EXPERIMENTAL STUDY OF KERF WIDTH AND TAPER ON LASER BEAM CUTTING ON ACRYLIC SHEET

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ABSTRACT

This thesis is mainly about the study and analysis of the kerf width and taper on acrylic sheet based on the experiments conducted using laser beam cutting machine and using various process parameter including laser power, cutting speed, cutting angle, nozzle gap and air pressure. The objective of this thesis is to study the kerf width and taper on laser beam cutting process on acrylic sheet, to analyze the effect of various process parameters on kerf width and taper on laser beam cutting process and also to study about laser beam machining process. The thesis discuss the experimental analysis to predict the effect of the process parameter on kerf width and taper on acrylic sheet. The work piece that we are going to use in the experiment is acrylic sheet that is also known by trade names such as Plexiglas, Acrylite, and Lucite which is commonly used in industry. This material is great for glazing, windows, cutting boards, or anywhere a clear material is needed. Besides that, it is also has better optical clarity than glass, light weight, good impact strength and clear. As mentioned, the experiments is conduct using laser beam cutting machine. The specimen is cut in square shape then a slit is made through the center of specimen to determine the kerf width and taper. From the results, it is observed that the parameter set in the experiment on laser beam cutting had effect on kerf width and taper. Secondly, the cutting speed, nozzle gap and laser power gives major impact on kerf width and taper. The kerf width and taper will increase considerably with the increase of laser power and nozzle gap and decreasing the cutting speed. The cutting angle and air pressure also gives some effect on kerf width and taper. Increasing cutting angle and air pressure will slightly increase the kerf width and taper. Low value of laser power, nozzle gap, cutting angle, air pressure and higher cutting speed will produce lowest/narrow kerf width and taper which means the finest cutting quality with good width and cut edge is produced.

ABSTRAK

Tesis ini membentangkan penyelidikan mengenai kelebaran rekahan dan ketirusan yang terhasil pada kepingan spesimen(akrilik) berdasarkan eksperimen yang dijalankan dengan menggunakan mesin pemotong lazer berpandukan pembolehubah proses termasuk kuasa lazer, kelajuan pemotongan, sudut pemotongan, jarak nozel dan tekanan udara. Objektif tesis ini ialah untuk mengkaji tentang kelebaran rekahan dan ketirusan yang terhasil pada kepingan spesimen dalam proses pemotongan mesin lazer, menganalisis kesan pembolehubah proses pada kelebaran rekahan dan ketirusan yang terhasil dalam proses pemotongan mesin lazer dan mengkaji tentang proses pemotongan oleh mesin lazer. Tesis ini membincangkan analisis melalui eksperimen yang dijalankan untuk mengenalpasti kesan pembolehubah proses kelebaran rekahan dan ketirusan yang terhasil pada kepingan spesimen. Bahan specimen yang digunakan dalam eksperimen ini ialah akrilik yang juga dikenalpasti dengan nama sientifiknya seperti *Plexiglas*, *Acrylite*, dan *Lucite* yang biasa digunakan dalam industri. Bahan ini bagus untuk pelicauan, tingkap, papan pemotong atau di mana sahaja bahan yang jelas atau terang diperlukan. Di samping itu, ia juga mempunyai kejelasan optik yang lebih bagus daripada gelas, ringan, kekuatan impak yang baik dan terang. Seperti yang telah diperkatakan, eksperimen ini dijalankan dengan menggunakan mesin pemotong lazer. Spesimen dipotong kepada bentuk segiempat dan belahan akan dibuat melalui tengah-tengah specimen untuk menentukan kelebaran rekahan/belahan dan ketirusan yang terhasil. Daripada keputusan yang diperolehi, dikenalpasti bahawa pembolehubah proses yang ditetapkan di dalam eksperimen pemotongan lazer mempunyai kesan terhadap kelebaran belahan dan ketirusan yang terhasil. Kedua, kelajuan pemotongan, jarak nozel dan kuasa lazer memberikan kesan yang besar terhadap pembentukan kelebaran belahan dan ketirusan pada spesimen. Kelebaran belahan dan ketirusan meningkat dengan mendadak dengan penambahan kuasa lazer dan jarak nozel dan pengurangan kelajuan pemotongan. Sudut pemotongan dan tekanan juga member sedikit kesan terhadap pembentukan kelebaran belahan dan ketirusan. Penambahan sudut pemotongan dan tekanan udara akan menambah sedikit kelebaran belahan dan ketirusannya. Nilai yang rendah untuk kuasa lazer, jarak nozel, sudut pemotongan, tekanan udara dan kelajuan pemotongan yang tinggi akan menghasilkan kelebaran belahan dan ketirusan yang paling kecil dan halus yang bermakna bahawa kualiti pemotongan terbaik dengan kelebaran dan sudut pemotongan yang baik dihasilkan.

