International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Laser Beam Machining - A Review on Current Development

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ABSTRACT

Wide varieties of non-conventional machining process are available in the manufacturing world. Out of different non-conventional machining processes Laser Beam Machining is highly used method for machining both metals and non-metals. A laser beam machining is a non-conventional machining method in which the operation is performed by laser light. This paper is elaborated on the applications of the laser beam machining in different areas of machining. It also lays the foundation for the industry and its relevance among the products of everyday life due to its wider applications.

INTRODUCTION

Conventional Machining process is a machining process in which the machining is carried out with the standard mechanical process. It uses a human operator to direct and control tools. The most common conventional machining methods are cutting, grinding, milling and turning.

Disadvantages Of Conventional Machining Process: Conventional methods need much time to machine heavy metal and alloys and also needs high energy and therefore increases costs. In some cases, standard equipment may not be available. Typical machinery also suffers from tool wear and loss of quality in the product due to residual pressures caused during the production process. As the general manufacturing process has low health tools due to contact with high surface wear, it is also possible to create high material waste. With the increasing demand for manufactured goods made of solid alloys and metals, more interest has shown unusual mechanical methods (i.e., non-conventional machining process).

Non-Conventional Machining Process: Non-conventional machining processes are defined as a group of processes that remove excess material with various techniques including electrical energy, electrical or chemical or a combination of these energy but do not use sharp cutting tools as they need to be used in traditional processes. Removal of the material may result from chip formation or non-chip formation. Very hard and cracked materials are difficult to use with a conventional machine processes such as turning, drilling, molding and grinding and hence non-conventional procedures also called advanced production processes. These are employed when traditional machinery processes are not feasible, satisfactory or cost effective for some reason as described below.

- Very complex sensitive objects that are difficult to handle with traditional equipment
- When the work is flexible or thin
- When component formation is very difficult.

Many types of non-conventional processes have been developed to meet the requirements of machining conditions. When these methods are used properly, they provide many benefits in addition to non-conventional processes.

In different non-conventional machining processes laser beam machining is one of the important process.

Laser Beam Machining Process: A laser beam machining is a non-conventional machining method in which the work is done with laser light. The laser lamp has high temperature claims on the work piece, due to the high position in which the work is performed. This process uses thermal energy to remove the material from the metal surface.

In this process, Laser Beam is called a monochromatic light, which is made to focus on a piece of work that will be built into the lens to give the most energy to melt and smell anything.

Uses of Laser Beam Machining Process: Lasers beam machining can be used for welding, coating, marking, surface treatment and cutting production processes.

It is used in automobile, shipbuilding, aerospace, metal, electronics, and the medical industry to obtain equipment with precision parts.

Applications of Laser Beam Machining: The laser beam machining process is used to make very small holes and also used in Spectroscopic Science, mass production machining, surgeries, sophisticated welding of non-abrasive and resistant materials, micro-drilling performance and in selected heat management of building materials. The major advantages of Laser Beam Machining lies in high Production rate of any material including non-metals that too without wear of tool.

LITERATURE SURVEY

M.M. Hanon et.al. (2011) [1] briefed the applications and processing difficulties of alumina ceramics. It reports theoretical and experimental results of drilling the alumina ceramic with thicknesses of 5 mm and 10.5 mm using millisecond pulsed Nd-YAG laser. Different effects had been determined using optical and Scanning Electron Microscopy (SEM) images taken from cross-sections of the drilled alumina ceramic samples. They simplified that depth of crater can be controlled as a function of peak power and pulse duration without any defect and states that cater depth can be increased by the number of laser pulse with some defects. In addition to experimental work, conditions have been simulated using ANSYS FLUENT package providing results, which are in good agreement with the experimental results.

A. Bharatish et.al. (2013) [2] examined the effect of laser beam machining on the quality parameters of the holes drilled in Alumina ceramics which are widely used in microelectronic devices, based on the examination of orthogonal array methodology and surface methodology.. They had stated regarding the multi objective optimization obtained by using both response surface model and gray relational analysis.

