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THE LASER BEAM APPLICATIONS TO MACHINING AND WELDING PROCESSES

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ABSTRACT: This paper presents the application of laser beam in machining and welding processes. Laser machines are able to cut intricate shapes and weld with great precision. Laser has a good life expectancy due to absence of dynamic forces and metal to metal contact during the cutting process. There are two types of laser commonly in use in manufacturing today, the CO_2 and neodymium-doped yttrium aluminium garnet (Nd-YAG).

1. INTRODUCTION

The new developments in manufacturing process have been realized by non-traditional manufacturing processes. These new techniques or processes can be divided into three major groups in concordance with remove or convert metals or other manufacturing materials [3,4], which are: chemical reaction, electrochemical action, and thermal action. In last years the thermal machining processes have been known a large usage in accuracy manufacturing process. There are four machining technologies that use an extremely high concentration of thermal energy to cutting metals and other engineering materials. These techniques are: Electron Beam Machining, Laser Beam Machining, Electrical Discharge Machining, and Plasma Beam Machining.

These processes present some similar properties and some that are dissimilar. Thus, electron beam, laser beam and electrical discharge machining processes remove metal by melting vaporization, while plasma beam machining removes metal by melting and blowing it away. The plasma beam and electrical discharge machining can be used only for machining conductive metals. The machining operations realized by electron beam, laser beam and plasma beam machining processes are some limited for the most parts to cutting, in cut-off and slitting operations, and for drilling and trepanning of holes.

The reason of this paper is to presents laser beam machining and welding process. Laser machines are able to cut intricate shapes and weld with great precision. Laser has a good life expectancy due to absence of dynamic forces and metal to metal contact during the cutting process. So, the machine construction may be substantially lighter by classic machines, reducing the static loading and also the dynamic loading during positioning.

2. LASER BEAM

The word *laser* is an acronym for "Light Amplification by the Stimulated Emission of Radiation" [1,2]. The three most important attributes of laser light are:

- It's coherent i.e. all photons that make up the beam are in phase with each other.
- It is collimated, because photons that diverge from the parallel are lost through the chamber walls a very parallel beam is issued.
- It is monochromatic, literally one colour, that is of one wavelength. Different media used to stimulate the photons generate different wavelengths, but each type of laser has a specific wavelength. The purity of the medium used is of paramount importance.

There are two types of laser commonly in use in manufacturing today, the CO_2 and neodymium-doped yttrium aluminium garnet (Nd-YAG).

The CO_2 laser [2] is the more powerful of the two (400W to 1500W) and is used primarily for cutting and profiling. They are capable of cutting up to 25mm thick carbon steel, however laser beams in general tend to create a tapered cut due in part to the spread of the beam past the focal point.

At these lasers could be made the following observations: although lasers produce a collimated beam from the chamber, this is generally of the order of 20–30mm in diameter; this beam is then focused down to a point typically microns in diameter. This concentration of energy is how what might at first appear to be the low power rating of a laser can generate enough heat to quickly cut metal.

The Nd-YAG laser while lacking the “brute force” of the CO_2 has many uses. It is particularly suitable for drilling small holes (2-3µm) to a depth approximately six times diameter. They are also used for engraving and etching (e.g. Part and issue numbers for traceability in aerospace components etc.). A significant advantage of the YAG laser is that the beam may be transmitted through fibre-optic cable. This is particularly useful when welding because it means that the focus head may be fitted to a robot arm or similar multi-axis manipulator to weld complex intersections. The CO_2 laser beam can’t be transmitted through fibre-optic cable and must be re-directed by means of mirrors. This generally means that the focus head on a CO_2 machine moves only in one (Z) axis to provide height and focus adjustment, the X and Y axes being controlled.

3. LASER BEAM MACHINING

Lasers are used in many applications such as cutting, drilling, scribing, and welding. Lasers emit an intense, coherent, highly collimated beam of single-wavelength lght. In materials the narrow beam is focused by an optical lens which made a small and intense spot of light on the surface of workpiece. Thus, the optical energy is converted into heat energy in zone of contact. This high energy is capable to melt or vaporizes any materials.