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Kw	Kerf Width
Kwt	Top kerf width
Kwb	Bottom kerf width

LIST OF ABBREVIATIONS

LBC	Laser Beam Cutting
HAZ	Heat Affected Zone
CO2	Carbon dioxide
CAD	Computer-aided drafting
RSM	Response Surface Method
CW	Continuous Wave
ANN	Artificial neural networks
TM	Taguchi Method
CCD	Central composite design
SEM	Scanning Electron Microscope

CHAPTER 1

INTRODUCTION

In this chapter, a briefly explanation on introduction about the project according to given title of PSM 1 which is Experimental Study of Kerf Width and Taper on Laser Beam Cutting on Acrylic Sheet will be shown. In this chapter, some important aspect will be discussed including objective, project background, problem statement and project scopes. This chapter is important to make sure that the project that is going to be done is being understood clearly.

1.1 Objective

i. To study the kerf width and taper on laser beam cutting process on acrylic sheet.
ii. To analyze the effect of various process parameters on kerf width and taper on laser beam cutting process.
iii. To study about laser beam machining cutting process.

1.2 Problem Statement

Laser beam cutting is commonly use nowadays but there is no extensively studied on kerf width and taper on acrylic sheet. So, this experiment is build to study and analyze the effect of various process parameters on kerf width and taper on laser beam cutting process. The expected output for the laser beam cutting process for roughness and heat affected zone (HAZ) may be investigate as well.

1.3 Project Background

The laser is invented in 1960s and is commonly used in the field of cutting sheet metals applications due to its accuracy and high of intensity. Laser beam cutting (LBC) can be used to cut conductive and nonconductive difficult-to-cut advanced engineering materials such as reflective metals, plastics, rubbers, ceramics and composites. Despite cutting difficult-to-cut materials, LBC is most extensively used in industries to attain complex shapes/profiles with close tolerances for cutting of steel sheets.

The most commonly used industrial lasers for cutting sheet metals are gaseous CO2 and solid state Nd:YAG. Nowadays, there are raise of interest in using Nd:YAG lasers for accuracy cutting of thin sheet metals as a results of its high intensity, low mean beam power, good focusing characteristics and narrow heat affected zone (HAZ).

In LBC process, the thermal energy of laser beam is used for melting and vaporizing the sheet metal (work piece). Then, the molten material is removed using an assist gas that is suitable at high pressure. Due to shorter wavelength of Nd:YAG laser compare to CO2, it is reflected to a lesser extent by metallic surfaces and the high absorptivity of the Nd:YAG laser enables cutting of even highly reflective materials with relatively less power. The performance of LBC usually depends on fine selection of input process parameters. The kerf taper always exist during LBC due to converging-diverging shape of laser beam profile.

Various researchers have experimentally studied the laser cut qualities such as kerf width and taper in order to analyze the effect of some process parameters on these quality characteristics. Chen (1999), during his study found that kerf width increases with the increase of laser power and decreasing the cutting speed during CO2 laser cutting of 3mm thick steel sheet. He also observed that oxygen or air gives wider kerf while using the inert gas gives the narrow kerf. Ghany and Newishy (2005) have found that the same variation of kerf width with cutting speed, laser power and type of gas and pressure as above during experimental study of Nd:YAG laser cutting of 1.2mm thick austenitic stainless steel sheet. They also found that kerf width is decreases with the increases of pulse frequency.

The same effect of laser power and cutting speed on kerf width during CO2 laser cutting of steel sheets of different thickness was observed by other researchers also (eg. [Duley and Gonzalez, 1974], [Lamikiz et al., 2005]). Lum et al. (2000) also show the same variation of kerf width with laser power and cutting speed during CO2 laser cutting of different fibre composites.

