Study the various cutting methods of steel material by using CO2 laser

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Abstract- The great interest in carbon dioxide lasers stems from their continuous power capability, high efficiency and ease of construction. The CO2 laser is a gas type laser with a wavelength of 10.6µm in infrared region. Their high efficiency and tremendous power outputhave made them one of the most commonly known transition wavelength facilitates laser cutting, drilling and marking of a wide variety ofmaterials in the electronics and medical industries. CO2 gas discharge laser operation was characterized in power, cutting speed and stability over a long time. The resultsindicate a good operation, optimum powers and beam quality with maximum speed. So CO2 laser are used for cutting and welding of metals and nonmetals. In this paper we discuss about cutting of steel material by using CO2 laser.

KeyWords-**CO2** ***laser, steel, cutting, various methods.***

IINTRODUCTION

Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications, but is also starting to be used by schools, small businesses, and hobbyists. Laser cutting works by directing the output of a high-power laser most commonly through optics. The laser optics and CNC (computer numerical control) are used to direct the material or the laser beam generated. A typical commercial laser for cutting materials would involve a motion control system to follow a CNC pattern to be cut onto the material. The focused laser beam is directed at the material, which then either melts, burns, vaporizes away, or is blown away by a jet of gas,leaving an edge with a high-quality surface finish. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials.

II INDUSTRICAL LASER CUTTING OF STAINLESS STEEL

Generation of the laser beam involves stimulating a lasing material by electrical discharges or lamps within a closed container. As the lasing material is stimulated, the beam is reflected internally by means of a partial mirror, until it achieves sufficient energy to escape as a stream of monochromatic coherent light. Mirrors or fiber optics are typically used to direct the coherent light to a lens, which focuses the light at the work zone. The narrowest part of the focused beam is generally less than 0.0125 inches (0.32 mm) in diameter. Depending upon material thickness, kerf widths as small as 0.004 inches (0.10 mm) are possible.In order to be able to start cutting from somewhere other than the edge, a pierce is done before every cut. Piercing usually involves a high-power pulsed laser beam which slowly makes a hole in the material, taking around 5–15 seconds for 0.5-inch-thick (13 mm) stainless steel, for example.

The parallel rays of coherent light from the laser source often fall in the range between 0.06–0.08 inches (1.5–2.0 mm) in diameter. This beam is normally focused and intensified by a lens or a mirror to a very small spot of about 0.001 inches (0.025 mm) to create a very intense laser beam. In order to achieve the smoothest possible finish during contour cutting, the direction of beam polarization must be rotated as it goes around the periphery of a contoured work piece. For sheet metal cutting, the focal length is usually 1.5–3 inches (38–76 mm).

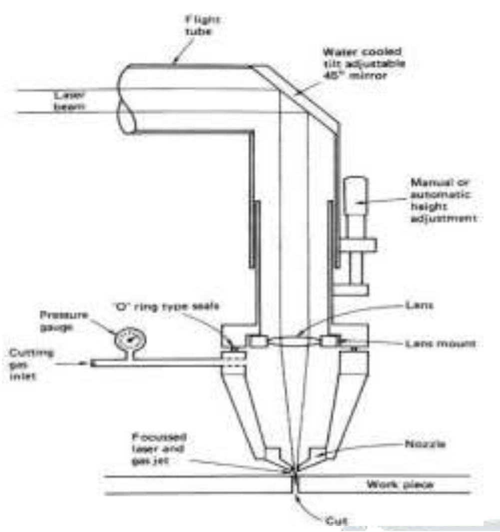
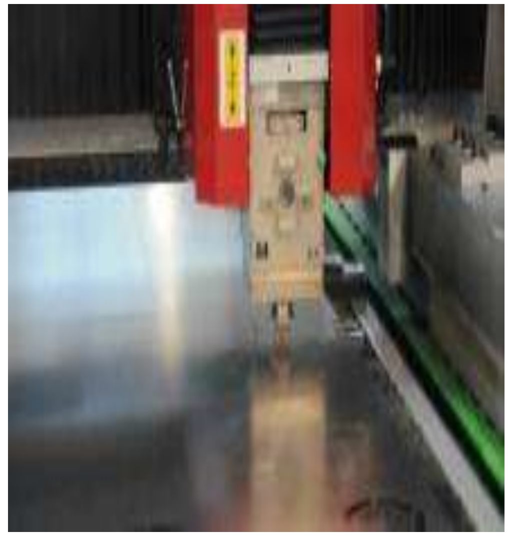


