IJRAME
ISSN (ONLINE): 2321-3051

INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING

IMPORTANCE OF LASER BEAM DRILLING IN AERONAUTICAL INDUSTRY

V.V.S.Nikhil Bharadwaj [1], V N Saikiran Aka [2], V.Gopichand [3], Parthasarathy Garre[4]

[1]*B.Tech Student, Aeronautical Department, MLRIT, Hyderabad,* vvsnikhilbharadwaj@gmail.com.
[2] *B.Tech Student, Aeronautical Department, MLRIT, Hyderabad,*
[3] *B.Tech Student, Aeronautical Department, MLRIT, Hyderabad*
[4] *Associate Professor, Aeronautical Department, MLRIT, Hyderabad*
Author Correspondence: Hyderabad, 9396965153, gps.mlrit@gmail.com

Abstract

The Laser beam Machining (LBM) uses a focused beam of high-intensity radiation from a laser to vaporize and so machine material at the point of focus. The very high power excimer lasers, which are developed for simultaneous drilling for huge amounts of small holes for instance for the aerospace industry are holes for cooling of engine parts and for boundary layer suction. Laser beam cutting (LBC) can be successfully used for the cutting of conductive and nonconductive materials. Laser machining is an attractive alternative to traditional machining of Al-2024 because critical operation parameters in aeronautic industry, such as processing time, versatility, contamination and finish can be improved. In this paper various types of LBM are included. The advantages of laser drilling are reproducibility, drilling speed, and the ability to achieve high aspect ratios, i.e. the ratio of depth of hole to its diameter. The nature of the laser beam used in laser drilling allows holes to be drilled in the hardest of materials, from aerospace alloys, diamond, and ceramics. Through the use of laser drilling, holes can be created even in coated materials. The main applications are in aerospace where cooling holes needs to be drilled. The programmable nature of lasers allows for very high speed drilling applications where many thousands of holes are required in short cycle times. The significance of LBM in aerospace industry is applied to laser beam drilling mostly.

***Keywords**:* LBM, aerospace, Laser Drilling, Kerf, HAZ.

1. Introduction

LBM is based on vaporize the material in a very small area by focused laser beam. It characterize by using a high energy beam of coherent light which is focused on an small spot on the work piece by a lens where the focused beam melts, vaporizes and molten material is ejected out from the melt area by pressurized gas jet. Laser cutting is the high speed cutting with a narrow kerf width that results in superior and enhanced quality, higher accuracy and greater flexibility [1]. Among all lasers Nd-YAG (solid laser) and CO2 laser (Gas Laser) are used for most of industrial applications, due to their high powers. Nd-YAG laser cutting becomes an excellent cutting process because of high laser beam intensity, low mean beam power, good focusing characteristics and narrow heat affected zone [2]. It is difficult to cut aluminum alloys with laser because of their high reflectivity, high thermal conductivity and self-extinguishing oxidation reaction with using oxygen as assist gas which is attributed to the fact that aluminum oxide forms a seal on the cut front, which prevents oxygen from penetrating into the melt for further reaction before it is fractured. Therefore, pulsed laser with high peak power is beneficial for cutting aluminum alloys. In cutting titanium alloys, a thin layer of hard and brittle oxide or nitride is formed on the cut surface when oxygen or nitrogen is used as assist gas. Thicker HAZ layers are produced due to the heat released from the nitriding and oxidation. Microcracks are formed on the cut surface as the results of tension forces on the laser cut surface and the brittleness of the titanium oxide and titanium nitride. The amount and dimensions of the microcracks can be reduced by increasing the cutting speed. The best corrosion resistance of the cut surface is achieved when cutting with Ar as assist gas [3]. It is suitable for cutting complex geometric profiles, for drilling miniature holes in sheet metal and precision machining of micro-parts [4]. Laser beam machining is commonly used for cutting, marking, engraving and making holes. The laser machining process is frequently used in various industries such as aerospace, automotive, bio-medical and MEMS etc. Nd: YAG laser and excimer pulsed laser are widely used in the micro-machining applications, medical and electronic industries. Laser beam drilling is also used for drilling closed spaced economical holes [5]. Increasing interest in the use of lasers for manufacturing can be attributed to several unique advantages, which are generally applicable to the entire range of materials processing applications, such as high productivity, non contact processing, elimination of finishing operations, adaptability to automation, reduced processing cost, improved product quality, greater material utilization, minimal heat-affected zone (HAZ) and green manufacturing [6]. Another development are the very high power kilowatt excimer lasers, which are developed for simultaneous drilling for huge amounts of small holes for instance for the aerospace industry holes for cooling of engine parts and for boundary layer suction [7].