1.4 Project Scopes

- Experimental study of kerf width and taper on laser beam cutting on acrylic sheet.
- Using PCNC Laser Cutting Machine to investigate the various process parameters on kerf width and taper on laser beam cutting process.
- Analyze results using available software.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Laser

A laser is a tool that emits light (electromagnetic radiation) through a process called stimulated emission. The word laser is a short form for light amplification by stimulated emission of rays. Laser light is typically spatially consistent, which means that the light either is emitted in a thin, low-divergence beam, or can be transformed into one with the help of optical components such as lenses.

Normally, lasers are contemplation of as emitting light with a slender wavelength spectrum ("monochromatic" light). This is not true of all lasers, however: some emit light with a wide spectrum, while others emit light at numerous separate wavelengths concurrently. The consistency of typical laser emission is typical. Most other light sources emit incoherent light, which has a phase that varies randomly with time and location.

A laser consists of a gain medium inside a highly reflective visual cavity, as well as a means to deliver energy to the gain medium. The gain medium is a material with properties that permit it to strengthen light by stimulated emission. In its simplest shape, a hollow space consists of two mirrors arranged such that light bounces back and forth, every time passing through the gain medium. Normally one of the two mirrors, the output coupler, is partly crystal clear.

The output laser beam is emitted through this mirror. Light of a exact wavelength that passes through the gain medium is amplified (increases in power); the surrounding mirrors make sure that the majority of the light makes a lot of passes through the gain medium, being amplified repetitively. Part of the light that is between the mirrors (that is, within the cavity) passes through the partially transparent mirror and escapes as a beam of light.

The course of supplying the energy necessary for the amplification is called pumping. The energy is naturally supplied as an electrical current or as light at a dissimilar wavelength. Such light may be provided by a flash lamp or possibly another laser. Most practical lasers have extra elements that influence properties such as the wavelength of the emitted light and the shape of the beam.

2.2 Laser Usage

Lasers can be used to process luxurious alloys as well as traditional materials such as stainless steel. Though, knowing the strengths and weaknesses of laser processing is the key to determining whether or not a laser is the exact choice for cutting. Although lasers are not the answer for each application, they can supply flexibility, efficient material use, and a repeatable, controlled process.

One advantage that lasers have over conservative processes such as stamping and punching is that they work with smallest contact. A usual cut width of .010 inch enables lasers to be used for small-radius cutting. This small kerf allows close nesting of parts and helps to lessen material waste. In addition, materials may be heat treated after cutting without the distortion that can happen with the grinding and reforming typically needed after processing by other methods.

Laser cutting becomes fewer efficient when material thickness increases. For instance, lasers may be ineffective for cutting carbon steel thicker than .4 inches. Laser cutting thickness limits are determined by heat conductivity, surface reflection at 10.6 microns, the vaporization point of alloys, the types of alloys, surface tension of molten materials, and part geometry.

As thickness increases, the likelihood of a blowout or thermal runaway also increases. By highly focusing its beam and reducing its spot size, the laser becomes a sharper cutting tool. For example, a laser's cutting ability increases significantly when the spot size is narrowed from even .004 to .011 inches in diameter. Ideally, the wavelength will allow 100 percent absorbability with the material. In many instances, the laser's ability to cut can be further improved by focusing the assist gas. The assist gas serves two purposes: to help in combustion, and to blow the debris or molten metal away from the kerf.

Other circumstances contribute to processing problems. If the thermal conductivity is high in a material such as aluminum, much of the energy is transferred laterally into the material, which results in inefficient cutting and reduced cutting speeds. As a general rule, if energy is transferred into a material inefficiently, the effectiveness of the cutting process is reduced. Certain amounts of metal become vapor or molten during the cutting process. The laser acts more like a plasma cutter when thicker materials are processed and larger amounts of material become molten.

2.3 Laser Processing

Laser processing is influenced by conductivity and the viscosity of metal in a liquid state. Carbon content assists in combustion, making higher-carbon steels—materials that are of higher quality and used as structural steels—combust quickly when they come into contact with the laser beam. Compared to more homogenous materials, carbon steels may contain a wide range of elements that have different melting points. During the thermal process, random reactions can occur because of element variance and the surface condition of the material. These surface conditions include scale, coatings, filth, and surface impurities. The dwelling process is sometimes used to cut particularly reflective material like aluminum.