Arun Kumar Pandey et.al. [3] (2011) investigated on Duralumin sheet with the aim to improve geometrical accuracy by simultaneously minimizing the kerf width and kerf deviations at top and bottom sides.

Pedram Parandoush et.al. (2014) [4] concluded that modeling and simulation of the LBM process is indispensable for optimization purposes. They also stated that modeling can be done by implementing analytical, numerical, experimental and artificial intelligence-based methods.

Shoujin Sun (2013) [5] explained that laser beam machining is the machining processes involving a laser beam as a heat source. They also described it as a thermal process used to remove materials without mechanical engagement with work piece material where the work piece is heated to melting or boiling point and removed by melt ejection, vaporization or ablation mechanisms. In contrast with a conventional machine tool, the laser radiation does not experience wear and material removal is not dependent on the hardness of the work peice but on the optical properties of the laser and the optical and thermo physical properties of the material.

Jonas Holmberg (2018) [6] studied on three high energy machining methods namely abrasive water jet machining (AWJM), electrical discharge machining (EDM) and laser beam machining (LBM) and also compared all three methods in terms of surface integrity to the reference, a ball nosed end milled surface. In this study it was concluded that AWJM resulted in the highest quality regarding surface integrity properties with compressive residual stresses in the surface region and a low surface roughness with texture from the abrasive erosion. Further, it was shown that EDM resulted in shallow tensile residual stresses in the surface and an isotropic surface texture with higher surface roughnes. However, even though both methods could be considered as possible alternatives to conventional milling they require post processing. The reason is that the surfaces need to be cleaned from either abrasive medium from AWJM or recast layer from EDM. It was further concluded that LBM should not be considered as an alternative in this case due to the deep detrimental impact from the machining process.

Rajarshi Mukherjee (2013) [7] focussed on the application of artificial bee colony (ABC) algorithm to determine the optimal Nd:YAG LBM process parameters while considering both single and multiobjective optimization of the responses. A comparative study with other population- based algorithms, like genetic algorithm, particle swarm optimization, and ant colony optimization algorithm, proves the global applicability and acceptability of ABC algorithm for parametric optimization. In this algorithm, exchange of information amongst the onlooker bees minimizes the search iteration for the global optimal and avoids generation of suboptimal solutions. The results of two sample paired t-tests also demonstrate its superiority over the other optimization algorithms. The parametric optimization problems for two Nd:YAG laser beam machining processes are solved applying ABC algorithm. For both the cases, the results of single as well as multi-objective optimization of the LBM process are derived. It is observed that the optimal values of the responses derived by ABC algorithm are far better than those obtained by the past researchers.

Avanish Kr. Dubey (2007) et.al [8] investigated and studied the effect of various factors/process parameters on the performance of Nd:YAG laser beam machining. He explained the importance of different design of experiments (DOE) methodologies used by various investigators for achieving the optimum value of different quality characteristics.

H.A. Eltawahni (2011) et.al. [9] explained about the laser cutting process.This article throws a light on how the width of laser cut or kerf, quality of the cut edges and the operating cost are affected by laser power,cutting speed, assist gas pressure, nozzle diameter and focus point position as well as the work-piece material.The work mainly aims to relate the cutting edge quality parameters namely: upper kerf, lower kerf, the ratio between them, cut section roughness and operating cost to the process parameters mentioned above. Then, an overall optimization routine was applied to find out the optimalcutting setting that would enhance the quality or minimize the operating cost.Finally, the optimal laser cutting conditions have been found at which the highest quality or minimum cost can be achieved.

Karim Khelouf (2012) et.al.[10] briefed about a transient numerical model that is developed to study the temperature field and the kerf shape during laser cutting process and also explained about the Fresnel absorption model that is used to handle the absorption of the incident wave by the surface of the liquid metal and the enthalpy-porosity technique is employed to account for the latent heat during melting and solidification of the material. They also specified about the VOF method that is used to track the evolution of the shape of the kerf. Temperature and velocity distribution, and kerf shape are all being investigated in this article.

R. S. Rana (2018) et.al. [11] Specified that many high strength steel are being cut using lasers and this machining has given exceptional result as compared to other non conventional machining process.