For machining process are available two types of lasers: the continuous power output and the pulsed output type. The continuous output types are capable of working at very low (microwatts) to higher (kilowatts) power output. Pulsed lasers can work at extremely high peak power (terawatts) and transmit hundreds of energy joules at each pulse.

The applications of laser in machining process {1,2] are: laser cutting, laser assisted machining, laser hole piercing and trepanning, and laser alloying and cladding.

The laser cutting is usually made with continuous power output or pulsed CO_2 lasers, or pulsed Nd-YAG laser machine. In general, laser cutting is gas-assisted with high-pressure gas used to blow molten metal from the kerf. For cutting oxidizable materials is used oxygen which increases the laser cutting speed. With CO_2 lasers can be cutting a variety of materials including most metals, ceramics, composites, glass, paper, quartz, plastics and wood.

The process of cutting with laser is depicted in fig.1. The workpiece rests on a sacrificial table (minimal point contact, when heavily pitted by laser overshoot is simply thrown away, hence the name). Workholding is minimal due to absence of cutting forces and when used is mainly for location. The focal point of the laser is focused onto the surface of the workpiece. The follower takes into account any variation in height of the workpiece. The material vaporises instantly, producing a kerf in the material. The machine axes move to generate the correct profile. A gas assist jet clears the molten metal that has not vaporised (as in oxy-fuel cutting). The gas assist gas may be one of two types, inert and exothermic. Inert gasses commonly used are nitrogen and argon. Exothermic gases are air or pure oxygen. Inert gases help keep oxidisation to a minimum, cool the cutting zone and prevent flammable materials burning. Exothermic gases cause a reaction that improves cutting performance.

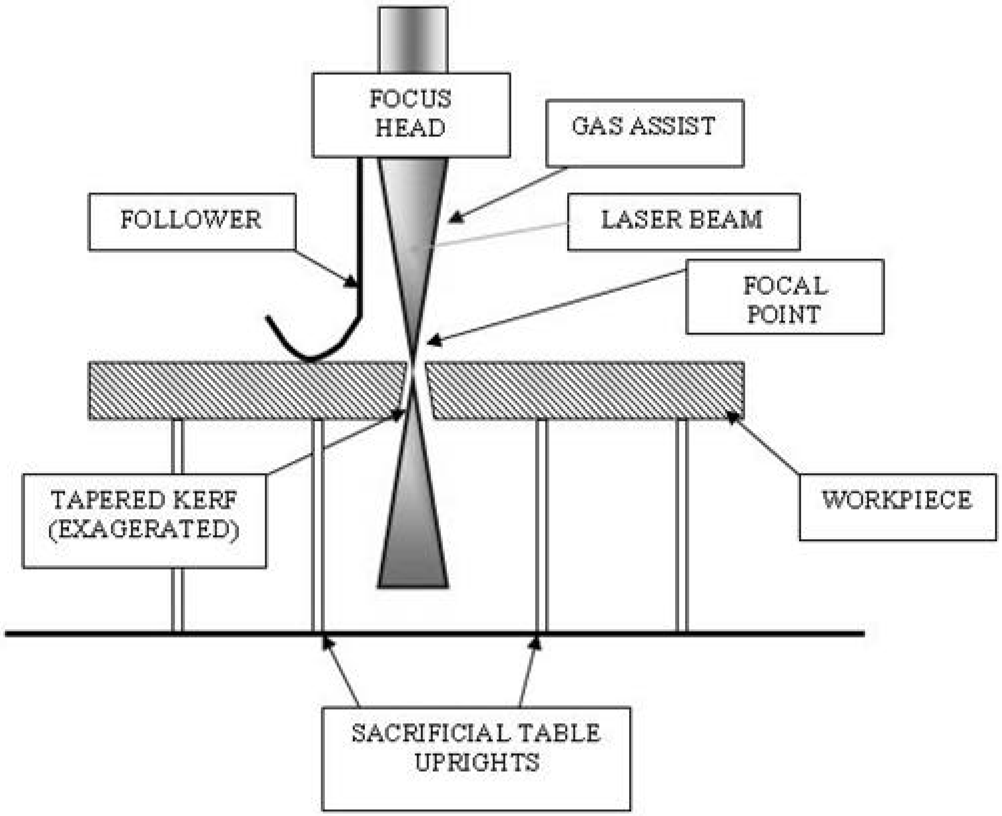

Fig.1. The chart of a laser cutting tool in operation, showing kerf, focus and sacrificial table.