A laser can dwell in the start position until the material reflectivity changes and before the motion system begins to move the laser. Surface tension, carbon content, and the absorbability of material at 10.6 microns also affect laser performance for example, because of its reflectivity, copper is very difficult to cut with a laser, but not with other cutting methods. Laser processing is more sensitive to material quality than are other processes. The surface finish can dramatically affect the quality of cutting. In most cases, steel must be clean, pickled, and oil-free. Impurities on low-grade steel are highly reactive to the thermal process, especially when oxygen is used as a processing gas. Hot rolled steel presents serious quality problems in cutting because of the surface scale.

The surface tends to melt in with the metal, creating an undesirable finish. If the material surface is not smooth, the assist gas and laser focus can be altered, affecting the quality of the cut. Laser cutting can depart a recast layer on the surface. Because lasers melt and burn some of the metal, remelted materials are deposited on the side of the cut edges and on the bottom of the cut. Setup time for a laser can be long when preparing to cut new materials. Nozzle size, power, optical focal length, assist gas, gas pressure, speed, and focal length can all influence the process. These parameters are so significant to the process that if they are not set correctly, the material cannot be cut. However, when the combinations are right, the speed of cutting can be several times faster than that of other cutting methods. Several methods can be used to reduce setup time. Keeping careful records is a must.

Via a dependable database of time-tested parameters of recognized materials, specifications, and conditions is critical in saving setup time. Parameters are often wide-ranging for the similar material. Requirements for surface finish, tolerances, heat-affected zone (HAZ), and flatness can significantly change the parameters. Setup time can be very much reduced by planning similar jobs to run together, creating modular fixtures, building ergonomic workstations, using shuttle tables, and simply keeping the material near the laser cutting table. A heat-affected zone (HAZ) is produced during laser cutting. A HAZ forms in metals when the temperature rises above the critical transformation point. In laser cutting, this is localized near the cutting zone.

In carbon steel, the higher the hardenability, the greater the HAZ for example, laser processing produces a HAZ of about .18 millimeter on 7-millimeter-thick, 4140 steel. Since the HAZ is brittle, this area has a lower tolerance for cracking during bending or stress. In most cases, the HAZ can be eliminated by post-heat treating the part, but there is a risk of distortion.

Distortion is more likely to occur when a laser is applied to thin materials with wall thicknesses of 0.001 to 0.005 inches or shim-stock material. Thinner materials are more easily distorted because a recast layer forms on the edge, and the resolidification of the molten material can more easily warp thinner material.

Distortion from laser processing is a result of the sudden rise in temperature of the material near the cutting zone. Distortion is also created by the rapid solidification of the cutting zone. In addition, distortion also can be attributed to the rapid solidification of material remaining on the sides of the cut. Adding a water quenching system to the laser cutting nozzle can reduce heat-induced stress. This process works well when cutting tubes with diameters less than 1/4 inch and usually prevents slag from forming on the opposing walls.

2.4 Laser Cutting Machine

Laser cutting machines can accurately produce complex exterior contours. The laser beam is typically 0.2 mm (0.008 in) diameter at the cutting surface with a power of 1000 to 2000 watts. Laser cutting can be complementary to the CNC/Turret process. The CNC/Turret process can produce internal features such as holes readily whereas the laser cutting process can produce external complex features easily. Laser cutting takes direct input in the form of electronic data from a CAD drawing to produce flat form parts of great complexity.

With 3-axis control, the laser cutting process can profile parts after they have been formed on the CNC/Turret process. Lasers work best on materials such as carbon steel or stainless steels. Metals such as aluminum and copper alloys are more difficult to cut due to their ability to reflect the light as well as absorb and conduct heat. This requires lasers that are more powerful. Lasers cut by melting the material in the beam path. Materials that are heat treatable will get case hardened at the cut edges. This may be beneficial if the hardened edges are functionally desirable in the finished parts. However, if further machining operations such as threading are required, then hardening is a problem.