LBM or more broadly laser material processing deals with machining and material processing like heat treatment, alloying, cladding, sheet metal bending etc. Such processing is carried out utilizing the energy of coherent photons or laser beam, which is mostly converted into thermal energy upon interaction with most of the materials. Nowadays, laser is also finding application in regenerative machining or rapid prototyping as in processes like stereo-lithography, selective laser sintering etc. Laser beam can very easily be focused using optical lenses as their wavelength ranges from half micron to around 70 microns. Focused laser beam as indicated earlier can have power density in excess of 1 MW/mm^2. As laser interacts with the material, the energy of the photon is absorbed by the work material leading to rapid substantial rise in local temperature. This in turn results in melting and vaporization of the work material and finally material removal. A coherent beam of monochromatic light is focused on the workpiece causing material removal by vaporization. Machines are generally CAD/CAM compatible, with 3-axis and 5-axis machines being generally available.

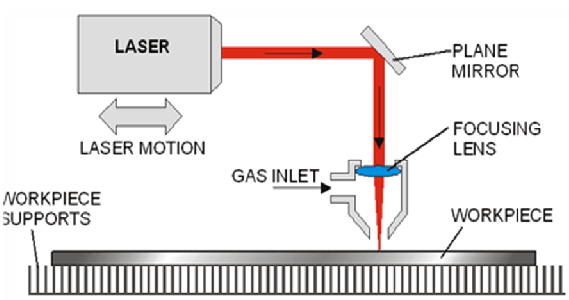

Figure 1: Principle of LBM

Vol.2 Issue.3, March 2014. Pgs: 270-274

2. Laser Beam Machining In Aeronautical Industry:

2.1. Laser Drilling:

Depending on the required quality (precision) and throughput (drilling time), different methods is used to produce holes in the mm-to-µm range in different materials. These drilling methods are single-pulse drilling, percussion drilling, trepanning, and helical drilling. Laser drilling provides an alternative to techniques such as electron beam drilling, electrical discharge machining (EDM), electrochemical drilling, and ultrasonic drilling. The laser is the tool of choice when holes are required with a diameter of < 100 µm and a high aspect ratio, machining under difficult operating conditions like defined angle of inclination, for holes in hard materials or for the generation of special geometries. The advantages of laser drilling are reproducibility, drilling speed, and the ability to achieve high aspect ratios, i.e. the ratio of depth of hole to its diameter. Challenges are the need to minimize recast, prevent burring, and reduce the number and length of micro-cracks in the wall of the drilled holes.

2.2. Percussion Laser Drilling:

Percussion laser drilling means adjusting the lasers focus spot size to determine the size of the hole. There is no relative motion between the laser beam and the part during the drilling process. The parameters and number of pulses are chosen to produce a good quality of the hole. Laser drilling holes in the 25µm to 1000µm diameter range is possible using this method but the limits vary according to the material. Most percussion drilled holes are in the 300µm-600µm diameter range. Percussion drilling allows a special drilling regime termed drilling 'on-the-fly' to greatly increase hole drilling speed. Drilling on the fly is usually performed on round turbine engine parts and uses signals from the motion systems encoders to trigger the laser at specific, consistently-spaced hole locations around the part. If ten pulses are required to percussion drill a hole then a drill on-the-fly system will rotate the part ten times, sending a laser pulse to each hole location per revolution. Laser drilling speed is increased because indexing time is eliminated from the cycle time. Percussion drilling can take advantage of pulse-shaping to improve the interaction of the laser beam with the material. This can also help control taper and improve the drilling speed.

Pulse shaping is programming the laser’s pulse temporal profile. By breaking up a long drilling pulse into two three or four shorter segments, separated by off-time, the hole quality can be improved and speed increased. Debris coming out of the hole can interfere with end of a longtime. Using a pulse shape with a lower peak power segment at the beginning can create a hole that has less initial bell-mouth taper.

2.3. Trepan Laser Drilling:

Trepan laser drilling requires a motion system to allow piercing with the laser and then motion of the beam relative to the part to 'cut' out the hole. Trepanning allows for a diameter tolerance about half that of percussion drilling. It enables the creation of shaped holes with a tailored taper or changing cross section with depth using a multi-axis system. This requires a system with good accurate motion capability and high-level programming capability. Trepanning also enables the cutting of specific shapes and large holes as well as complex 3D trimming of large parts. Holes drilled in metals are judged by the hole diameter tolerance, taper, recast thickness, and micro cracking. Hole diameter in percussion drilled holes is generally less than +/- 50µm and in trepanned holes the tolerance tightens to about +/- 25µm. Recast is the molten metal that resolidifies around the hole’s inner diameter. Recast thicknesses vary with the alloy and hole depth but is generally less than 100µm. Hole depth can be as high a 50mm but most drilling tasks have hole depths of less than 15mm.

2.4. Laser Cutting:

Many lasers can be used for laser cutting; provided their beam can be focused on a small spot with sufficient intensity to melt the material and their specific wavelength is absorbed in the material. CO_2 and exciter gas lasers as well as solid-state lasers, such as Nd:YAG and Yt:YAG lasers, are the most commonly used in the field of materials processing. Diode lasers, as another example of solid-state lasers, do not provide similar beam quality and intensity and may be used for the cutting of non-metallic materials.