Jose Mathews et.al.[12] developed Guessing models based on key process parameters, i.e. speed, pulse power, pulse length, pulse frequency measurement and gas pressure. They analyzed the area affected by the heat (HAZ) and the taper of the cut area. Also validated the process parameters using the response method (RSM) and concluded that the thermal properties of the material and the fractional volume of the fibers are the main features that control the operation of the cut.

Chinmay K. Desai et.al.[13] investigated on the chemical activity of micro-organisms of thermoplastics with different parameters, namely laser beam insertion, subtle heat of vaporization, laser power and cutting speed. 25-W CO 2 (CW) laser recording machine used for investigation. Experimental results suggest that laser beam absorptivity, cutting power and cutting speed are the most influential factors in cutting depth. Two adjustment parameters are included in this analysis using linear regression how to improve the theory model. The comparison clearly shows that all three models that provide accurate prediction of cutting depth.

Shang Liang Chen et.al.[14] studied on the effects of gas formation on soft CO_2 laser cutting steel. In this study, differences in gas production and gas pressure were present selected as outstanding features. Their effects on cut quality are being investigated, with a slightly different reference to gas formation. Gas mixtures used in this study contains oxygen, argon, nitrogen, helium. From the test results, found that high oxygen purity is required high performance CO 2 laser cutting of soft metal. Only a small amount of oxygen pollution (1.25%) will reduce the cutting speed by 50%. 3 mm thick steel CO 2 laser cut, fine cut was not found in the current study using low pressure - up to 6 bar - inert gas (nitrogen, argon, helium) cutting.

Choudhury, I. A. et.al. [15] investigated on CO_2 laser cutting of three polymeric compounds namely polypropylene (PP), polycarbonate (PC) and polymethyl methacrylate (PMMA) to test the effect of the main input laser sharpening parameters (laser power, sharp cutting speed and air pressure) in laser cutting quality of different polymers as well to develop model estimates relating to the parameters of the input and output process. From the analysis, they observed that PMMA has low HAZ, followed by PC and PP. Also by size, PMMA has more cutting edge quality than PP and PC. Advanced response models can be used for practical purposes by manufacturing industry. Finally they concluded that all three polymeric materials showed the same width of tendency to err in spite of various material structures.

K. Huehnlein et.al.[16] worked on laser cutting of alumina ceramic layers using design of experiments method (DOE). They used both continuous wave of 500 W fiber laser as well as 200 W CO_2 laser and compared a small 250μm cut on ceramic substrate layers using DOE commercial software. Their results demonstrate the DOE's ability to scale laser processes.

S.L. Campanelli et.al.[17] worked on the settings of 3D production facilities to get high surface finishing by laser milling technology using a pulsed laser marker Nd: YVO4 laser with a wavelength of 1064nm. They experimented on aluminum-magnesium alloy to assess the impact of laser power, frequency, density, pulse width, scan speed laser source, on the effectiveness of the material extraction.

L. Rihakova et.al.[18] worked on the micromachining of glass, silicon and ceramics and studied on the interaction of these objects with laser beams and recent research held laser treatment equipment is provided. They conclude that ultrafast micromachining is characterized by the excellent quality of medical, high-quality materials process accuracy, low HAZ, and microcracks production.

Shoujin Sun et.al. [19] Studied on laser beam machining processes that include laser beam as heat source. They concluded that in contrast to the standard machine tool, the laser beams do not get worn, and the removal of the material does not depend on its hardness but on the visual properties of the laser as well as the physical and thermal properties of the object.

CONCLUSION

Major areas of research presented in previous sections shows that laser beam machining is gaining much importance in non-conventional machining process. Various researchers have contributed their works in different fields of laser beam machining. The discussions presented in the last sections represent the attention given to the laser beam machining in non-conventional machining process. From this study, the scope for further work may be as follows.

Laser beam machining can be used especially for precision machining process. Most of the researchers concentrated machining on metals and the effect of laser beam parameters on machining aspects. Less work was reported on machining of non-metals especially of ceramics. So, further studies can be done on effect laser beam machining on various ceramic materials.

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