasing use and demand lots of researches had been carried out in last few years. The main aim of these researches is to optimize the process parameters of the laser beam machining process. Laser beam machining is a process in which the quality of the output machined component depends upon various input parameters. Considering this an attempt has made in this paper after referring various research works to explain in detail about the relation

between the input parameters and output quality and the effect on the output quality parameters by changing the input parameters. This paper will provide an idea about the range of input parameters required for obtaining the desired quality at the output. The quality of the material after the laser cutting is very important. Major development require in LBM is improvement in surface quality by reducing the spreading of heat affected zone and increasing the accuracy in particularly micromachining. Any improvement in this area will have a very great importance in the field of machining and manufacturing. Laser machining is a very complex thermal process and numerous techniques and methods are developed to optimize the process parameters of the LBM. Therefore, it is the aim of this paper to help you in proper understanding of various parameters [7].

4. CHARACTERISTICS OF LASER: A LASER BEAM HAS THE FOLLOWING PROPERTIES:

1) A laser beam is highly monochromatic.
2) Laser ray is highly pure beam of light.
3) It is an intense beam of light.
4) Highly directional.
5) Highly collimated.
6) The light produced by laser is coherent.

These properties allow laser light to be focused, using optical lens, onto a very small spot with resulting high-power densities.

5. TYPES OF LASER:

1) Gas laser:

Gas lasers generally have a wide variety of characteristics. Gas lasers using many gases have been built and used for many purposes. They are one of the oldest types of laser. For example, (a) helium- neon (HeNe) laser is common in education because of its low cost. (b) carbon dioxide lasers are often used in industry for cutting and welding. (c) metal ion lasers are gas lasers that generate deep ultraviolet wavelengths. Other example is Argon-ion, Helium-silver (HeAg), neon-copper (NeCu), laser etc.

2) Solid laser:

A solid-state laser is one in which the atoms that emit light are fixed within a crystal or a glassy material. For example, (a) Ruby rod (the chromium atoms embedded in the ruby's aluminium oxide crystal). (b) Yttrium orthovanadate (Nd: YVO4), Yttrium lithium fluoride (Nd:YLF) and Yttrium aluminium garnet (Nd:YAG). They are used for cutting, welding and marking of metals and other materials, and also in spectroscopy and for pumping dye lasers.

3) Semiconductor laser:

It is a unique, and perhaps that most important, types of laser. It is unique because of its smaller dimensions (mm×mm×mm), and its natural integration capabilities with micro electronic circuitry.

For example, (a) Silicon laser is important in the field of optical computing. (b) Vertical cavity surface-emitting lasers, (VCSELs) whose emission direction is perpendicular to the surface of the water. (c) Quantum cascade lasers have an active transition between energy sub-bands of an electron in a structure containing several quantum wells (2).

6. SETUP AND WORKING OF LASER BEAM MACHINING:

Laser beam machining utilizes the narrow beam of intense monochromatic light which melts and vaporize the material of the workpiece. The setup for this process is shown in the fig. It mainly consists of:

1) Laser generation unit: in this unit ruby rod, flash lamp, power supply, mirrors are used for production of laser beams. The solid-state laser i.e. ruby rod is used in the form of cylindrical crystal with 10 mm diameter and 150 mm long. The ends are finished to close optical tolerances. The flash lamp is wounded around the ruby rod and it is connected to electric power supply. The inner surface of the container wall is made highly reflective all the light on the ruby rod. The electrical power supply is designed to give 250 to 1000 watts energy to the flash lamp.
2) Cooling arrangement: the ruby rod becomes less efficient at higher temperatures and gives maximum efficiency at when kept at a very low temperature. Hence cooling system is provided in which liquid nitrogen is used, sometimes air- or water-cooled provision is also made, but it has less effectiveness compared to liquid nitrogen.
3) Collimating lens: the highly amplified beam of laser light is focused on workpiece through a lens, it gives high energy density which melts and vaporizes the metal.
4) Workpiece tables: the workpiece to be cut is placed on the aluminium work table which is resistant to the laser beam. The laser head is

transverse over the workpiece and table can be moved as per requirement.

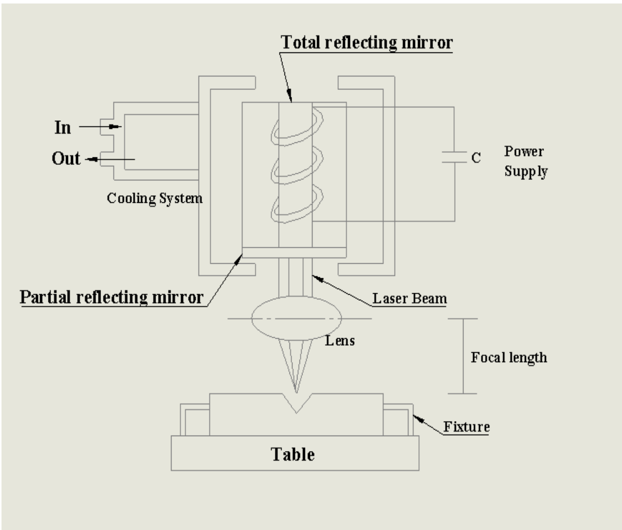

Figure 1: Setup for Laser Beam Machining

7. CONTROLLING PARAMETERS:

1. Focal length: the workpiece should be placed close to the lens for machining. If focal length is less, straight holes will be produced. If the focal length is more, taper holes will be produced.
2. Power density: the power density of the beam determines whether the beam will perform the function of cutting or welding. For machining operation, the power density should be higher i.e. around 1.5×10^7 W/cm^2.
3. Focal length: it is the distance between laser beam and the workpiece. If the laser is very close to workpiece, the divergence of the beam occurs for small focal length in the metal cutting.