The edge quality of most materials cut with a CO_2 laser is very good. A certain amount of taper or undercut is presented on both sides of kerf. The kerf undercut can be controlled to a certain extent by the location of focal point of laser, taper and undercut is decreased as the focal point of laser is moved deeper into the surface of workpiece.

Generally, a pulsed laser is preferred to continuous power laser when is necessary to have enough average power to melt and vaporize the material being cut, and minimizes the heat-affected zone. This is important for cutting ceramics and other refractory materials where excess heat along the sides of kerf could cause microcracking.

In last time, the laser cutting of complex shapes from sheet metals with multi-axis CNC laser cutting machines became usual by replacing more costly shearing and punching operations, reducing the time of cycle process, eliminated the hard tooling requirements for punch press work and other equipments.

Laser-assisted machining used a laser to preheat and soft the shear area just ahead of cutting tool (fig.2). So, the energy of laser beam is absorbed by the surface of workpiece and converted in heat, due to increase the shear temperature in this zone and changes the physical properties of workpiece which reduce the cutting forces, that is required for hard materials. All of these improve the tool life and metal removal rates.

Laser-assisted machining is used with success in turning and cutting process, which is improved the machinability of superalloys and ceramic materials.

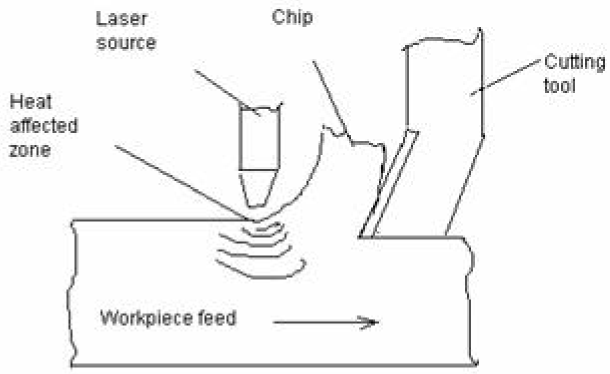

Fig.2. Laser-assisted machining arrangement.

Can be used CO_2 and Nd-YAG laser being necessary to determine the optimum cutting and beam parameters for each type of laser. The best results was obtained when laser beam is focused into elliptical form in front of tool, heated only a vertical cross section of workpiece slightly in advance of shear area.

Laser hole piercing and trepanning machining is used to realize holes in low machinabilty materials, and can be extended for any material, ranging from very light filter paper to most of the hardest materials, including diamonds. This operation has a significant disadvantage that the holes produced didn't have precisely straight and smooth walls. The hole taper can be minimized by repiercing a hole and adjusting the beam focus after the first shot. Most hole piercing is made with pulsed CO_2 and Nd-YAG lasers. Trepanning is actually more of cutting operation and either continuous or pulsed power lasers may be used. Generally, pulsed CO_2 laser is used for pierced of rubber and many plastic materials, and Nd-YAG laser is used by pierced diamonds.

Laser alloying and cladding machining is carried out to alter the metal surface to enhance its character while retaining certain properties of substrate material. In both of operations the alloying material is applied to the surface and melted with CO_2 laser beam. In many cases, the alloying material is in powder form or powder-solvent slurry. An important depth of substrate material is melted and mixed with the melted alloying powder to form a substantial alloyed surface layer after the two materials have solidified. Cladding is done similar except the depth of substrate melting is limited, which assure the cladding material to bond with the substrate material.

Alloying and cladding are made by passing a defocused or integrated CO_2 laser beam over the surface to be melted. Can be used a variety of material which improve the surface hardness and wear resistance, such as nickel-based chromium carbides and tungsten carbide nickel alloys.

Laser alloying and cladding techniques could occurs some slight surface irregularities due to rippling effect during the melting and subsequent solidification, being necessary some secondary operation finishing to resulted a flat surface.

