A Review on Laser Beam Machining

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Abstract : Laser beam machining is a widely used non-traditional, thermal energy based advanced machining process which can be applied for a wide range of work materials. The laser beam is focussed for desired melting and vaporisation of the work piece. It is most suitable for cutting geometrically complex profiles and making miniature holes in a sheet metal. Among the various type of lasers used in industries, CO_2 and Nd:YAG lasers are most widely used. This paper reviews about the research work that has been carried out so far in the field of LBM of different work materials and profiles.

Keywords: LBM (Laser Beam Machining), Nd:YAG (Neodymium-doped yttrium aluminium garnet)

I.INTRODUCTION

Laser stands for "Light Amplification by Stimulated Emission of Radiation". This working principle was first introduced by Albert Einstein in 1917, though the first laser for experimentation was developed around 1960s [1]. Laser Beam Machining is one of the most widely used advanced machining processes (AMPs) which are used for machining wide range of materials. The LBM isused for drilling, cutting, marking, welding, heat treatment, cladding, alloying, sheet metal bending etc. These processes are carried out utilizing the energy of coherent photons or laser beam, which is converted into thermal energy when it interacts with work materials [2-4].This paper reviews on the various research works carried out in LBM process and it includes LBM variations and its applications on different fields of industry.

II.LASER BEAM MACHINING

Laser beam machining (LBM) isa thermal energy based advanced machining process in which the material is removed by melting, vaporization and chemical degradation. Laser beam can be easily focused using optical lenses as their wavelength ranges from half micron to around 70 microns. Thefocused laser beam can have power density of 1 MW/mm^2. As laser interacts with thematerial, the energy of the photon is absorbed by the work material which leads to rapid increase in local temperature. This high temperature results in melting and vaporization of the work material and thus material removal takes place [1,5]. Laser light is very different compared to ordinary light because it has the photons of same wavelength, phase and frequency. Therefore, laser beams have high power density, better focussing characteristics and are highly directional. Such characteristics of laser beam are useful in machining of wide variety of materials. The most widely used laser for LBM applications are: - Nd:YAGand CO_2laser,among different types of lasers [6].

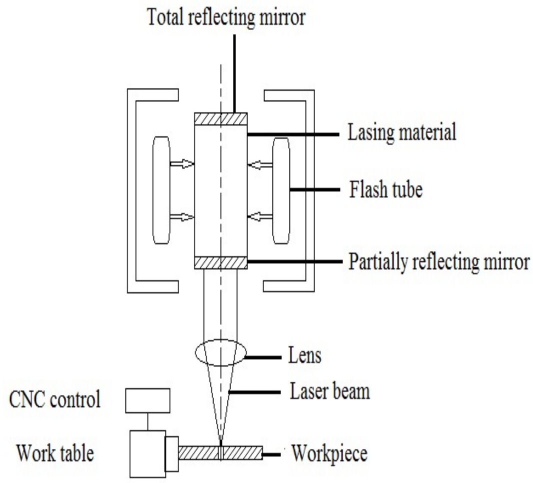

Fig. 1. Schematic diagram of laser beam machine.

III. VARIATIONS OF LASER BEAM MACHINING

The main variations of LBM are drilling which is (1-D), cutting and grooving (2-D), turning and milling (3-D) and micromachining. In recent years laser drilling has become one of the most accepted economical drilling process for drilling numerous holes in wide range of structures. There are two types of laser beam drilling processes: - trepan laser beam drilling and percussion laser beam drilling. Trepan drilling involves cutting around the circumference of the hole to be generated, whereas in percussion drilling, it drills directly through the work material with no relative movement of the laser or work material. The main advantage of laser percussion drilling over trepan drilling is the reduction in the processing time [7-9].

Laser beam cutting and laser beam grooving are 2-D operations which have gained popularity in applications like punching, cut-off and marking of metals, plastics and ceramics. Laser beam cutting is finding applications more than any other conventional or non-conventional cutting process because of material versatility, high material utilisation, no tool wear, high accuracy, production flexibility and high surface finish [10].

Laser beam turning and laser beam milling are 3-D operations which require two or more simultaneous laser beams to achieve the desired profile in the work material [11].The past researchers have suggested different observations regarding laser beam milling. Tsai et al. [12] have experimented on the laser milling of ceramics by fracture technique in which a focused laser beam is used to scribe the grooves on the work surface all around the machining zone and then a defocused laser beam is used for heating this zone. The heat induces the tensile stress and the stress concentration increases at the groove tip which results the fracture in the direction of groove cracks.