A hole cut with a laser has an entry diameter larger than the exit diameter, creating a slightly tapered hole. The minimum radius for slot corners is 0.75 mm (0.030 in). Unlike blanking, piercing, and forming, the normal design rules regarding minimum wall thicknesses, minimum hole size (as a percent of stock thickness) do not apply. The minimum hole sizes are related to stock thickness and can be as low as 20% of the stock thickness, with a minimum of 0.25 mm (0.010 in) for upto 1.9 mm (0.075 in). Contrast this with normal piercing operations with the recommended hole size 1.2 times the stock thickness. Burrs are quite small compared to blanking and shearing.

They can be almost eliminated when 3D lasers are used and further, eliminate the need for secondary deburring operations. As in blanking and piercing, considerable economies can be obtained by nesting parts, and cutting along common lines. In addition, secondary deburring operations can be reduced or eliminated.

2.5 Concept of Laser

The laser principle was described by Albert Einstein as early as the beginning of the century, but not until the 1960s was it developed into a (very low power) system for commercial use. In the 1970s, systems for material treatment were launched and opened up a wide range of technological benefits for existing applications, as well as completely new applications. Since then, laser technology has undergone a number of major development improvements and continues to do so, in the same manner as developments in PC technology.

Today, lasers affect all areas of business and private life. For example, telecommunications use laser-driven fiber technology, expiry dates are laser marked and scanners, bar code readers, CD players, remote controls, etc. make use of lasers. The laser power required for these applications is very small, far too small for materials treatment. Laser cutting, welding or surface treatment of metals requires lasers for materials treatment that offer much higher laser powers.

Basically, electrical energy is transferred into a light beam of a single wavelength during the beam generation process in the laser resonator, for example during the CO2 laser process. The laser beam is essentially parallel, which makes it easy to transfer over a long distance to the place where it is needed. At the processing area, the laser beam is focused into a very small spot providing the energy needed to heat, melt and even evaporate metals immediately. The largest group of high-power laser applications is laser cutting of metals, since high-precision cut samples can be produced with high cutting speeds. The advantages of laser welding include very narrow seam widths with considerably fewer weld distortions compared with traditional welding methods.

Laser surface treatment covers a number of applications such as annealing, hardening, spraying/coating or cleaning of surfaces or secret areas of a surface or a component. Regardless of the application, lasers provide a precise and easily adjustable tool without mechanical contact to the workpiece and it is amazing to follow the evolution of this tool and see new applications emerging almost daily. Laser processes require electricity and generate radiation. This can be dangerous if the person using the equipment does not have sufficient knowledge of the equipment and the installation and does not work with care.

2.6 Laser Cutting

Laser cutting is a thermal cutting process in which a cut kerf (slot) is formed by the heating action of a focused traversing laser beam of power density on the order of 10^4 W mm^{-2} and combination with the melt shearing action of a stream of inert or active assist gas.

The focused laser beam melts the material throughout the material thickness and a pressurized gas jet, acting coaxially with the laser beam, blows away the molten material from the cut kerf. The laser cutting process types, defined according to their dominant transformation process, include: laser fusion cutting (inert gas cutting), laser oxygen cutting and laser vaporization cutting. These cutting methods discussed in detail in the following sections are applicable for the cutting of metals commonly used in industry.

2.6.1 Laser fusion cutting

Also called inert gas melt shearing, this process is based on transformation of the material along the kerf into the molten state by heating with laser energy and the molten material blown out of the kerf by a high-pressure inert gas jet. The laser beam is the only heat source during this cutting process and the high-pressure inert gas jet is responsible for melt ejection.

The inert gas jet is also responsible for shielding the heated material from the surrounding air as well as protecting the laser optics. It is applicable to all metals especially stainless steels and other highly alloyed steels, aluminium and titanium alloys. A high quality cut edge is formed but the cutting speeds are relatively low in comparison with active gas cutting mechanisms.

The advantage of this process is that the resulting cut edges are free of oxides and have the same corrosion resistance as the substrate. The main technical demand is to avoid adherent melt (dross attachment) at the bottom edges of the kerf.

2.6.2 Laser oxygen cutting

The focused laser beam heats the material in an oxidizing atmosphere and ignites an exothermic oxidation reaction of the oxygen with the material. The exothermic reaction supports the laser cutting process by providing additional heat input in the cutting zone resulting into higher cutting speeds compared to laser cutting with inert gases.