2.5. Laser Fusion Cutting:

With fusion cutting you can cut metal as well as other fusible materials, such as ceramics. Nitrogen or argon is used as the cutting gas here. The gas is blown through the kerf at pressures ranging from 2 to 20 bar. Argon and nitrogen are inert gases. This means that they do not react with the molten metal in the kerf. They simply blow it out toward the bottom. Simultaneously, they shield the cut edge from the air. The great advantage of fusion cutting: cut edges are oxide free and do not require further treatment. Nevertheless, the laser beam must supply all of the energy needed for cutting. For this reason, cutting speeds as high as those in flame cutting can be achieved only in thin sheets. Piercing is also more difficult. Some cutting systems allow you to use oxygen to pierce the material and then switch over to nitrogen for cutting.

2.6. Laser Flame Cutting:

Flame cutting is a standard process primarily used for cutting mild steel. In flame cutting, oxygen is used as the cutting gas. The oxygen is blown into the kerf at pressures of up to 6 bars. There, the heated metal reacts with the oxygen and it begins to burn and oxidize. The chemical reaction releases large amounts of energy – up to five times the laser energy – and assists the laser beam. Flame cutting makes it possible to cut at high speeds and handle jobs involving thick plates such as mild steel with thicknesses in excess of 1.25 inches.

2.7. Sublimation Laser Drilling:

High-quality edges for precision cutting. In this process, the idea is to use the laser to vaporize the material with as little melting as possible. In the kerf, the material vapor creates high pressure that expels the molten material from the top and bottom of the kerf. The process gas – nitrogen, argon, or helium – serves solely to shield the cut surfaces from the environment. It ensures that the edges remain oxide free. For this reason, a gas pressure of 1 to 3 bars is sufficient. More energy is needed to vaporize metal than to melt it. For this reason, sublimation cutting requires high laser power and is slower than other cutting processes. However, it produces high-quality cuts; this process is rarely used in sheet metal fabrication. Its use, however, becomes attractive in applications involving particularly delicate cutting work. Such applications include the production of stints. In metal processing, sublimation cutting is the exception; with nonmetals, it is very common. Many non-metal materials are regularly processed with sublimation cutting. Typical materials include plastic sheeting and textiles, which vaporize even when only a small amount of energy is applied and materials that do not melt, such as wood, cardboard, or foam.

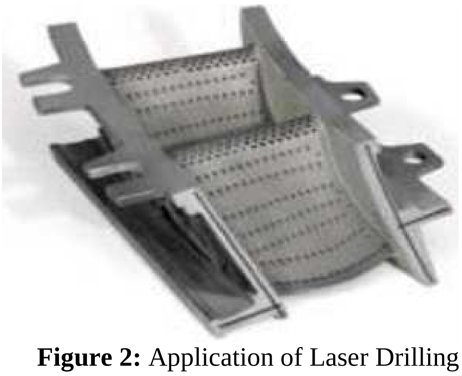

Figure 2: Application of Laser Drilling

3. Conclusion:

When optimal focus position is centered in the workpiece, there is an optimal interaction between the number of required scans, the diameter on the LASER beam input as well as on the output side, and the associated flank angle. The further off-centered the focus position is the more scans are required for a full cut. The diameter on the LASER beam output side vanes, the deeper the focus is positioned in the work piece. The optimal feed rate obtained from literature, amounts to 8 mm/s. This results in a pulse overlap of 97.7 %. Thus the significance of LBM in aerospace applications focuses more in laser beam drilling.

References:

[1] Dr Miroslav Radovanovic, “Laser Cutting Machines For 3-D Thin Sheet Parts” 8th International Conference, Târgu Jiu, May 24-26, 2002.

[2] Arun Kumar Pandey and Avanish Kumar Dubey, “Intelligent Modeling of Laser Cutting of Thin Sheet” International Journal of Modeling and Optimization, Vol. 1, No. 2, June 2011.

[3] Shoujin Sun and Milan Brandt, “Laser Beam Machining” Nontraditional Machining Processes, Springer-Verlag London 2013, DOI: 10.1007/978-1-4471-5179-1_2.

[4] Ruben Phipon1, B.B.Pradhan, “Control Parameters Optimization of Laser Beam Machining Using Genetic Algorithm”, International Journal Of Computational Engineering Research, Vol. 2 Issue. 5.

[5] Mohammed Sarvar Rasheed, “Comparison of Micro-Holes Produced By Micro-EDM with Laser Machining”, International Journal of Science and Modern Engineering, Volume-1, Issue-3, February 2013.

[6] J. W. Jung, C. M. Lee, “Cutting Temperature and Laser Beam Temperature Effects on Cutting Tool Deformation in Laser-assisted Machining”, Proceedings of the International Multi Conference of Engineers and Computer Scientists 2009 Vol II, IMECS 2009, March 18 - 20, 2009, Hong Kong.

[7] Johan Meijer, “Laser beam machining (LBM), state of the art and new opportunities”, Journal of Materials Processing Technology 149 (2004) 2–17.