Micromachining denotes the machining of work parts having dimensions below 1mm. Laser beam is used for micromachining operations with short pulses varying from microsecond to femtosecond and high frequencies in kHz range. Pulsed Excimer and Nd:YAG lasers are most widely used for micromachining applications in medical and electronic sectors [13,14].

IV. APPLICATIONS OF LBM

Laser beam machining has wide range of applications in the field of aircraft industry, automobile industry, civil structures, electronic industries, house appliances and nuclear sectors. LBM is ideally suitable for cutting stainless steel which is a distinguishable engineering material used in automobiles and house appliances [15,16].LBM is also used for machiningAdvanced high strength steels (AHSS) which have major applications in car industry and boiler works [17].LBM is the most suitable machining process to machine nickel based superalloys which is an important aerospace material [18]. Other than metals and alloys LBM is also used to machine ceramic work materials. Commercial piezoceramic discs are laser cut to provide complex shapes in rainbow actuators [19]. LBM can cut intricate profiles and thick sections in commercially available ceramic tiles easily rather than using other cutting process like diamond saw, hydrodynamic or USM which are time consuming and expensive in processing of particular shape and thickness[20]. Short pulsed Nd:YAG lasers are used to cut semiconductor packages in electronic industry [21]. LBM is used for processing hard and brittle composite materials like marble, stone and concrete which have wide application in the field of civil structures [22,23]. Q-switched diode pumped solid state lasers can be used to produce 3D intricate profiles by laser milling of a wide range of materials including tool steels, aerospace alloys, thermal barrier coatings, diamond and diamond substitutes [24].

V. FIELDS OF LBM RESEARCH

A. Material Removal Rate (MRR)

Lau et al [25] have studied that during laser beam cutting of carbon fibre composites, the compressed air removes more material compared to argon inert gas. During pulsed Nd:YAG laser cutting, the effect of pulse intensity (kW) on depth of cut or MRR increases for all metal matrix composites, carbon fibre composites and ceramics composites [26]. Investigational study for cutting stainless steel sheets up to 2cm thick from a long distance (1m) without using any assist gas was performed in pulsed mode taking pulsed frequency (100-200Hz), peak power (2-5kW) and cutting velocity (0.05-0.5m/min) as process variables. The result shows that the high peak power and low pulse frequency were found to be favourable for higher cutting speeds [27,28].

B. Mechanical properties

Some researchers have studied the mechanical properties of laser machined work parts and they concluded that crack formation and thermal damages affect the strength of workmaterials. Zhang et al [29] have found that the mean value of flexural strength was reduced to 40% of original material after laser beam cutting and laser micro-machining of silicon wafers shows that breaking limit is substantially reduced after laser beam cutting.

C. Surface roughness

It is considered as one of the most important parameter representing the quality of machined surface.S.-L. Chen [30] have found that the Surface roughness value was minimized on increasing the gas pressure in case of nitrogen and argon but only air gives poor surface finish beyond 6bar pressure and surface finish was better at higher speeds. I. Black et al [31] have studied that the surface roughness of thick ceramic tiles during CO_2 laser cutting is mainly affected by ratio of power to cutting speed, gas type and its pressure, material composition and thickness. Also, by using nitrogen assist gas and lesser power intensities the surface roughness was found to be reduced [32,33].

D. Metallurgical characteristics

The metallurgical characteristic change of laser machined work parts is governed mainly by heat affected zone (HAZ). The HAZ during LBM is reduced by controlling various factors. Increasing feed rate and decreasing power generally lead to decrease in HAZ [34-37]. Zhang et al[38]examined that the pulsed laser cutting using low pulse width with low wavelength laser gives less HAZ compared to high wavelength laser with high pulse width. During Nd:YAG laser drilling of nickel superalloys, it shows decrease in HAZ on increasing the beam angle to surface. Also, during pulsed Nd:YAG laser cutting of ceramic sheet HAZ increases with increase in pulse energy and feed rate but decrease very little when pulse frequency increases [39-41].

VI. FUTURE DIRECTIONS OF LBM

Many researchers have contributed in different sectors but due to complicated nature of the LBM process,lots of works are still required to be done. Mostly, recent published works are mainly related to laser cutting,drilling and micromachining but 3-D LBMoperations like turning and milling, still awaitsfor industrial use. Controlling more than one laser beams at different angles simultaneously is not an easy task during 3-D machining.The thickness of the work material is another constraint during LBM processwhich can be minimized by improving the quality of the laser beam. The use of LBM is limited only up to complex profile cutting of sheet metals but due to development of advanced engineering materials, there is a need to develop it for cutting of difficult-to-cut materials. Therefore, modifications in LBM can be an area of future research.

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