The laser beam is responsible for igniting and stabilizing a burning process within the kerf, and the assist gas blows out the molten material from the cut zone and protects the laser optics. Laser oxygen cutting is applicable to mild steel and low-alloyed steel. The oxides reduce the viscosity and surface tension of the melt and thereby simplify melt ejection.

2.6.3 Laser vaporization cutting

The material is heated beyond its melting temperature and eventually vaporized. A process gas jet is used to blow the material vapor out of the kerf to avoid precipitation of the hot gaseous emissions on the workpiece and to prevent them from condensation within the developing kerf.

Typical materials that are cut by the vaporization method are acrylic, polymers, wood, paper, leather and some ceramics. This method has a high power requirement that depends on the thermal properties of the material. High power densities are obtained by appropriate adjustment of the laser radiation and focusing. For cutting of metals, laser vaporization cutting is the method with the lowest speed among other methods.

2.7 Laser Technology

A laser beam is a source of energy that can be focused to a small spot. It interacts with materials without direct contact. Laser capabilities have increased over time. To better understand the potential provided by lasers, we must be familiar with the technology and its nuances. Before deciding which type of laser to use, we should understand how lasers work, laser-material interaction, laser parameters, and opportunities for using lasers.

2.7.1 Device Opportunities for Lasers

Lasers are used in device manufacturing for a variety of processes. Lasers can also be used for drilling either through-cut or blind holes. This process can be adapted for drilling micro fluidic channels in medical diagnostic equipment and for holes in micro syringes used for drug delivery.

Laser welding and marking are often used for implantable and surgical tools. In addition, lasers are routinely used for surface texturing, such as surface modification of orthopedic implants, to improve surface adhesion.

2.7.2 How Lasers Work

Lasers work relatively simply. A photon encourages other photons to be emitted and travel with it to form a large number of photons traveling together in a beam of light. Most of the lasers used today were demonstrated in the 1960s, including Nd:YAG, CO_2, and semiconductor lasers. Although the technologies are mature, there have been advances in lasers, including the development of systems that produce short pulse widths such as picoseconds and femtosecond lasers.

Laser wavelengths used in material processing extend from ultraviolet to infrared and include the visible spectra. In addition to laser type, there are many important aspects of laser selection, including laser cavity design, delivery optics, and laser-material interaction.

2.7.3 Laser-Material Interaction

As a beam of laser light impinges on a material's surface, energy is partially reflected, partially absorbed, and partially transmitted depending on the material type and laser wavelength. Of the light energy impinging on the surface, the portion that is absorbed is of interest in material processing.

Light is absorbed in the form of electronic and vibration excitation of the atoms, and energy converts into heat, which dissipates to adjacent atoms. As more and more photons are absorbed, the material temperature increases, thereby increasing the fraction of light absorbed.

The optical absorption length is the length over which photon energy is absorbed so that beam intensity drops to 1/e (37%) of its original value. The energy absorbed over this volume produces thermal energy that is diffused to a distance of

$$L = [4Dt]^{1/2},$$

where L equals diffusion length, D is the thermal diffusivity, and t is the pulse width of the laser.

If the thermal diffusion length is much longer than the absorption length, temperature rise at the laser spot will be limited. By contrast, if the diffusion length is shorter than the absorption length, there will be a very rapid rise in temperature, leading to melting and possible evaporation.

By equating the optical absorption length to thermal diffusion distance, a threshold value can be obtained and used as a guide to selection of pulse-width duration for a particular frequency. Given that absorption distances are similar for metals, the difference in time scales results from the differences in diffusion distances.

For example, stainless steel has poor heat conductivity compared with nickel and therefore can be micromachined by much longer pulse widths. With femtosecond pulses, the interaction between the laser and materials is thought to occur in a nonlinear multiphoton process because of the high power density and short time frames.

The process is so fast that one can think of the beam practically plucking atoms from the surface without disturbing adjacent atoms. Femtosecond lasers are suitable for micromachining because they do not leave a disturbed layer on the exposed surfaces.

2.8 Application of Laser

Laser cutting is one of the major applications of industrial lasers in manufacturing. Thousands of laser cutting systems are in use around the world for cutting metal sheet, plate, tubing and formed parts.