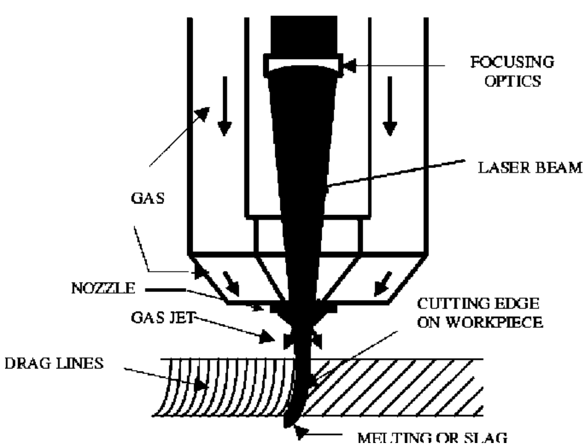

Figure 2: Laser Torch Terminology

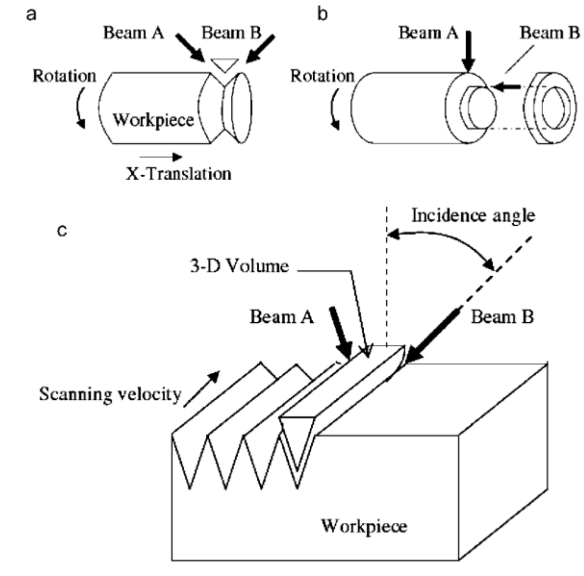

Figure 3: Laser cutting operation

8. APPLICATIONS OF LBM:

1. Laser welding: it is useful for joining sheet metal or stock pieces of about 2.5 mm thick or less. Many metals and alloys can be welded by laser like low carbon steel, stainless steel, titanium and its alloys, silicon bronze, etc. another advantage of laser welding is no need of grinding after welding.
2. Laser cutting: a laser beam can be used in cutting metals, plastics, ceramics, textiles, cloth and even glass. It can also use for cutting complex shapes with sharp concern and slots. It is useful for cutting of steel, titanium, nickel, certain refractory materials and plastics but cutting of aluminium and copper has been especially problematic.
3. Laser engraving: laser beam can be utilized for making or engraving so as to produce controlled surface pattern on a workpiece.
4. Laser drilling: it has ability to make small and very small holes of shallow depth. Most of the laser beam machining are useful for drilling of small holes in fuel filters, carburettor nozzles, hypodermic needles, jet engine blades cooling holes, etc. in air craft turbine industry, laser drilling used for making holes for air bleeds etc.

9. ADVANTAGES OF LASER BEAM MACHINING

1. There's no direct contact between tool and workpiece as no physical tool is required
2. Tool's absence offers no tool wear problems
3. Micro holes with large depth to diameter ratio can be drilled by using LBM

4. The properties of machined materials or magnetic materials does not get affected by laser beam machining
5. LBM is capable to cut through air, gas, vacuum and even through liquid
6. In this process no burrs or chips are produced
7. Angular drilling or cutting can be obtained by tilting the workpiece
8. Mechanical force is not exerted on the workpiece results in smooth machining of fragile workpiece
9. Any metals or non-metals can be machined like tungsten, ceramics, zincromium, etc
10. Laser beam is capable to travel longer distances without diffraction and can be focused at longer distances where weld, drill and cut is not easily possible
11. It is used for various operations like drilling, engraving, cutting, welding, trimming, etc

10. DISADVANTAGES OF LASER BEAM MACHINING

1. The capital and operating cost is very high
2. The material removing rate is very low
3. It cannot cut the reflective and highly conductive material like aluminium, copper and its alloys
4. Skilled operator is required for channeling and operating the process
5. The output energy of the laser is difficult to control precisely
6. Safety procedures are to be followed strictly for safe and trouble-free performance
7. Machined holes may have taper from entry to exit
8. Flash lamp has limited life

11. CONCLUSION

Laser Beam Machining is one of the widely used unconventional machining method that is capable of producing the complex and precise shapes with very less tolerance. The main focus is related to the laser drilling, laser cutting, and laser-induced bending. The execution of this LBM needed professional expertise and operational costs are quite expensive. With the time there is lot of improvements in the LBM and its assisted processes as well as optimization techniques, which made some new research scopes in the LBM. Developments in modeling techniques have made new research scopes in the LBM and improves the performance of LBM process.

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