Diagram of a laser cutter



Laser cutting process on a sheet of steel

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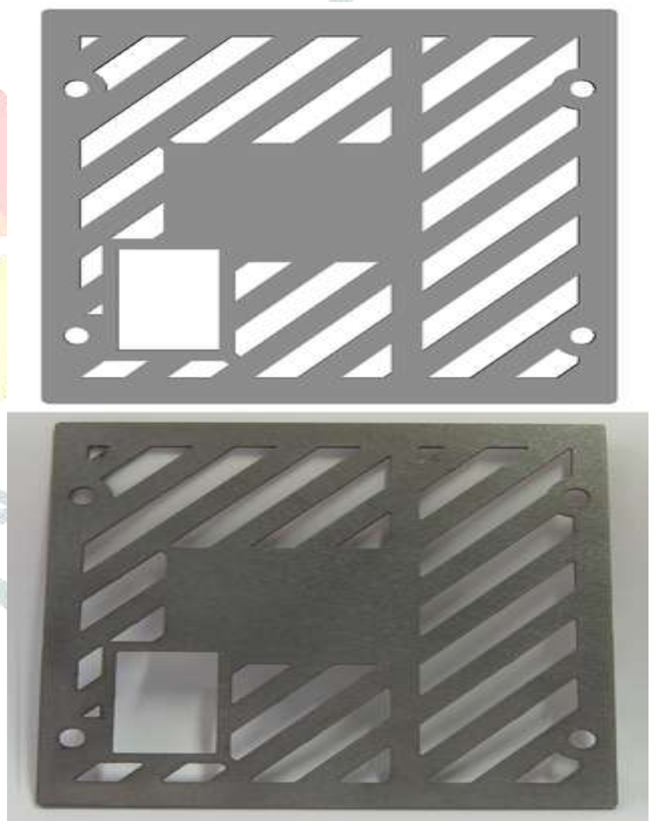

Industrial laser cutting of steel with cutting instructions

CAD (top) and stainless steel laser-cut part (bottom)

Programmed through the CNC interface

III ADVANTAGES OF LASER CUTTING OVER MECHANICAL AND PLASMA CUTTING

- Easier work holding.
- Reducing contamination of work piece since there is no cutting edge which can become contaminated by the material.
- Reducing chance of warping the material that is being cut as laser systems have a small heat-affected zone.
- More precise.
- Required less energy.

IV TYPES OF LASERS USED IN LASER CUTTING

There are three main types of lasers used in laser cutting. The CO_2 laser is suited for cutting, boring, and engraving. The neodymium (Nd) and neodymium yttrium-aluminium-garnet (Nd-YAG) lasers are identical in style and differ only in application. Nd is used for boring and where high energy but low repetitions are required. The Nd-YAG laser is used where very high power is needed and for boring and engraving. Both CO_2 and Nd/ Nd-YAG lasers can be used for welding.

Common variants of CO_2 lasers include fast axial flow, slow axial flow, transverse flow, and slab.

VCUTTING OF STEEL SHEET BY USING CO2 LASER

CO_2 lasers are commonly "pumped" by passing a current through the gas mix (DC-excited) or using radio frequency energy (RF-excited). The RF method is newer and has become more popular. Since DC designs require electrodes inside the cavity, they can encounter electrode erosion and plating of electrode material on glass ware and optics. Since RF resonators have external electrodes they are not prone to those problems.

CO_2 lasers are used for industrial cutting of many materials including mild steel, aluminium, stainless steel, titanium, paper, wax, plastics, wood, and fabrics. YAG lasers are primarily used for cutting and scribing metals and ceramics.

In addition to the power source, the type of gas flow can affect performance as well. In a fast axial flow resonator, the mixture of carbon dioxide, helium and nitrogen is circulated at high velocity by a turbine or blower. Transverse flow lasers circulate the gas mix at a lower velocity, requiring a simpler blower. Slab or diffusion cooled resonators have a static gas field that requires no pressurization or glassware, leading to savings on replacement turbines and glassware.

The laser generator and external optics (including the focus lens) require cooling. Depending on system size and configuration, waste heat may be transferred by a coolant or directly to air. Water is a commonly used coolant, usually circulated through a chiller or heat transfer system.

A laser micro jet is a water-jet guided laser in which a pulsed laser beam is coupled into a low-pressure water jet. This is used to perform laser cutting functions while using the water jet to guide the laser beam, much like an optical fiber, through total internal reflection. The advantages of this are that the water also removes debris and cools the material. Additional advantages over traditional "dry" laser cutting are high dicing speeds, parallel kerf, and omnidirectional cutting.

Fiber laser is a type of solid state laser that's been rapidly growing within the metal cutting industry. Unlike CO_2, Fiber technology utilizes a solid gain medium, as opposed to a gas or liquid. The “seed laser” produces the laser beam and is then amplified within a glass fiber. With a wavelength of only 1.064 micrometers fiber lasers produce an extremely small spot size (up to 100 times smaller compared to the CO_2) making it ideal for cutting reflective metal material. This is one of the main advantages of Fiber compared to CO_2.

4000 watts co2 laser cutter

VI METHODS OF LASER CUTTING

There are many different methods in cutting using lasers, with different types used to cut different material. Some of the methods are vaporization, melt and blow, melt blow and burn, thermal stress cracking, scribing, cold cutting and burning stabilized laser cutting.