Laser cutting is characterized by flexibility in the range of materials to which it can be applied. Laser cutting is used to cut all types of metals, including carbon, superalloys, titanium, plastics and ceramics. It is also characterized by precision where the narrow kerf of the laser cut with precision of modern CNC machine tools gives precision measured in the thousandths of inches or tenths of millimeters.

Besides that, there is edge quality – high quality edges which can be painted without additional finishing are readily produced by laser cutting. Then comes distortion-free where there is no physical contact between the workpiece and a cutting tool.

Finally, there is high material utilization where the narrow kerf combined with low distortion allows programmers to reduce waste or scrap material remaining after processing. When a focused high power laser beam is absorbed at the surface of the material being cut and melts the material, laser cutting is begins.

After that, the melted material is removed through the backside of the material by an assist gas which is directed into a cut using a nozzle. In this process, the oxygen is used in cases where oxidation of the edge is allowable and when cutting metals for which the reaction between the oxygen and molten metal increases the cutting rate.

The key parameters for laser sheet metal cutting are the laser type, average power, continuous wave (CW) or pulsed, focusing lens focal length and cutting speed. To produce cut edges that are oxide free, the inert gases, such as nitrogen or argon,are used. Laser cutting is used with sheet, plate, tubing and a wide range of formed 3D parts.

Modern laser systems are extremely flexible - operators can change from one part to another in as little time as it takes for the CNC's computer to load a new program. Typical elements of a laser sheet metal cutting system in addition to the machine tool and laser are offline programming or CAM software including nesting for sheet metal cutting, automated sheet loading systems and fume collector.

2.9 Laser Cutting and Application

Laser cutting has become a popular method of producing short runs of sheet metal parts. Current laser systems are able to easily cut out any shape presented to them; their computers can generate tool paths, set cutting parameters and optimize nesting so that the manufacturing process is highly automated. There is, however, a danger associated with this degree of automation: it allows us to forget that laser cutting is a thermal process, and metal is being melted and otherwise altered so we can get our parts cut. It is important to be aware of the effects of the process on the product.

The first, gas-assisted fusion cutting is performed by concentrating the light from a laser onto a surface so that the material melts. The melted material is then removed by flowing gas. The second method, reactive gas-assisted cutting, is the same except that the gas reacts with the material, providing more energy for the process.

The laser beam, aimed vertically down in the drawing, is focused by a lens onto the surface of the material to be cut. The space between the lens and the work is enclosed by a chamber that is pressurized by incoming assist gas which exits through a nozzle onto the workpiece. This arrangement is sometimes called a "coaxial gas jet cutting nozzle".

The most common application of lasers in fabrication is the cutting of carbon steel sheet. Oxygen is generally used as an assist gas. The purity of the oxygen assist gas has a dramatic effect on cutting speed and quality. The molten steel has a very great affinity for oxygen and so removes it from the assist gas.

As the assist gas flows down the cut edge, an aerodynamic boundary layer forms where gas velocity is low and there is little mixing. Even if the assist gas is pure coming out of the nozzle, it entrains air and has appreciable nitrogen content at the bottom of the kerf.

Cutting performance with thick steel can be considerably improved by using a compound nozzle that surrounds the central coaxial oxygen jet with a lower-velocity annular oxygen flow. Appropriate combinations of laser power, travel speed and oxygen flows damp the oscillations and produce quite smooth edges. If the oxygen flow is increased, the oscillations become stronger and increase the surface roughness.

2.10 Process of Laser Cutting

Laser cutting is a process whereby material is cut to shape using a laser beam under computer control. A wide range of materials can be cut in this way although today they tend to be mainly metals with other non-metals such as plastics and ceramics being cut by high pressure water jet and other methods.

It is true that laser cutting is being used more and more in areas such as aerospace, motorsport and other highly technical and high precision industries but the fact remains that a large percentage of work passing through job shops (laser cutting subcontractors) is of a fairly mundane nature, without a requirement for tolerances measured in microns.

A large amount of laser cutting work would, at one time, have been carried out by gas cutting. Laser cutting does not cause distortion through heat, it leaves a clean edge and is able to include holes and cut outs of (almost) any shape and size. The fact that standard