4. LASER WELDING

Laser welding represents a fusion welding process [2], where the heat of high laser-coherent beam is focused on the joint to be welded. In general this process is similar with electron-beam process with difference that laser welding is required no vacuum to perform this process. The laser welding assures a high quality weld, deep penetration, and a narrow heat-affected zone. A suitable medium, that ruby crystal or gas mixture of CO_2 is stimulated. So, a crystal is stimulated by a bright flash of light (fig.3) or a gas is stimulated by an electrical discharge due raised ions to an unsteady level and than fall back and released an intense burst with monochromatic light. The light is amplified by reflection from one end and the surge of light from the other end of laser is focused by optical system.

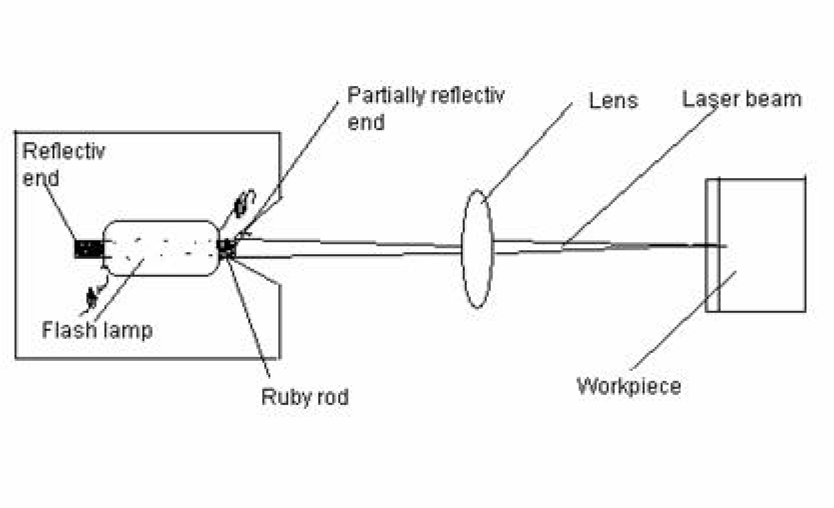

Fig. 3. The laser system used for welding.

The solid-state laser equipment is compact but less that 2% efficient and heat generated limits it to a pulsed output of low capacity. For a system with a rate of 400 W, which can deliver 29 J/pulse with a time of 0.65 milliseconds up to 100 pulses/sec have a low cost with a system with three to five axes, a part manipulator and CNC which the price is expensive. For a piece over a 1.6x2 m work surface can be used a machine with a power of 800 W continuous laser traversed by CNC with facilities for oxygen-assisted cutting. The high cost of these machines limits lasers application by more conventional methods of welding.

Laser welding could be done in a lot of ways and presents some advantages. A seam is welded by a series of overlapping fused spots with a pulsed laser or continuously by a powerful gas laser, which is twice faster that solid-state laser. A laser beam can be exact controlled and directed anywhere and concentrated as needed, even on minute spots on microelectronic devices. The weld can be done each in inaccessible areas using mirrors and inside transparent enclosures, or to join fine wires inside their insulation. The beam doesn't add foreign substances to the weld.

Laser beams have been concentrated to small spots of light with density of 4.5 GW/cm^2 enough to vaporize any metal instant, and takes from 1.5–15.5 MW/cm^2 for normal melting and cutting operations.

In addition of welding lasers have many applications for surface hardening metals and cutting process such as drilling tiny holes and slicing, trimming and scribing of ceramics, semiconductors, films, cloth, wood, plastics, metal sheets, even in heat treatment. In heat treatment with laser the metal is heated far below the melting point and a concentrated light beam can be oscillated to produce a raster which distributed the heat over a large zone and keep the temperature within the required range.

A significant advantage of laser welding is that filler rods need not be used and two dissimilar metals can be welded. The two pieces to be welded are butted together (to a close tolerance) the laser beam passes along the intersection, melting both sides and stirring the metals together. Very accurate welds with good structural integrity can be made with a laser beam.

5. CONCLUSIONS

The laser beam has a significant application in manufacturing process which is necessary a high quality and accurately of workpiece. The laser machines used in machining and welding process are more expensive such classic machine, but these presented the advantage of shorted the time of cycle process, removed a lot of significant tools and equipment required in common machining, improved the physic properties and precision of workpiece finished.

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