- **Vaporization cutting**
  In vaporization cutting the focused beam heats the surface of the material to boiling point and generates a keyhole. The keyhole leads to a sudden increase in absorptivity quickly deepening the hole. As the hole deepens and the material boils, vapor generated erodes the molten walls blowing eject out and further enlarging the hole. Non melting material such as wood, carbon and thermoset plastics are usually cut by this method.
- **Melt and blow**
  Melt and blow or fusion cutting uses high-pressure gas to blow molten material from the cutting area, greatly decreasing the power requirement. First the material is heated to melting point then a gas jet blows the molten material out of the kerf avoiding the need to raise the temperature of the material any further. Materials cut with this process are usually metals.
- **Thermal stress cracking**
  Brittle materials are particularly sensitive to thermal fracture, a feature exploited in thermal stress cracking. A beam is focused on the surface causing localized heating and thermal expansion. This results in a crack that can then be guided by moving the beam. The crack can be moved in order of m/s. It is usually used in cutting of glass.
- **Stealth dicing of silicon wafers**
  The separation of microelectronic chips as prepared in semiconductor device fabrication from silicon wafers may be performed by the so-called stealth dicing process, which operates with a pulsed Nd:YAG laser, the wavelength of which (1064 nm) is well adopted to the electronic band gap of silicon (1.11 eV or 1117 nm).
- **Reactive cutting**
  Also called "burning stabilized laser gas cutting", "flame cutting". Reactive cutting is like oxygen torch cutting but with a laser beam as the ignition source. Mostly used for cutting carbon steel in thicknesses over 1 mm. This process can be used to cut very thick steel plates with relatively little laser power.

VII TOLERANCES AND SURFACE FINISH

New laser cutters have positioning accuracy of 10 micrometers and repeatability of 5 micrometers.

Standard roughness Rz increases with the sheet thickness, but decreases with laser power and cutting speed. When cutting low carbon steel with laser power of 800 W, standard roughness Rz is 10 μm for sheet thickness of 1 mm, 20 μm for 3 mm, and 25 μm for 6 mm.

$Rz = 12.528 \cdot (S^{0.542})/((P^{0.528}) \cdot (V^{0.322}))$, where: $S =$ steel sheet thickness in mm; $P =$ laser power in kW (some new laser cutters have laser power of 4 kW.); $V =$ cutting speed in meters per minute.

This process is capable of holding quite close tolerances, often to within 0.001 inch (0.025 mm) Part geometry and the mechanical soundness of the machine have much to do with tolerance capabilities. The typical surface finish resulting from laser beam cutting may range from 125 to 250 micro-inches (0.003 mm to 0.006 mm).

VIII POWER CONSUMPTION

The main disadvantage of laser cutting is the high power consumption. Industrial laser efficiency may range from 5% to 45%. The power consumption and efficiency of any particular laser will vary depending on output power and operating parameters. This will depend on type of laser and how well the laser is matched to the work at hand. The amount of laser cutting power required, known as *heat input*, for a particular job depends on the material type, thickness, process (reactive/inert) used, and desired cutting rate.

Amount of heat input required for various material at various thicknesses using a CO2 laser [watts].

Material	**Material thickness**				
	0.51mm	1.0mm	2.0mm	3.2mm	6.4mm
Stainless steel	1000	1000	1000	500	250
Aluminum	1000	1000	1000	3800	10000
Mild steel	-	400	-	500	-
Titanium	250	210	210	-	-
Plywood	-	-	-	650	-
Boron/epoxy	-	-	-	3000	-

IX PRODUCTION AND CUTTING RATES

The maximum cutting rate (production rate) is limited by a number of factors including laser power, material thickness, process type (reactive or inert,) and material properties.

Common industrial systems (≥1 kW) will cut carbon steel metal from 0.51 – 13 mm in thickness. For all intents and purposes, a laser can be up to thirty times faster than standard sawing.

Cutting rates for various materials and thicknesses using a CO_2 laser [cm/second]

Material	**Material thickness**				
	0.51mm	1.0mm	2.0mm	3.2mm	6.4mm
Stainless steel	42.3	23.28	13.76	7.83	3.4
Aluminum	33.87	14.82	6.35	4.23	1.69
Mild steel	-	8.89	7.83	6.35	4.23
Titanium	12.7	12.7	4.23	3.4	2.5
Plywood	-	-	-	-	7.62
Boron/epoxy	-	-	-	2.5	2.5

X CONCLUSION

CO2 laser with appropriate characteristics of wavelength, power, coherent and monochromatic laser radiation, for the cutting of steel (metallic) materials according to industrial application, where it is possible combine high reliability andlow operating cost. The work done is mainly application study of theperformance of a CW CO2 laser system for cuttingmetallicmaterials. Thus, the common variants include construction of axial flow, continuous wave carbon dioxide laser wasproposed for the current work. The experimental results show thatthe cutting quality varies with the kind of the materials and cuttingspeed. This system will allow carrying out different industrial applications.

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